SUBJECT: Price elasticity

REFERENCE: 017a to 017c, PUB/MH I-0256

PREAMBLE: We conducted a regression analysis using the % change of weather adjusted average consumption (kWh) per customer as the dependant variable, and the % change of real average price ($/kWh) the year before (t-1) as the independent variable (data provided by MH for PUB/MH 1-0256). The resulting coefficient of -0.24 for the X variable is consistent with a short term price elasticity of -0.20. The regression statistics could potentially be greatly improved by using more precise data, notably monthly price and consumption data for a specific set of customers, as it is commonly done for price elasticity analyses elsewhere. Our graph also seems to show a correlation between the average price of electricity and the average consumption. In the case of PUB/MH 1-0256, the aggregation of price and consumption information across all customers by Manitoba Hydro can lead to misleading data and imprecision, for example swings in prices or consumption levels that are not caused by rate increases but by other factors (number of customers by market segment, average consumption by market segment, etc.). This imprecision of data could also explain some outliers in our analysis (notably the year 2010/11).

ORIGINAL DATA (from PUB/MH 1-0256) | **REGRESSION ANALYSIS**

	% Delta Real $/kWh	% Delta kWh/Customer (weather adjusted)	y kWh/Customer (t)	x Real $/kWh (t-1)
1990/91				
1991/92	0.10%	0.96%		
1992/93	-0.30%	-0.31%	-0.31%	0.10%
1993/94	-3.02%	0.95%	0.95%	-0.30%
1994/95	-0.28%	3.05%	3.05%	-3.02%
1995/96	-2.51%	-1.13%	-1.13%	-0.28%
1996/97	-1.29%	1.84%	1.84%	-2.51%
1997/98	-0.40%	2.25%	2.25%	-1.29%
1998/99	-1.60%	1.35%	1.35%	-0.40%
1999/00	-2.08%	2.28%	2.28%	-1.60%
2000/01	-3.04%	1.44%	1.44%	-2.08%
2001/02	-1.86%	-0.27%	-0.27%	-3.04%
2002/03	-3.57%	2.42%	2.42%	-1.86%
2003/04	-1.47%	0.86%	0.86%	-3.57%
2004/05	0.51%	1.10%	1.10%	-1.47%
2005/06	1.23%	1.00%	1.00%	0.51%
2006/07	-2.69%	-2.09%	-2.09%	1.23%
2007/08	0.68%	1.62%	1.62%	-2.69%
2008/09	1.16%	0.12%	0.12%	0.68%
2009/10	4.43%	0.23%	0.23%	1.16%
2010/11	1.01%	2.04%	2.04%	4.43%
2011/12	-0.10%	-1.16%	-1.16%	1.01%

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.343871200453598
R Square	0.118247402501399
Adjusted R Square	0.0692611470848099
Standard Error	0.0131119269132911
Observations	20

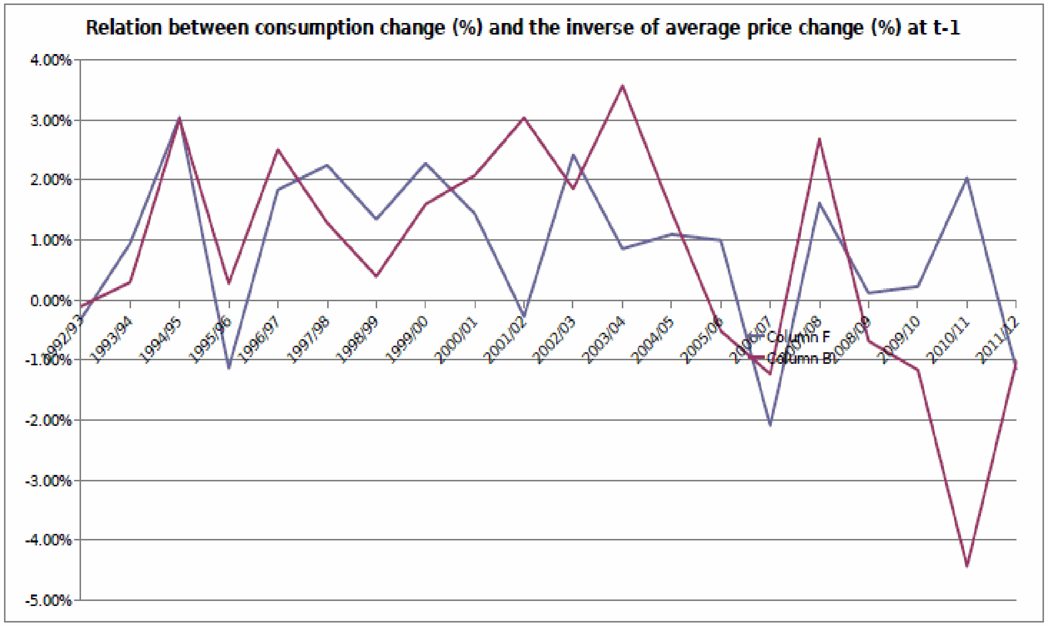
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000415002207	0.000415002207	2.413889396032	0.137669052691
Residual	18	0.003094607293	0.000171922627		
Total	19	0.0035096095			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.00699737850931675	0.003151954734	2.220012373078	0.039498893695	0.000375367338	0.013619389680
X Variable 1	-0.239842760598166	0.154371786736	-1.55366965473	0.137669052691	-0.56416584974	0.084480328547

INVERSE OF % DELTA PRICE (for graph)

-0.10%
0.30%
3.02%
0.28%
2.51%
1.29%
0.40%
1.60%
2.08%
3.04%
1.86%
3.57%
1.47%
-0.51%
-1.23%
2.69%
-0.68%
-1.16%
-4.43%
-1.01%



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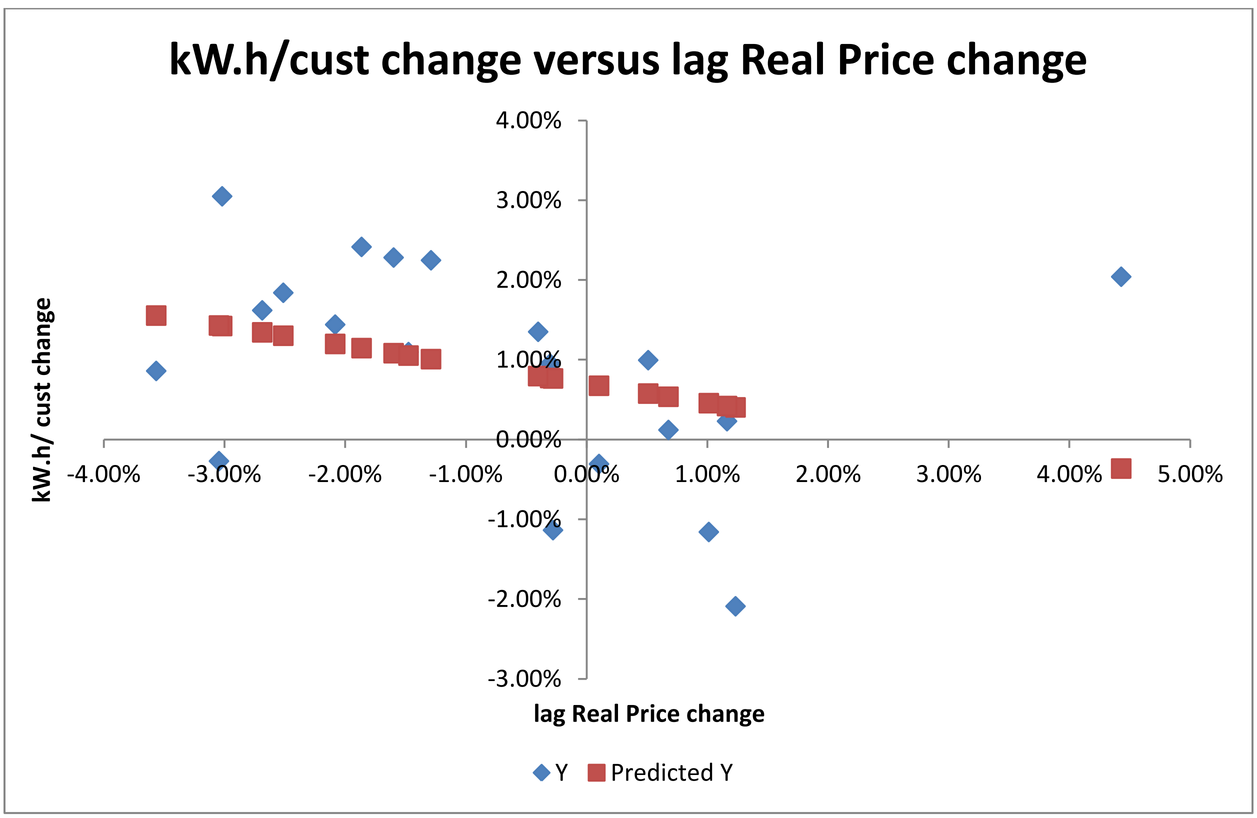
QUESTION:

Please compute the price elasticity using Manitoba Hydro's historic data, found on page 2 of this document, ideally based on monthly data at the customer (household and/or business) level, and broken out by market segment.

RESPONSE:

Based upon the above request, Manitoba Hydro reproduced the supplied regression result with the data to obtain the -0.24 coefficient value. The regression has an adjusted R^2 of just 7%, the t-ratio is not significant at -1.6, and the estimate has low accuracy with its 95% confidence interval covering -0.56 to +0.08. The plot of the Y to X values shows this regression to be a poor predictor:



There are many difficulties involved in estimating price elasticity that require more than a simplistic analysis:

1. When using a small number of annual data points, there are many factors other than price that could be contributing to the observed changes in annual use. It is difficult to determine what factors need to be included without detailed assessment.
2. Using just annual data is often very dependent on the specific data points available. For example, in the above data set, the estimated price coefficient can vary greatly if only a single year of data is missing, e.g. if the year the average use went down over 2% was missing, then the price coefficient result would become -0.16. If the year the price grew over 4% was missing, then the result would become -0.54.
3. Autocorrelation of the residuals needs to be addressed and removed from this result for it to be considered valid. Correcting for autocorrelation improves the R^2 of the analysis based on annual data points significantly to 95% and the price coefficient lowers to -0.19 but still has a t-ratio of -1.09 indicating that it is still not significantly different from zero; its 95% confidence interval covers -0.54 to +0.15.

Manitoba Hydro then used monthly data rather than annual data, as requested above. Doing this does not necessarily add significant precision to an analysis. Average monthly prices are computed as total revenue for the sector each month divided by the kW.h for each month. However, the underlying rates per unit consumption only change when new rates are approved, approximately annually. Usage has an annual cycle and growth will only be noticed between years, not between months. Monthly data simply preserves the yearly relationships and replicates them twelve times. This results in better statistics, but in reality the annual relationship is still the driver. Running the same regression with monthly data for the GS Mass Market sector and correcting for autocorrelation at lags of 1 and 12 months gives an R^2 of 94%, a price coefficient of -0.29 and a t-ratio of -4.17 that now appears to be significant solely due to the use of 264 observations rather than 22. However, its 95% confidence interval is still wide, covering -0.43 to –0.15.

In addition, the residuals under the analysis based on monthly data need to be checked to ensure they are not still correlated to the price. If there is correlation, then the price effect will be inflated and additional work will likely be required to remove the supply-side price effect. This would include determining price relationships with such factors as the cost of service for the sector, the export price and Manitoba Hydro's profit or loss, each of which can affect the price.

It is questionable as to whether this general procedure is valid and usable for all average use data. If it were valid, then it would also be expected to work for other sectors. Attempting to use this same procedure to regress average use monthly data for Residential customers against real price gives a price coefficient of +0.05. A positive elasticity is of course, not realistic. Using the standard error of the estimate indicates the value may range between -0.18 and +0.27. The same analysis for General Service Top Consumers gives a price coefficient of -1.66 with a 95% confidence interval that ranges from -1.42 to -1.89.

A major difficulty in this type of analysis is the use of price as the only predictor variable. The assumption that price is the only influencing variable will allow any coincidental growth pattern to be associated to the price effect, regardless of whether or not the changes were actually caused by the changes in price. To properly identify a price effect, all other major factors must be removed. A model of this sort must be formulated properly before it can produce results that can be trusted. For example, for General Service Mass Market, the load is likely affected not only by price but also by:

1. Market drivers, such as: GDP, company earnings, salaries,
2. The increase of average building size over time, i.e., the average use should be divided into its components: (square footage / customer) * (average use / square foot) with the latter being analyzed for price elasticity.

3. Analysis by building type, e.g. schools may have different price elasticities than offices or restaurants.

4. Demand Side Management (DSM) initiatives in the past may have contributed to helping people adjust to price changes. The proportion of this contribution should be determined so that a price-only effect can be obtained.

Removing these exogenous effects would result in more accuracy in estimating the price effect, but only if accurate data for these effects was available. Considerable work and expertise is required in determining price elasticity.

The question asks to compute the price elasticity using Manitoba Hydro's historic data based on monthly data at the customer (household and/or business) level broken out by market segment. This method produces results of -0.29 for General Service Mass Market, +0.05 for Residential Basic and -1.66 for General Service Top Consumer where the outcomes for the Residential Basic and General Service Top Consumer sectors are not reasonable. It would not be appropriate to accept this methodology for the General Service Mass Market sector, while considering it not acceptable for the other two sectors. A method for computing price elasticities should only be used if the predictor variables included are appropriate and if the results are reasonable.

SUBJECT: Price elasticity

REFERENCE: 017a to 017c, PUB/MH I-0257

PREAMBLE: We conducted a regression analysis using the % change of weather adjusted average consumption (kWh) per customer as the dependant variable, and the % change of real average price ($/kWh) the year before (t-1) as the independent variable (data provided by MH for PUB/MH 1-0256). The resulting coefficient of -0.24 for the X variable is consistent with a short term price elasticity of -0.20. The regression statistics could potentially be greatly improved by using more precise data, notably monthly price and consumption data for a specific set of customers, as it is commonly done for price elasticity analyses elsewhere. Our graph also seems to show a correlation between the average price of electricity and the average consumption. In the case of PUB/MH 1-0256, the aggregation of price and consumption information across all customers by Manitoba Hydro can lead to misleading data and imprecision, for example swings in prices or consumption levels that are not caused by rate increases but by other factors (number of customers by market segment, average consumption by market segment, etc.). This imprecision of data could also explain some outliers in our analysis (notably the year 2010/11).

ORIGINAL DATA (from PUB/MH 1-0256) / **REGRESSION ANALYSIS**

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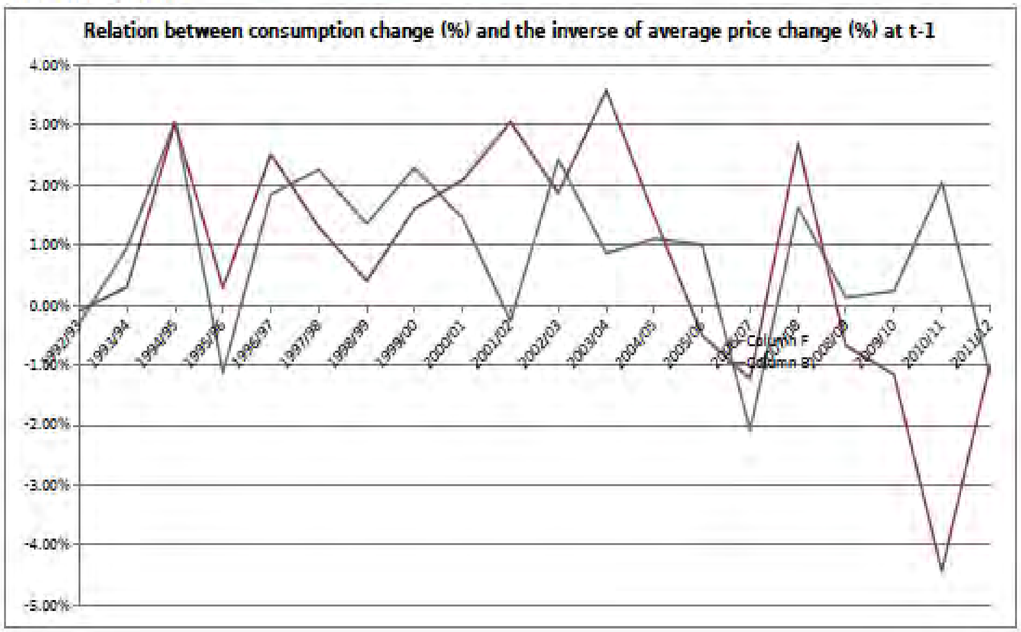

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QUESTION:

Please present, in tabular format, revised GWh and MW demand forecasts based on the results of the analysis requested in 001a) above.

RESPONSE:

As noted in Manitoba Hydro's response to GAC_CAC/MH II-001(a), the analysis was undertaken but produced conflicting price elasticity results between the Residential Basic, General Service Mass Market, and Top Consumer customer groups. Therefore, the analysis from GAC_CAC/MH II-001(a) was unable to provide reasonable values for the price elasticity of electricity for Manitoba Hydro customers.

Manitoba Hydro notes that responses to other information requests have been prepared that indicate how GW.h and MW would change given certain assumed price elasticity scenarios. Please refer to Manitoba Hydro's responses to CAC/MH II-054 for the effect of a price elasticity of -0.06, and CAC_GAC/MH I-017b for the effect of a -0.2 short run and -1.0 long run price elasticity.

Notwithstanding the above qualifications, Manitoba Hydro has evaluated the respective sector forecasts using the coefficients derived in the response to GAC_CAC/MH II-001(a) and the resulting hypothetical load impacts are indicated in the tables below:

Fiscal Year	Residential Basic Forecast	Res Basic With Assumed Price Effect	Res Basic Price Effect (GW.h)
		0.05	
2013/14	7339	7346	6
2014/15	7458	7472	14
2015/16	7538	7559	21
2016/17	7624	7652	28
2017/18	7730	7766	36
2018/19	7842	7886	44
2019/20	7953	8006	52
2020/21	8063	8124	61
2021/22	8173	8242	69
2022/23	8290	8368	78
2023/24	8405	8492	87
2024/25	8520	8617	97
2025/26	8635	8742	106
2026/27	8750	8866	116
2027/28	8864	8991	126
2028/29	8983	9120	136
2029/30	9102	9249	147
2030/31	9219	9377	158
2031/32	9337	9506	169
2032/33	9454	9635	180

Fiscal Year	GS Mass Market Forecast	GS Mass Mkt with Assumed Price Effect	GS Mass Mkt Price Effect (GW.h)
		-0.29	
2013/14	8550	8507	-43
2014/15	8701	8610	-92
2015/16	8858	8716	-141
2016/17	9018	8826	-192
2017/18	9174	8929	-245
2018/19	9325	9026	-299
2019/20	9470	9116	-353
2020/21	9613	9203	-409
2021/22	9756	9289	-467
2022/23	9898	9373	-525
2023/24	10040	9455	-585
2024/25	10179	9534	-645
2025/26	10318	9611	-707
2026/27	10456	9686	-770
2027/28	10592	9758	-834
2028/29	10736	9837	-899
2029/30	10878	9913	-966
2030/31	11020	9987	-1033
2031/32	11154	10053	-1101
2032/33	11288	10118	-1170

Fiscal Year	GS Top Consumers Forecast	GS Top Cons with Assumed Price Effect -1.66	GS Top Cons Price Effect (GW.h)
2013/14	5925	5755	-170
2014/15	6036	5681	-355
2015/16	6110	5573	-537
2016/17	6145	5431	-713
2017/18	6140	5259	-881
2018/19	6232	5173	-1059
2019/20	6322	5085	-1237
2020/21	6412	4998	-1414
2021/22	6517	4922	-1595
2022/23	6615	4842	-1773
2023/24	6715	4763	-1952
2024/25	6815	4684	-2131
2025/26	6915	4606	-2309
2026/27	7015	4528	-2487
2027/28	7115	4450	-2665
2028/29	7215	4373	-2842
2029/30	7315	4297	-3018
2030/31	7415	4221	-3194
2031/32	7515	4145	-3370
2032/33	7615	4070	-3545

SUBJECT: DSM

REFERENCE: CAC/MH I-005a

QUESTION:

Please provide a brief explanation for each measure included in your answer to GAC-CAC 005a (round 1), as to why these measures were excluded at the technical level.

RESPONSE:

The following response is provided by EnerNOC Utility Solutions.

Sector	End-Use	Energy Efficiency Measure	Reason Excluded
Residential	Heating / Cooling	Heat Pump - Room, High Efficiency Air Source	Not included in the initial market profile
Residential	HVAC (all)	Insulation, Ducting	Not applicable since ducts are in conditioned space in MB
Residential	HVAC (all)	Ducting, Repair and Sealing	Not applicable since ducts are in conditioned space in MB
Residential	Cooling	Windows, Install reflective film	Not suitable for Manitoba climate
Residential	Cooling	Roofs, High Reflectivity	Not suitable for Manitoba climate
Residential	HVAC (all)	Thermostat, Clock/Programmable	Energy Use Survey that indicated that a significant percentage of customers set back their thermostats manually without a setback thermostat, and the decertification of thermostats from the Energy Star designation
Residential	Water Heating	Water Heater, Heat Pump	Not suitable in Manitoba climate
Residential	Water Heating	Water Heater, Solar	Not economic due to high initial product cost and maintenace (glycol replacement)
Residential	Water Heating	Water Heater, Ground-Source Heat Pump	Not cost effective for water heating use only due to low water temperature
Residential	Water Heating	Hot Water System Pumps, High Efficiency	Measure does not result in energy savings, water savings only
Residential	Water Heating	Water Heater, Thermostat Setback	Countervenes Manitoba Plumbing code (bacteria growth)
Residential	Water Heating	Water Heating, Heat Trap	Low savings due to interactive effects
Residential	Interior Lighting	Fluorescent Torchieres	Measure savings have been included in LED and compact fluorescent categories (both lamps and fixtures)
Residential	Exterior Lighting	Compact Fluorescent Lamps, Screw-In	Not suitable for Manitoba climate
Residential	Appliances	Clothes Dryer, Heat Pump	Not commercially available in North America
Residential	Appliances	Clothes Dryer, Microwave	Not commercially available in North America
Residential	Appliances	Clothes Dryer Duct Heat Recovery	Not commercially available in North America
Residential	Cooling	Evaporative Cooler	Not suitable for Manitoba climate
Residential	Water Heating	Water Heater - Electric, tankless	Screened out due to system constraints
Commercial	Cooling	Chilled Water, Reset	Excluded in error by EnerNOC
Commercial	Cooling	Air Conditioner, Evaporative Cooler	EnerNOC can't model this in BEST so it was excluded. Based on previous study in New Mexico with an ideal market, the market opportunity for this measure is very small
Commercial	Cooling	Thermal Energy Storage - Cooling	Not an energy-efficiency measure
Commercial	HVAC	Ducting, Insulation	Not applicable since ducts are in conditioned space in MB
Commercial	HVAC	Ducting, Repair and Sealing	Not applicable since ducts are in conditioned space in MB
Commercial	Water Heating	Water Heater - Electric, Tankless	Screened out due to system constraints
Commercial	Water Heating	Water Heating, Heat Trap	Most commercial systems have re-circulation loops, as a result, heat trap does not provide any benefit
Commercial	Water Heating	Water Heating, Tank Blanket	Low savings due to interactive effects
Commercial	Water Heating	Water Heater, Install Timer	Demand Control Timer does not reduce Load or usage
Commercial	Water Heating	Water Heater, Thermostat Setback	Contervenes MB Plumbing Code (bacteria growth)
Commercial	Water Heating	Water Heating, Solar Water Heating System	Not economic due to high initial product cost and maintenace (glycol replacement)
Commercial	Heating	Ducting, Insulation	Not applicable since ducts are in conditioned space in MB
Commercial	Heating	Ducting, Repair and Sealing	Not applicable since ducts are in conditioned space in MB
Commercial	Misc.	Commercial Washer	Not included in the initial market profile
Commercial	Misc.	Commercial Dryer	Not included in the initial market profile
Commercial	Interior Lighting	Fluorescent, Delamp and Install Reflectors	Qualitatively screened out since this measure is already widely implemented outside programs
Industrial	Cooling	Thermal Energy Storage - Cooling	This is not an energy-efficiency measure
Industrial	Heating / Cooling	Heat Pump - Air-Source, High-Efficiency	Not included in the initial market profile
Industrial	Heating / Cooling	Heat Pump - Air-Source, Maintenance	Not included in the initial market profile
Industrial	Heating / Cooling	Heat Pump - Ductless and Variable Refrigerant Flow System	Not included in the initial market profile
Industrial	Heating / Cooling	Heat Pump - Room, High Efficiency	Not included in the initial market profile
Industrial	Heating / Cooling	Heat Pump, Geothermal or Water Source	Heat pumps are generally not considered in the industrial sector since electric resistance heating is not normally used in the industrial sector
Industrial	HVAC	Ducting, Repair and Sealing	Not applicable since ducts are in conditioned space in MB
Industrial	HVAC	HVAC Retrocommissioning	Included in Comprehensive retrocommissioning measure

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SUBJECT: DSM

REFERENCE: CAC/MH I-008b

QUESTION:

Please provide more details as to the calculations used for early retirements, compared to other opportunity types. For example, how are energy savings adjusted during the early retirement period vs the post early-retirement, how is the economic cost of units adjusted, etc.

RESPONSE:

The following response is provided by EnerNOC Utility Solutions.

The DSM potential study assessed two early retirement measures: the removal of a second refrigerator and the removal of a second freezer. The modeling for this is straightforward with savings for each measure and a measure adoption rate for each year. The measure savings for these early retirement measures do not change over the study timeframe.

The study did not assess the early replacement of equipment. All measures were treated as being replaced at end of life.

SUBJECT: DSM

REFERENCE: CAC/MH I-013b

QUESTION:

Please provide the price elasticities per end use and fuel type that were used to model changes in equipment utilization.

RESPONSE:

The following response is provided by EnerNOC Utility Solutions.

Residential	End Use	Fuel	CDD Days	HDD Days	Electricity price	Natural gas price
Residential	Cooling	Electric	40.0%	0.0%	-15.1%	0.0%
Residential	Heating	Electric	0.0%	100.0%	-15.1%	0.0%
Residential	HVAC Other	Electric	4.8%	87.9%	-15.1%	0.0%
Residential	Water Heating	Electric	0.0%	0.0%	-15.1%	0.0%
Residential	Interior Lighting	Electric	0.0%	0.0%	-15.1%	0.0%
Residential	Exterior Lighting	Electric	0.0%	0.0%	-15.1%	0.0%
Residential	Appliances	Electric	0.0%	0.0%	-7.6%	0.0%
Residential	Electronics	Electric	0.0%	0.0%	-15.1%	0.0%
Residential	Miscellaneous	Electric	0.0%	0.0%	-15.1%	0.0%
Residential	Heating	Natural Gas	0.0%	100.0%	0.0%	-15.1%
Residential	Water Heating	Natural Gas	0.0%	0.0%	0.0%	-15.1%
Residential	Appliances	Natural Gas	0.0%	0.0%	0.0%	-7.6%
Residential	Miscellaneous	Natural Gas	0.0%	0.0%	0.0%	-15.1%

Commercial	End Use	Fuel	CDD Days	HDD Days	Electricity price	Natural gas price
Commercial	Cooling	Electric	40.0%	0.0%	-10.0%	0.0%
Commercial	Space Heating	Electric	0.0%	100.0%	-10.0%	0.0%
Commercial	Ventilation	Electric	0.0%	0.0%	-10.0%	0.0%
Commercial	Water Heating	Electric	0.0%	0.0%	-10.0%	0.0%
Commercial	Interior Lighting	Electric	0.0%	0.0%	-10.0%	0.0%
Commercial	Exterior Lighting	Electric	0.0%	0.0%	-10.0%	0.0%
Commercial	Refrigeration	Electric	0.0%	0.0%	-5.0%	0.0%
Commercial	Food Preparation	Electric	0.0%	0.0%	-10.0%	0.0%
Commercial	Office Equipment	Electric	0.0%	0.0%	-10.0%	0.0%
Commercial	Miscellaneous	Electric	0.0%	0.0%	-10.0%	0.0%
Commercial	Space Heating	Natural Gas	0.0%	100.0%	0.0%	-10.0%
Commercial	Water Heating	Natural Gas	0.0%	0.0%	0.0%	-10.0%
Commercial	Food Preparation	Natural Gas	0.0%	0.0%	0.0%	-10.0%
Commercial	Miscellaneous	Natural Gas	0.0%	0.0%	0.0%	-10.0%

Industrial	End Use	Fuel	CDD Days	HDD Days	Electricity price	Natural gas price
Industrial	Cooling	Electric	40.0%	0.0%	-10.0%	0.0%
Industrial	Heating	Electric	0.0%	100.0%	-10.0%	0.0%
Industrial	Ventilation	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Interior Lighting	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Exterior Lighting	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Pumps	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Fans & Blowers	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Compressed Air	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Conveyors	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Other Motors	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Process Heating	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Process Cooling an	Electric	0.0%	0.0%	-5.0%	0.0%
Industrial	Electro-Chemical P	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Other Process	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Miscellaneous	Electric	0.0%	0.0%	-10.0%	0.0%
Industrial	Heating	Natural Gas	0.0%	100.0%	0.0%	-10.0%
Industrial	Process Heating	Natural Gas	0.0%	0.0%	0.0%	-10.0%
Industrial	Process Cooling	Natural Gas	0.0%	0.0%	0.0%	-5.0%
Industrial	Other Process	Natural Gas	0.0%	0.0%	0.0%	-10.0%
Industrial	Miscellaneous	Natural Gas	0.0%	0.0%	0.0%	-10.0%

SUBJECT: DSM

REFERENCE: CAC/MH I-015a

QUESTION:

Please provide appendices B, C and D in Excel format.

RESPONSE:

Please see the following files:

- Appendix B Equipment Measures
- Appendix B Non-Equipment Measures
- Appendix C Equipment Measures
- Appendix C Non-Equipment Measures
- Appendix D Equipment Measures
- Appendix D Non-Equipment Measures

SUBJECT: DSM

REFERENCE: CAC/MH I-018a

PREAMBLE: According to response CAC/MH I-018a, Manitoba Hydro has used the RIM test because marginal costs vary according to seasons.

QUESTION:

Please explain why Manitoba Hydro considers the RIM test to be better than any other tests when marginal costs have a seasonal pattern.

RESPONSE:

Manitoba Hydro does not consider the RIM test to be better than any other test. All benefit/cost metrics are assessed using marginal values which reflect the seasonality of the energy savings for energy efficiency measures.

Manitoba Hydro's response to GAC_CAC/MH I-018a (assuming this is the IR which was intended to be referenced as opposed to CAC/MH I-018a) refers to the use of RIM in conjunction with the Levelized Utility Cost (LUC) in undertaking the DSM assessment. The reason for needing to use the RIM in conjunction with the LUC is directly related to marginal costs varying according to seasons. The RIM provides more insight into understanding the meaning and value associated with a LUC.

SUBJECT: DSM

REFERENCE: CAC/MH I-018a

PREAMBLE: According to response CAC/MH I-018a, Manitoba Hydro has used the RIM test because marginal costs vary according to seasons.

QUESTION:

Please explain why Manitoba Hydro didn't consider using seasonal avoided costs, like those used in Ontario and many other jurisdictions.

RESPONSE:

Manitoba Hydro's marginal benefits are seasonal with separate values for the summer and winter periods.

SUBJECT: DSM

REFERENCE: CAC/MH I-023f

QUESTION:

Please provide a copy of the September 2008 Navigant Consulting report that was used to characterize LED lamps.

RESPONSE:

Please see the attached report.

EIA - Technology Forecast Updates – Residential and Commercial Building Technologies - Reference Case

Residential and commercial lighting, commercial refrigeration, and commercial ventilation technologies

Presented to:

Energy Information Administration

September 2008

Navigant Consulting, Inc.
1801 K Street, NW, Suite 500
Washington, D.C. 20006
(202) 973-2400
www.navigantconsulting.com

Reference No. xxxxxxxxx.xx

September 2008

Table of Contents

Objective

The objective of this study is to develop baseline and projected performance/cost characteristics for residential and commercial end-use equipment.

- 2003 and 2005 baselines, as well as today's (2008)
  - Review of literature, standards, installed base, contractor, and manufacturer information
  - Provide a relative comparison and characterization of the cost/efficiency of a generic product
- Forecast of technology improvements that are projected to be available through 2030
  - Review of trends in standards, product enhancements, Research and Development (R&D)
  - Projected impact of product improvements and enhancement to technology

The performance/cost characterization of end-use equipment developed in this study will assist EIA in projecting national primary energy consumption.

Methodology

Input from industry, including government, R&D organizations, and manufacturers, was used to project product enhancements concerning equipment performance and cost attributes.

- Varied sources ensure a balanced view of technology progress and the probable timing of commercial availability.
- Technology developments impact performance and cost forecasts.
- Technology forecasting involves many uncertainties.
- All cost forecasts are shown in real, 2008 dollars

Definitions

The following tables represent the current and projected efficiencies for residential and commercial building equipment ranging from the installed base in 2003 and 2005, to the highest efficiency equipment that is expected to be commercially available by 2030, assuming incremental adoption. Below are definitions for the terms used in characterizing the status of each technology.

- 2003/2005 Installed Base: the "average" equipment in use in each year.
- Typical: average product being sold in the particular timeframe.
- High: the product with the highest efficiency available in the particular timeframe.
- Reference Case: the projected end-use characteristics assuming end-use trends stay the same.
- CCT: The correlated color temperature (CCT) is the temperature of a blackbody that best matches the color of a given light source. It describes the color appearance of the source, measured on the Kelvin (K) scale. Lamps with a CCT below 3500 K are "warm", and appear more reddish in color.
- CRI: The color rendering index (CRI) is the measure of the effect of a light source on the color appearance of objects in comparison to a reference case with the same CCT.

Performance/Cost Characteristics Residential Incandescent Lighting

Residential Incandescent Lighting – 60W

	2005	2008		2014*		2020**	
	Typical	Typical	High	Typical	High	Typical	High
Typical Wattage	60	60	60	43	43	N/A	N/A
Lumens	850	850	850	750	750	N/A	N/A
Efficacy (lm/W)	14.2	14.2	14.2	17.4	17.4	N/A	N/A
Lamp price ($)	$0.25	$0.25	$0.25	$4.57	$4.57	N/A	N/A
Cost ($/klm)	$0.29	$0.29	$0.29	$6.09	$6.09	N/A	N/A
Average Life (1000 hrs)	1.0	1.0	1.0	3.0	3.0	N/A	N/A
CRI	100	100	100	100	100	N/A	N/A

*The Energy Independence and Security Act of 2007 prescribes standards for current 60-watt incandescent lamps as of January 1, 2014. Starting in 2014, we assume 60-watt incandescents will be replaced by halogen infrared incandescents.

**In 2020, EISA 2007 sets a minimum efficacy for general service lamps of 45 lm/W. These standards can not be met with existing commercialized incandescent lamp technologies.

Performance/Cost Characteristics Residential Incandescent Lighting

Residential Incandescent Lighting – 75W

	2005	2008		2013*		2020	
	Typical	Typical	High	Typical	High	Typical	High
Typical Wattage	75	75	75	53	53	N/A	N/A
Lumens	1170	1170	1170	1050	1050	N/A	N/A
Efficacy (lm/W)	15.6	15.6	15.6	19.8	19.8	N/A	N/A
Lamp price ($)	$0.37	$0.37	$0.37	$4.69	$4.69	N/A	N/A
Cost ($/klm)	$0.32	$0.32	$0.32	$4.47	$4.47	N/A	N/A
Average Life (1000 hrs)	0.75	0.75	0.75	3.0	3.0	N/A	N/A
CRI	100	100	100	100	100	N/A	N/A

*The Energy Independence and Security Act of 2007 prescribes standards for current 75-watt incandescent lamps as of January 1, 2013. Starting in 2013, we assume 75-watt incandescents will be replaced by halogen infrared incandescents.
**In 2020, EISA 2007 sets a minimum efficacy for general service lamps of 45 lm/W. These standards can not be met with existing commercialized incandescent lamp technologies.

Performance/Cost Characteristics Residential Incandescent Lighting

Residential Incandescent Lighting

- The residential incandescent lighting characterized in this report is a 60 watt and a 75 watt medium screw based incandescent lamp.
- A standard 60 watt incandescent lamp produces approximately 850 lumens. A standard 75 watt incandescent lamp produces approximately 1170 lumens (GE, 2008; OSRAM, 2008, Philips, 2008). There is little variation in light output between products. Therefore, there is little variation in lamp efficacy.
- The Energy Independence and Security Act of 2007 (EISA 2007) established standards for 60W lamps effective in 2014 and 75W lamps effective in 2013. These standards can be achieved if incandescent bulbs use halogen infrared technologies.
- EISA 2007 also established a requirement that DOE establish standards for general service lamps that are equal to or greater than 45 lm/W by 2020. These standards can not be achieved by any incandescent technology currently on the market.
- GE has issued a press release stating that they have a technology in development that may ultimately achieve an efficacy of 60 lm/W (GE, 2007). However, GE has not stated what technology will be used to achieve these efficacies. Therefore we could not develop a price for this lamp.
- California's Appliance Efficiency Regulations include efficiency regulations for general service incandescent lamps with certain bases. California is currently undergoing a rulemaking to reduce indoor residential lighting by not less than 50% of 2007 levels over the next 10 years in accordance with Assembly Bill 1109. They are going to regulate general purpose lighting (incandescent lamps) and portable lighting fixtures.
- The average incandescent bulb sold is 69 W (NEMA, 2005)
- Fixture prices not included.

Performance/Cost Characteristics Residential Reflector Lamps

Residential Reflector Lamps

	2005	2008			2010			2020			2030		
	Typical	Inc.	Hal.	CFL	Inc.	Hal.	CFL	Inc.	Hal.	CFL	Inc.	Hal.	CFL
Typical Wattage	65	65	50	16	65	50	16	65	50	16	65	50	16
Lumens	620	620	660	750	621	661	754	627	668	773	634	675	792
Efficacy (lm/W)	9.5	9.5	13.2	46.9	9.6	13.2	47.1	9.7	13.4	48.3	9.7	13.5	49.5
Lamp Price ($)	$1.38	$1.38	$4.23	$5.92	1.4	4.2	5.9	1.3	4.1	5.7	1.3	4.0	5.6
Lamp Cost ($/klm)	$2.23	$2.23	$6.41	$7.89	$2.21	$6.36	$7.81	$2.13	$6.14	$7.43	$2.06	$5.93	$7.07
Average Life (1000 hrs)	2.0	2.0	3.0	8.0	2.0	3.0	8.1	2.1	3.1	8.5	2.1	3.2	8.9
CRI	100	100	100	82	100	100	82	100	100	82	100	100	82

Residential Reflector Lamps

- The residential reflector lamps characterized in this report is a 65W BR30 incandescent, a 50W PAR30 halogen, and a 16W BR30 Reflector compact fluorescent. All of these systems produce approximately 630 lumens (DOE, 2008).
- Approximately 12% of lamps in a residential home are reflector lamps (RLW Analytics, 2005)
- EPACT92 established minimum performance standards for some reflector lamps and provided exemptions for certain specialty applications (e.g., ER/BR, vibration service, more than 5% neodymium oxide, impact resistant, infrared heat, colored). EPACT92 effectively phased-out R-shaped tungsten filament incandescent reflector lamps at certain wattages and bulb diameters, replacing them with more efficient and cost effective tungsten-halogen parabolic aluminized reflector (PAR) lamps. EISA2007 took away certain exemptions from EPACT 1992, requiring certain previously exempted lamps to meet EPACT92 minimum performance standards by January 1, 2008. The 65W BR30, a large majority of the incandescent reflector lamp market is still exempted.
- The following future improvements for the system were assumed to occur over a 20 year period: Efficacy +2%, Life +5%, and Price -5% (NCI, 2006). These improvements can be made by improved filament design and placement, higher pressure capsules, or higher efficiency reflector coatings.
- DOE is currently undergoing a rulemaking to review and amend existing efficacy standards for incandescent reflector lamps. (DOE, 2008)
- Fixture prices not included.

Performance/Cost Characteristics Residential Compact Fluorescent Lighting

Residential Compact Fluorescent Lighting

	2005	2008		2010		2020		2030	
	Typical	Typical	High	Typical/ Standard	High	Typical/ Standard	High	Typical/ Standard	High
Typical Wattage	13	13	13	13	13	13	13	13	13
Lumens	825	825	900	829	905	850	927	871	950
Efficacy (lm/W)	63.5	63.5	69.2	63.8	69.6	65.4	71.3	67.0	73.1
Lamp Price ($)	$3.19	$2.17	$3.59	$2.16	$3.57	$2.11	$3.48	$2.05	$3.40
Cost ($/klm)	$4.28	$2.63	$3.99	$2.60	$3.95	$2.48	$3.76	$2.36	$3.57
Average Life (1000 hrs)	10.0	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3
CRI	82	82	82	82	82	82	82	82	82

Residential Compact Fluorescent Lighting

- The residential compact fluorescent lamp characterized in this report is a 13 watt compact fluorescent lamp.
- Compact Fluorescents contain mercury and therefore require appropriate disposal. In addition, because the color rendering index of compact fluorescents is lower than that incandescent lamps (82 compared to 100), the quality of the light of a compact fluorescent is poor.
- Shipments of compact fluorescents have recently increased to approximately 270 million in 2007. (EPA, 2008) There are currently approximately 400 million compact fluorescents installed in residential homes. (RLW Analytics, 2005a-b) (DOE, 2008)
- EPACT 2005 sets performance for medium based compact fluorescent lamps. It adopts Energy Star performance requirements (August 6, 2001 version) for efficacy, lumen maintenance, lamp life, rapid cycle stress test, CRI, etc. The standard is effective for lamps manufactured on or after January 1, 2006. The Secretary may revise these requirements by rule or establish other requirements at a later date. *[Note: EPACT 2005 standards do not apply to CFL lamps with screw bases other than medium (e.g., pin based)]*
- Energy Star® and the Consortium for Energy Efficiency (CEE) offer voluntary specifications for CFL lamps.
- The following future improvements were assumed to occur over a 20 year period: Efficacy +5%, Life +10%, and Price -5% (NCI, 2006).
  - Improvements in efficacy can be made by using more rare-earth phosphors in compact fluorescent lamps. Lifetime improvements can be made by improving the electrodes.
- Fixture prices not included.

Residential Torchieres

	2005	2008			2010			2020			2030		
	Typical	Inc.	Hal.	CFL	Inc.	Hal.	CFL	Inc.	Hal.	CFL	Inc.	Hal.	CFL
Typical Wattage	253	180	154	37	180	154	37	180	154	37	180	154	37
Lumens	4300	2670	2670	2670	2675	2675	2683	2702	2702	2750	2729	2729	2819
Efficacy (lm/W)	17.0	14.8	17.3	72.7	14.9	17.3	73.1	15.0	17.5	74.9	15.2	17.7	76.8
Lamp Price ($)	$4.21	$2.29	$1.11	$12.83	$2.28	$1.11	$12.76	$2.22	$1.08	$12.44	$2.17	$1.05	$12.13
Lamp Cost ($/klm)	$0.98	$0.86	$0.42	$4.80	$0.85	$0.41	$4.76	$0.82	$0.40	$4.52	$0.79	$0.39	$4.30
Average Life (1000 hrs)	2.1	1.0	1.8	10.0	1.0	1.8	10.1	1.0	1.9	10.6	1.1	1.9	11.1
CRI	98	100	100	82	100	100	82	100	100	82	100	100	82

Residential Torchieres

- The residential torchiere characterized in this report emits approximately 2670 lumens. The typical characteristics are a weighted average of a halogen, incandescent, and CFL torchieres based. The 2005 typical wattage is based on 2003 installed base data. The 2008 typical wattage is based on EPACT standards.
- EPACT 2005 sets performance for torchieres. It sets a maximum wattage consumption of 190 W. This analysis assumes that the market would transition to a 180W incandescent lamp.
- Energy Star® and the Consortium for Energy Efficiency (CEE) offer voluntary specifications for torchieres.
- Fixture prices not included. Fixture price range: Halogen- $10-$30; Incandescent- $10-$30; CFL-$40-$70
- Additional data on makeup of torchiere market from FY2005 DOE Priority Setting and the 2005 California Residential Appliance Saturation Survey (RLW Analytics, Inc, 2005a-d).
- Assuming that the prevalence of torchieres is the same in California as in the rest of the United States, there are approximately 61 million torchieres in use in 29% of U.S. households, as of 2007 (NCI Estimate; RLW Analytics, Inc, 2005a-d).

Technology	2005 Installed Base	2003 Shipments
Halogen	41%	11%
Incandescent	48%	82%
CFL	11%	7%

Performance/Cost Characteristics Residential Linear Fluorescent Lighting

Residential Linear Fluorescent Lighting (2-lamp system)

	2005	2008			2010		2020		2030	
	F32T8	F40T12	F32T8	F28T5	F32T8	F28T5	F32T8	F28T5	F32T8	F28T5
Lamp Wattage	64	80	64	56	64	56	64	56	64	56
Lamp Lumens	5040	5760	5040	5452	5065	5479	5192	5616	5322	5757
System Wattage	56	70	56	68	56	68	56	68	56	68
System Lumens	4435	3917	4435	5452	4457	5479	4569	5616	4683	5757
Lamp Efficacy (lm/W)	78.8	72.0	78.8	97.4	79.1	97.8	81.1	100.3	83.2	102.8
System Efficacy (lm/W)	79.2	56.0	79.2	80.2	79.6	80.6	81.6	82.6	83.6	84.7
Lamp Price ($)	$3.44	$4.70	$3.44	$14.42	$3.42	$14.35	$3.34	$13.99	$3.25	$13.64
Ballast Price ($)	$16.13	$18.73	$16.13	$30.30	$16.05	$30.15	$15.65	$29.39	$15.26	$28.66
Lamp Cost ($/klm)	$0.68	$0.82	$0.68	$2.65	$0.68	$2.62	$0.64	$2.49	$0.61	$2.37
Average Lamp Life (1000 hrs)	20	20	20	20	20.2	20.2	21.2	21.2	22.3	22.3
CRI	75	72	75	82	75	82	75	82	75	82

Residential Linear Fluorescent Lighting

- The residential linear fluorescent lighting in this report is characterized by a two-lamp system (one ballast) that emits approximately 5,500 system lumens.
- Assumptions
  - Low efficiency unit: 2 F34T12 lamps with a residential low power factor magnetic ballast (Ballast Factor =0.68)
  - Typical efficiency unit: 2 F32T8 lamps with instant start electronic ballast (Ballast Factor=0.88)
  - High efficiency unit: 2 F28T5 lamps with instant start electronic ballast (Ballast Factor=1)
- DOE set minimum efficiency standards for T12 fluorescent ballasts. The regulation raises the minimum Ballast Efficacy Factors (BEF) for T12 fluorescent ballasts, which effectively promotes the use of T8 lamp and ballast systems. The Federal Ballast Rule covers 2-foot U-shaped Rapid Start, 4-foot Rapid Start, 8-foot Instant Start and 8-foot High Output T12 fluorescent ballasts. Ballast manufacturers cannot manufacture T12 ballasts operating full wattage lamps for new luminaires after April 1, 2005. Ballast manufacturers cannot manufacturer T12 ballasts operating reduced wattage lamps for new luminaires after July 1, 2009. Residential ballasts are exempted from regulation.
- California's Title 24 mandates the use of electronic ballasts with high efficacy luminaires (including fluorescent) of 13 W or higher (CEC, 2005)
- The following future improvements were assumed to occur over a 20 year period: Efficacy +5%, Life +10%, and Price -5% (NCI, 2006). Improvements can be made by using more rare-earth phosphors. Improvements in life can be made by using better electrodes.
- Reported lumens are “mean” lumens.
- Fixture prices not included.

Performance/Cost Characteristics Residential Solid-State Lighting

Residential Solid-State Lighting

	2005	2008	2010	2020	2030
	LED	LED	LED	LED	LED
Typical Wattage	36.4	9.9	6.5	3.2	3.2
Lumens	630	630	630	630	630
Efficacy (lm/W)	17.3	63.6	97.2	195.5	195.5
Lamp Price ($)	$190	$76	$47	$13	$13
Cost ($/klm)	$301	$120	$74	$21	$21
Average Life (1000 hrs)	50	50	50	50	50
CRI	92	92	92	92	92
CCT	2700	2700	2700	2700	2700

Residential Solid-State Lighting

- The residential solid-state lighting characterized is a warm white LED reflector lamp for use in an open downlight reflector.
- The efficacy projection is based on the projection of efficacy of a commercial cool white luminaire in the March 2008 Solid-State Lighting Multi-Year Program Plan. Cool white LEDs are used for this analysis because it is common to create a warm white product by mixing cool white LEDs with monochromatic red LEDs. Efficacy projection is linear.
- Current and future "typical" projections for $/klm for the LED devices are based on the March 2008 Solid-State Lighting Multi-Year Program Plan. Price projections for the LED device electronics, heat sink, labor and overhead are NCI estimates. Price projection is exponential.
- Prices for fixtures are not included.

Common Lighting Technologies in EIA Commercial Building Types

Building Type	Incandescent	CFL	Halogen	Linear Fluorescent	HID	SSL
Assembly	X	X	X	**X**	X	
Education	X	X	X	**X**	X	
Food sales	X	X	X	**X**		
Food service	**X**	X	X	X		
Health care	X	X	X	**X**	X	
Lodging	X	X	X	**X**	X	
Office–large	X	X	X	**X**	X	
Office–small	X	X	X	**X**	X	
Mercantile and service	X	X	X	**X**	X	
Warehouse	X	X	X	**X**	X	
Other	X	X	X	X	X	

Source: NCI, 2002.

X This lighting technology is commonly found in this building type (>10% of lighting electricity use from this technology) .

X This lighting technology is the **MOST** common in this building type.

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Performance/Cost Characteristics Commercial Incandescent Lighting

Commercial Incandescent Lighting

	2003	2008	2012*	2020**
	100W Inc	100W Inc	72W Inc	72W Inc
Lamp Wattage	100	100	72	N/A
Lamp Efficacy (lm/W)	16.9	16.9	20.7	N/A
System Lumens	997	997	879	N/A
System Efficacy (lm/W)[1]	10.0	10.0	12.2	N/A
Average Life (1000 hrs)	0.75	0.75	3.00	N/A
Cost ($/klm l)[2]	$0.17	$0.17	$3.09	N/A
Cost ($/klm l/f)[3]	$12.55	$12.55	$19.14	N/A
CRI	100	100	100	N/A
Total Installed Cost ($)	$66	$66	$71	N/A
Annual Maintenance Cost ($)	$3.44	$3.44	$0.86	N/A

*The Energy Independence and Security Act of 2007 prescribes standards for current 100-watt incandescent lamps as of January 1, 2012. Starting in 2012, 100-watt incandescents will be replaced by halogen infrared incandescents.
**In 2020, EISA 2007 sets a minimum efficacy for general service lamps of 45 lm/W. These standards can not be met with existing commercialized incandescent lamp technologies.

[1] Losses in fixture included.
[2] Includes lamp price only. (l)
[3] Include lamp price and fixture price. (l/f)

Commercial Incandescent Lighting

- The Commercial incandescent lighting characterized in this report is a 100 watt medium screw based incandescent lamp (NCI, 2002) in an open down light recessed can fixture (~$12) with a fixture efficiency of 59% (DOE, 2008).
- A The Energy Independence and Security Act of 2007 (EISA 2007) established standards for 100W lamps effective in 2012. These standards can be achieved if incandescent bulbs use halogen infrared technologies.
- EISA 2007 also established a requirement that DOE establish standards for general service lamps that are equal to or greater than 45 lm/W by 2020. These standards can not be achieved by any incandescent technology currently on the market.
- GE has issued a press release stating that they have a technology in development that may ultimately achieve an efficacy of 60 lm/W (GE, 2007). However, GE has not stated what technology will be used to achieve these efficacies. Therefore we could not develop a price for this lamp.
- California's Appliance Efficiency Regulations include efficiency regulations for general service incandescent lamps with certain bases. California's Appliance Efficiency Regulations include efficiency regulations for general service incandescent lamps with certain bases. California is currently undergoing a rulemaking to reduce commercial lighting by not less than 25% of 2007 levels over the next 10 years in accordance with Assembly Bill 1109. They are going to regulate general purpose lighting (incandescent lamps).
- Total installed cost includes equipment and installation costs. Annual maintenance costs and installation costs are calculated using labor rate and labor time to install/replace equipment from RS Means and the fluorescent and incandescent energy conservation standard advanced notice of proposed rulemaking (lamps ANOPR). Maintenance costs include labor only based on 3,376 operating hours per year. (lamps ANOPR)

Performance/Cost Characteristics Commercial Compact Fluorescent Lighting

Commercial Compact Fluorescent Lighting

	2003		2008		2010		2020		2030	
	26W CFL	42W CFL	26W CFL	42W CFL	26W CFL	42W CFL	26W CFL	42W CFL	26W CFL	42W CFL
Typical Wattage	26	42	26	42	26	42	26	42	26	42
Lamp Efficacy (lm/W)	67.3	64.3	67.3	64.3	67.6	64.6	69.3	66.2	71.1	67.9
System Lumens	1068	1647	1068	1647	1073	1655	1100	1697	1127	1739
System Efficacy (lm/W)[1]	41.1	39.2	41.1	39.2	41.3	39.4	42.3	40.4	43.4	41.4
Average Life (1000 hrs)	10	12	10	12	10.1	12.1	10.6	12.7	11.1	13.4
Cost ($/klm l)[2]	$2.95	$3.22	$2.95	$3.22	$2.92	$3.19	$2.77	$3.03	$2.64	$2.89
Cost ($/klm l/f)[3]	$16.28	$12.71	$16.28	$12.71	$16.00	$12.49	$15.22	$11.88	$14.48	$11.30
CRI	82	82	82	82	82	82	82	82	82	82
Total Installed Cost ($)	$71	$75	$71	$75	$71	$75	$71	$74	$70	$74
Annual Maintenance Cost ($)	$0.37	$0.37	$0.37	$0.37	$0.37	$0.37	$0.37	$0.37	$0.37	$0.37

[1] Losses in fixture included.
[2] Includes lamp price only. (l)
[3] Include lamp price and fixture price. (l/f)

Commercial Compact Fluorescent Lighting

- The commercial compact fluorescent lamp characterized in this report is a 26 and 42 watt screw-base compact fluorescent lamp in an open down light recessed can fixture (~$12) with a fixture efficiency of 61%.
- EPACT 2005 sets performance for medium based compact fluorescent lamps. It adopts Energy Star performance requirements (August 6, 2001 version) for efficacy, lumen maintenance, lamp life, rapid cycle stress test, CRI, etc. The standard is effective for lamps manufactured on or after January 1, 2006. The Secretary may revise these requirements by rule or establish other requirements at a later date. *[Note: EPACT 2005 standards do not apply to CFL lamps with screw bases other than medium (e.g., pin based)]*
- Energy Star® and the Consortium for Energy Efficiency (CEE) offer voluntary specifications for CFL lamps.
- California's Title 24 mandates the use of electronic ballasts with high efficacy luminaires (including fluorescent) of 13 W or higher (CEC, 2005)
- The following future improvements were assumed to occur over a 20 year period: Efficacy +5%, Life +10%, and Price -5% (NCI, 2006). Improvements in efficacy can be made by using more rare-earth phosphors in compact fluorescent lamps. Lifetime improvements can be made by improving the compact fluorescent lamp electrodes.
- Total installed cost includes equipment and installation costs. Annual maintenance costs and installation costs are calculated using labor rate and labor time to install/replace equipment from RS Means and the lamps ANOPR. Maintenance costs include labor only based on 3,650 operating hours per year.

Performance/Cost Characteristics Commercial Halogen Lighting

Commercial Halogen Lighting – General and Quartz

	2003		2008		2010		2020		2030	
	90W Halogen	70W HIR	90W Halogen	70W HIR	90W Halogen	70W HIR	90W Halogen	70W HIR	90W Halogen	70W HIR
Typical Wattage	90	70	90	70	90	70	90	70	90	70
Lamp Efficacy (lm/W)	14.6	18.0	14.6	18.0	14.6	18.0	14.7	18.2	14.9	18.4
System Lumens	1218	1172	1218	1172	1221	1174	1233	1186	1245	1198
System Efficacy (lm/W)[1]	13.5	16.7	13.5	16.7	13.6	16.8	13.7	16.9	13.8	17.1
Average Life (1000 hrs)	2.5	3.0	2.5	3.0	2.5	3.0	2.6	3.1	2.6	3.2
Cost ($/klm l)[2]	$3.66	$4.97	$3.66	$4.97	$3.64	$4.93	$3.51	$4.76	$3.39	$4.60
Cost ($/klm l/f)[3]	$13.98	$15.78	$13.98	$15.78	$13.88	$15.67	$13.40	$15.12	$12.93	$14.60
CRI	100	100	100	100	100	100	100	100	100	100
Total Installed Cost ($)	$71.00	$72.00	$71.00	$72.00	$71.00	$72.00	$70.00	$72.00	$70.00	$71.00
Annual Maintenance Cost ($)	$1.41	$1.17	$1.41	$1.17	$1.41	$1.17	$1.41	$1.17	$1.41	$1.17

[1] Losses in fixture included.
[2] Includes lamp price only. (l)
[3] Include lamp price and fixture price. (l/f)

Commercial Halogen Lighting – General and Quartz

- The commercial halogen lighting characterized in this report is a lamp that emits approximately 1100 lumens in an open down light recessed can fixture (~$12) with a fixture efficiency of 93% (DOE, 2008).
- Assumptions
  - Typical efficiency unit: 90W halogen PAR38 (quartz)
  - High efficiency unit: 70W halogen infrared reflector PAR38 (quartz)
- Halogen infrared reflector (HIR) lamps contain a tungsten halogen capsule with a film coating on the inside of the capsule. The coating reflects infrared radiation back into the lamp filament, which forces the filament to burn at a higher temperature. This increases the efficacy of the lamp, without reducing operating life.
- EPACT92 established minimum performance standards for some reflector lamps and provided exemptions for certain specialty applications (e.g., ER/BR, vibration service, more than 5% neodymium oxide, impact resistant, infrared heat, colored). EPACT92 effectively phased-out R-shaped tungsten filament incandescent reflector lamps at certain wattages and bulb diameters, replacing them with more efficient and cost effective tungsten-halogen parabolic aluminized reflector (PAR) lamps. EISA2007 took away certain exemptions from EPACT 1992, requiring certain previously exempted lamps to meet EPACT92 minimum performance standards by January 1, 2008.
- The following future improvements for the system were assumed to occur over a 20 year period: Efficacy +2%, Life +5%, and Price -5% (NCI, 2006). These improvements can be made by improved filament design and placement, higher pressure capsules, or higher efficiency reflector coatings.
- Total installed cost includes equipment and installation costs. Annual maintenance costs and installation costs are calculated using labor rate and labor time to install/replace equipment from RS Means and the lamps ANOPR. Maintenance costs include labor only based on 3,450 operating hours per year. (lamps ANOPR)

Performance/Cost Characteristics Commercial Linear Fluorescent Lighting T5

Commercial Linear Fluorescent Lighting – T5 (2-lamp system)

	2003		2008		2010		2020		2030	
	F28T5	F28T5 HE	F28T5	F28T5 HE	F28T5	F28T5 HE	F28T5	F28T5 HE	F28T5	F28T5 HE
System Wattage	66	62	66	62	66	62	66	62	66	62
System Lumens	4698	4862	4698	4862	4721	5143	4839	5272	4960	5404
Lamp Efficacy (lm/W)	95.0	103.5	95.0	103.5	95.5	104.0	97.9	106.6	100.3	109.3
System Efficacy (lm/W)[1]	71.2	78.4	71.2	78.4	71.5	83.0	73.3	85.0	75.2	87.2
Cost ($/klm)[2]	$1.44	$1.46	$1.44	$1.46	$1.43	$1.45	$1.36	$1.38	$1.29	$1.31
Cost ($/klm l/b/f)[3]	$26.95	$26.21	$26.95	$26.21	$26.69	$24.65	$25.38	$23.45	$24.15	$22.30
Average Lamp Life (1000 hrs)	20	20	20	20	20.2	20.2	21.2	21.2	22.3	22.3
CRI	85	85	85	85	85	85	85	85	85	85
Total Installed Cost ($)	$155	$156	$155	$156	$154	$155	$151	$152	$148	$149
Annual Maintenance Cost ($)	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73

[1] Losses in fixture included.
[2] Includes lamp price only.
[3] Include lamp price, ballast price, and fixture price. (l/b/f)

Performance/Cost Characteristics Commercial Linear Fluorescent Lighting T5

Commercial Linear Fluorescent Lighting – T5HO (2- and 4-lamp systems)

	2003		2008		2010		2020		2030	
	2L F54T5HO	4L F54T5HO	2L F54T5HO	4L F54T5HO	2L F54T5HO	4L F54T5HO	2L F54T5HO	4L F54T5HO	2L F54T5HO	4L F54T5HO
System Wattage	120	240	120	240	120	240	120	240	120	240
System Lumens	8132	18060	8132	18060	8430	18150	8641	18604	8857	19069
Lamp Efficacy (lm/W)	88.0	88.0	88.0	88.0	88.4	88.4	90.6	90.6	92.9	92.9
System Efficacy (lm/W)[1]	67.8	75.2	67.8	75.2	70.3	75.6	72.0	77.5	73.8	79.5
Cost ($/klm)[2]	$1.00	$1.00	$1.00	$1.00	$0.99	$0.99	$0.94	$0.94	$0.89	$0.89
Cost ($/klm l/b/f)[3]	$11.74	$7.99	$11.74	$7.99	$11.27	$7.91	$10.72	$7.53	$10.19	$7.16
Average Lamp Life (1000 hrs)	20	20	20	20	20.2	20.2	21.2	21.2	22.3	22.3
CRI	85	85	85	85	85	85	85	85	85	85
Total Installed Cost ($)	$124	$173	$124	$173	$123	$172	$121	$168	$119	$165
Annual Maintenance Cost ($)	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73

[1] Losses in fixture included.
[2] Includes lamp price only.
[3] Include lamp price, ballast price, and fixture price. (l/b/f)

Commercial Linear Fluorescent Lighting – T5 (2- and 4-lamp systems)

- The commercial linear T5 fluorescent lighting characterized in this report are a two-lamp system (one ballast and one 2 lamp fixture with an efficiency of 88% for F28T5 and 85% for F54T5HO) and a four-lamp system (one ballast and one 4 lamp fixture with an efficiency of 95% for F54T5HO).
- T5 lamps are approximately 40% narrower than T8 lamps and almost 60% narrower than T12 lamps. This allows T5 lamps to be coated with higher quality, more efficient phosphor blends than larger diameter lamps, resulting in a more efficacious lamp. The compact size of T5 lamps also permits greater flexibility in lighting design and construction.
- Assumptions:
  - Typical efficiency unit: 2 F28T5 lamps (28W each) with electronic ballast (Ballast Factor=1)
  - High efficiency unit: 2 F28T5 lamps (28W each) with electronic ballast (Ballast Factor=0.95)
  - Typical efficiency unit: 2 F54T5 high output lamps (54W each) with electronic ballast (Ballast Factor=1)
  - Typical efficiency unit: 4 F54T5 high output lamps (54W each) with electronic ballast (Ballast Factor=1)
- Reported lumens are “mean” lumens.
- The following future improvements were assumed to occur over a 20 year period: Efficacy +5%, Life +10%, and Price -5% (NCI, 2006). Efficiency and life improvements can be made by using improved phosphors and electrodes.
- Many utilities offer rebates for T5 high output fixtures, generally to replace HID high bay fixtures. The programs include new construction incentives, customized programs, retrofit and upgrade incentives.
- Total installation costs are $273 for a 4-lamp F54T5HO high bay system and $230 for a 2-lamp F54T5HO low bay system. Annual maintenance costs are $3.94 for these F54T5HO high and low bay systems.
- Total installed cost includes equipment and installation costs. Annual maintenance costs and installation costs are calculated using labor rate and labor time to install/replace equipment from RS Means and lamps ANOPR. Maintenance costs include labor only based on 3,435 operating hours per year. (lamps ANOPR)

Performance/Cost Characteristics Commercial Linear Fluorescent Lighting > 4ft. T8/T12

Commercial Linear Fluorescent Lighting – > 4 ft. T8/T12 (2-lamp system)

	2003				2008			2010		2020		2030	
	F96T12	F96T12 ES	F96T8 Typical	F96T8 High	F96T12 ES	F96T8 Typical	F96T8 High	F96T8 Typical	F96T8 High	F96T8 Typical	F96T8 High	F96T8 Typical	F96T8 High
System Wattage	158	126	113	100	126	113	100	113	100	113	100	113	100
System Lumens	10208	7546	8300	8311	7546	8300	8311	9480	10708	9717	10976	9959	11250
Lamp Efficacy (lm/W)	78.7	77.7	86.9	98.2	77.7	86.9	98.2	87.4	98.7	89.6	101.2	91.8	103.7
System Efficacy (lm/W)[1]	64.6	59.9	73.5	83.1	59.9	73.5	83.1	83.9	107.1	86.0	109.8	88.1	112.5
Cost ($/klm)[2]	$0.93	$0.69	$0.75	$1.16	$0.69	$0.75	$1.16	$0.75	$1.15	$0.71	$1.09	$0.68	$1.04
Cost ($/klm l/b/f)[3]	$4.99	$6.15	$5.98	$6.66	$6.15	$5.98	$6.66	$5.21	$5.14	$4.95	$4.89	$4.71	$4.65
Average Lamp Life (1000 hrs)	12.0	12.0	15.0	18.0	12.0	15.0	18.0	15.2	18.2	15.9	19.1	16.7	20.0
CRI	70	62	75	85	62	75	85	75	85	75	85	75	85
Total Installed Cost ($)	$100	$96	$99	$105	$96	$99	$105	$99	$104	$98	$103	$96	$102
Annual Maintenance Cost ($)	$4.52	$4.52	$4.27	$4.11	$4.52	$4.27	$4.11	$4.27	$4.11	$4.27	$4.11	$4.27	$4.11

[1] Losses in fixture included.
[2] Includes lamp price only.
[3] Include lamp price, ballast price, and fixture price. (l/b/f) 29

Performance/Cost Characteristics Commercial Linear Fluorescent Lighting > 4ft. T8/T12

Commercial Linear Fluorescent Lighting – > 4 ft. T8/T12HO (2-lamp system)

	2003	2008	2010	2020	2030
	F96T8HO	F96T8HO	F96T8HO	F96T8HO	F96T8HO
System Wattage	160	160	160	160	160
System Lumens	11488	11488	13120	13448	13784
Lamp Efficacy (lm/W)	82.6	82.6	83.0	85.0	87.2
System Efficacy (lm/W)[1]	71.8	71.8	82.0	84.0	86.1
Cost ($/klm)[2]	$0.93	$0.93	$0.92	$0.87	$0.83
Cost ($/klm l/b/f)[3]	$8.73	$8.73	$7.61	$7.24	$6.88
Average Lamp Life (1000 hrs)	24.0	24.0	24.2	25.5	26.7
CRI	78	78	78	78	78
Total Installed Cost ($)	$154	$154	$154	$151	$149
Annual Maintenance Cost ($)	$4.41	$4.41	$4.41	$4.41	$4.41

[1] Losses in fixture included.
[2] Includes lamp price only.
[3] Include lamp price, ballast price, and fixture price. (l/b/f)

Commercial Linear Fluorescent Lighting – > 4 ft. T8/T12 (2-lamp system)

- The commercial linear fluorescent lighting (> 4 ft.) characterized in this report a two-lamp system (one ballast and one fixture with a 92% fixture efficiency) that emits approximately 7,000 system lumens.
- Assumptions
  - 2 F96T12 lamps (75W each) with magnetic ballast (Ballast Factor =0.94)
  - 2 F96T12 lamps (60W each) with magnetic ballast (Ballast Factor =0.88)
  - 2 F96T8 lamps (59W each) with electronic ballast (Ballast Factor=0.88)
  - High efficiency 2 F96T8 lamps (59W each) with electronic ballast (Ballast Factor=0.78)
  - 2 F96T8HO lamps (86W each) with electronic ballast (Ballast Factor=0.88)
- Reported lumens are "mean" lumens.
- The following future improvements were assumed to occur over a 20 year period: Efficacy +5%, Life +10%, and Price -5% (NCI, 2003). Improvements can be made through improved phosphors and electrodes.
- DOE set minimum efficiency standards for T12 fluorescent ballasts. The regulation raises the minimum Ballast Efficacy Factors (BEF) for T12 fluorescent ballasts, which effectively promotes the use of T8 lamp and ballast systems. The Federal Ballast Rule covers 2-foot U-shaped Rapid Start, 4-foot Rapid Start, 8-foot Instant Start and 8-foot High Output T12 fluorescent ballasts. Ballast manufacturers cannot manufacturer T12 ballasts operating full wattage lamps for new luminaires after April 1, 2005. Ballast manufacturers cannot manufacturer T12 ballasts operating reduced wattage lamps for new luminaires after July 1, 2009.
- California's Title 24 mandates the use of electronic ballasts with high efficacy luminaires (including fluorescent) of 13 W or higher (CEC, 2005)
- Total installed cost includes equipment and installation costs. Annual maintenance costs and installation costs are calculated using labor rate and labor time to install/replace equipment from RS Means and the lamps ANOPR. Maintenance costs include labor only based on 3,435 operating hours per year. (lamps ANOPR).
- Total installation costs are $235 and annual maintenance costs are $3.82 for 2-lamp F96T8HO high bay and low bay systems.

Performance/Cost Characteristics Commercial Linear Fluorescent Lighting ≤ 4ft. T8/T12

Commercial Linear Fluorescent Lighting - ≤ 4 ft. T8/T12 (2-lamp system)

	2003		2008							2010					
	F34T 12	F32T8	F34T 12	F32T8 HE Magn.	F32T8	F32T8 HE	F32T8 HE w/ OS	F32T8 HE w/ HE Fixture	F32T8 Super	F32T8 HE Magn.	F32T8	F32T8 HE	F32T8 HE w/ OS	F32T8 HE w/ HE Fixture	F32T8 Super
System Wattage	72	58.5	72	73	58.5	51.9	51.9	49.9	49.9	73	58.5	51.9	51.9	49.9	49.9
System Lumens	2996	3282	2996	3506	3282	3128	3128	3496	3236	3523	3298	3144	3144	3513	3252
Lamp Efficacy	67.6	78.8	67.6	78.8	78.8	84.7	84.7	84.7	91.1	79.1	79.1	85.1	85.1	85.1	91.5
System Efficacy (lm/W)1	41.6	56.1	41.6	48.0	56.1	60.3	60.3	70.1	64.8	48.3	56.4	60.6	60.6	70.4	65.2
Cost ($/klm)2	$0.65	$0.68	$0.65	$0.68	$0.68	$0.99	$0.99	$0.99	$1.14	$0.68	$0.68	$0.98	$0.98	$0.98	$1.12
Cost ($/klm l/b/f)3	$9.60	$12.93	$9.60	$14.93	$12.93	$14.19	$15.15	$16.84	$14.10	$14.78	$12.80	$14.04	$15.00	$16.67	$13.96
Average Lamp Life (1000 hrs)	20	20	20	20	20	20	10	20	24	20.2	20.2	20.2	10.1	20.2	24.2
CRI	62	75	62	75	75	82	82	82	82	75	75	82	82	82	82
Total Installed Cost ($)	$56	$69	$56	$79	$69	$71	$74	$86	$73	$79	$69	$71	$74	$86	$72
Annual Maintenance Cost ($)	$3.77	$2.73	$3.77	$2.73	$2.73	$2.73	$2.73	$2.73	$2.56	$2.73	$2.73	$2.73	$2.73	$2.73	$2.56

[1] Losses in fixture included.
[2] Includes lamp price only.
[3] Include lamp price, ballast price, and fixture price. (l/b/f)

Performance/Cost Characteristics Commercial Linear Fluorescent Lighting ≤ 4ft. T8/T12

Commercial Linear Fluorescent Lighting - ≤ 4 ft. T8/T12 (2-lamp system cont.)

	2020						2030					
	F32T8 HE Magn.	F32T8	F32T8 HE	F32T8 HE with OS	F32T8 HE w/ HE Fixture	F32T8 Super	F32T8 HE Magn.	F32T8	F32T8 HE	F32T8 HE with OS	F32T8 HE w/ HE Fixture	F32T8 Super
System Wattage	73	58.5	51.9	51.9	49.9	49.9	73	58.5	51.9	51.9	49.9	49.9
System Lumens	3611	3381	3222	3222	3601	3333	3699	3463	3300	3300	3688	3414
Lamp Efficacy	81.1	81.1	87.2	87.2	87.2	93.8	83.1	83.1	89.3	89.3	89.3	96.1
System Efficacy (lm/W)1	49.5	57.8	62.1	62.1	72.2	66.8	50.7	59.2	63.6	63.6	73.9	68.4
Cost ($/klm)2	$0.64	$0.64	$0.93	$0.93	$0.93	$1.07	$0.61	$0.61	$0.89	$0.89	$0.89	$1.02
Cost ($/klm l/b/f)3	$14.06	$12.18	$13.36	$14.27	$15.85	$13.28	$13.37	$11.58	$12.71	$13.57	$15.08	$12.63
Average Lamp Life (1000 hrs)	21.2	21.2	21.2	10.6	21.2	25.4	22.2	22.2	22.2	11.1	22.2	26.6
CRI	75	75	82	82	82	82	75	75	82	82	82	82
Total Installed Cost ($)	$78	$68	$70	$73	$84	$71	$76	$67	$69	$72	$83	$70
Annual Maintenance Cost ($)	$2.73	$2.73	$2.73	$2.73	$2.73	$2.56	$2.73	$2.73	$2.73	$2.73	$2.73	$2.56

[1] Losses in fixture included.
[2] Includes lamp price only.
[3] Include lamp price, ballast price, and fixture price. (l/b/f)

Commercial Linear Fluorescent Lighting – ≤ 4 ft. T8/T12 (2-lamp system)

- The commercial linear fluorescent lighting (< 4 ft.) characterized in this report is a two-lamp system (one ballast and one fixture) that emits approximately 4,000 system lumens.
- Assumptions
  - F34T12 Unit: 2 F34T12 lamps (34W each) with magnetic ballast (Ballast Factor =0.88), fixture efficiency = 74%
  - F32T8 Unit HE Magnetic Unit: 2 F32T8 lamps with a high efficiency magnetic ballast (Ballast Factor = 0.94), fixture efficiency = 74%
  - F32T8 Unit: 2 F32T8 lamps (32W each) with instant start electronic ballast (Ballast Factor=0.88), fixture efficiency = 74%
  - F32T8 HE Unit: 2 high efficiency F32T8 lamps (32W each) with instant start electronic ballast (Ballast Factor=0.78), fixture efficiency = 74%
  - F32T8 HE w/ OS unit: 2 high efficiency F32T8 lamps (32W each) with electronic ballast (Ballast Factor=0.78)and occupancy sensor (designed for 1,000 sq. ft. or ~25 two lamp systems, fixture efficiency = 74%.
  - F32T8 HE w/ HE Fixture: 2 high efficiency F32T8 lamps (32W each) with instant start electronic ballast (Ballast Factor=0.75), fixture efficiency = 86%
  - F32T8 Super unit: 2 very high efficiency F32T8 lamps (32W each) with electronic ballast (Ballast Factor=0.75), fixture efficiency = 74%.
- Though system watts for the F32T8 HE with the occupancy sensor are the same as the F32T8 HE, occupancy sensors can result in 17% to 60% energy savings due to reduced operating hours. (LRC) Savings potential is highly dependent on the time-delay programmed into the sensor, which ranges from 5-30 minutes and room type. Shorter time delays save more energy, but possibly at expense of lamp life. Occupancy sensors can reduce fluorescent lamp lifetime by as much as 50% (Lutron). This decrease in lifetime results in higher overall maintenance costs.
- Reported lumens are “mean” lumens.
- The following future improvements were assumed to occur over a 20 year period: Efficacy +5%, Life +10%, and Price -5% (NCI, 2006). Improvements in efficacy and life can be made with better phosophors and electrodes.
- DOE set minimum efficiency standards for T12 fluorescent ballasts. The regulation raises the minimum Ballast Efficacy Factors (BEF) for T12 fluorescent ballasts, which effectively promotes the use of T8 lamp and ballast systems. Ballast manufacturers cannot manufacturer T12 ballasts operating full wattage lamps for new luminaires after April 1, 2005. Ballast manufacturers cannot manufacturer T12 ballasts operating reduced wattage lamps for new luminaires after July 1, 2009.
- Total installed cost includes equipment and installation costs. Annual maintenance costs and installation costs are calculated using labor rate and labor time to install/replace equipment from RS Means. Maintenance costs include labor only based on 3,435 operating hours per year. (lamps ANOPR)

Performance/Cost Characteristics Commercial HID High Bay Lighting

Commercial HID High Bay Lighting

	2003			2008		2010		2020		2030	
	400W MV	250W MH	150W HPS	250W MH	150W HPS	250W MH	150W HPS	250W MH	150W HPS	250W MH	150W HPS
System Wattage	453	293	189	295	189	291	189	291	189	291	189
System Lumens	13061	12245	13061	12245	13061	15419	13191	16267	13917	17080	14613
Lamp Efficacy (lm/W)	36.0	54.0	96.0	54.0	96.0	68.0	97.0	71.7	102.3	75.3	107.4
System Efficacy (lm/W)[1]	28.8	41.8	69.1	41.5	69.1	53.0	69.8	55.9	73.6	58.7	77.3
Cost ($/klm)[2]	$1.09	$1.23	$1.20	$1.23	$1.20	$2.58	$1.19	$1.77	$0.81	$1.64	$0.75
Cost ($/klm l/b/f)[3]	$10.39	$12.06	$13.13	$12.06	$13.13	$12.89	$12.93	$11.88	$11.92	$11.03	$11.07
Average Lamp Life (1000 hrs)	24	10	24.0	10	24	15.0	24.2	15.8	25.6	16.6	26.9
CRI	50	65	22	65	22	65	22	65	22	65	22
Total Installed Cost ($)	$270	$282	$306	$282	$306	$333	$305	$328	$301	$323	$296
Annual Maintenance Cost ($)	$3.82	$4.68	$3.82	$4.68	$3.82	$4.19	$3.82	$4.19	$3.82	$4.19	$3.82

[1] Losses in fixture included.
[2] Includes lamp price only.
[3] Include lamp price, ballast price, and fixture price. (l/b/f)

Commercial HID High Bay Lighting

- The commercial HID high bay lighting characterized in this report is a one lamp and one ballast system in a high bay open metal reflector fixture (efficiency = 91%) that emits approximately 13,000 system lumens.
- Assumptions
  - Low efficiency unit: 400W mercury vapor lamp with magnetic ballast
  - Typical efficiency unit: 250W metal halide lamp with probe start magnetic ballast
  - High efficiency standards compliant unit: 250W metal halide lamp with pulse start magnetic ballast
  - High efficiency unit: 150W high pressure sodium lamp with magnetic ballast.
- High bay lighting is defined as "interior lighting where the roof trusses or ceiling height is greater than 25ft. above the floor." (IESNA, 2000)
- DOE is performing a determination to see if energy conservation standards for HID lamps would be technologically feasible and economically justified, and would result in significant energy savings. The Department published a draft report for public comment, High-Intensity Discharge Lamps Analysis of Potential Energy Savings, in December 2004 .
- EPACT 2005 requires that mercury vapor lamp ballasts shall not be manufactured or imported after January 1, 2008. EISA 2007 established efficiency standards for probe start magnetic ballasts (94%) and pulse start magnetic or electronic ballasts (88%) effective January 1, 2009 which will cause currently sold probe start magnetic ballasts to become obsolete.
- California is currently undergoing a rulemaking to reduce commercial lighting by not less than 25% of 2007 levels over the next 10 years in accordance with Assembly Bill 1109. They are going to regulate HID Metal Halide Fixtures.
- The following future improvements were assumed to occur over a 20 year period: Efficacy +10%, Life +10%, and Price -5% (NCI, 2006). Improvements can be made by using ceramic arctubes, and improved electrodes. (NCI, 2005).
- Utilities in MA, NY, OR, TX, VT, WA, WI, FL and CA offer non-regulatory incentive programs to promote energy efficient HID lighting.
- Total installed cost includes equipment and installation costs. Annual maintenance costs and installation costs are calculated using labor rate and labor time to install/replace equipment from RS Means and lamps ANOPR. Maintenance costs include labor only based on 3,650 operating hours per year.
- Total installation costs are $273 and annual maintenance costs are $3.94 for a 4-lamp F54T5HO high bay system.
- Total installation costs are $235 and annual maintenance costs are $3.82 for a 2-lamp F96T8HO high bay system.

Performance/Cost Characteristics Commercial HID Low Bay Lighting

Commercial HID Low Bay Lighting

	2003			2008		2010		2020		2030	
	MH 175	MV175	HPS70	MH 175	HPS70	MH 175	HPS70	MH 175	HPS70	MH 175	HPS70
System Wattage	210	208	93	210	93	194	93	194	93	194	93
System Lumens	6669	5176	4130	6669	4130	9094	4171	9594	4401	10074	4621
Lamp Efficacy (lm/W)	50.3	39.0	77.9	50.3	77.9	68.6	78.6	72.3	83.0	76.0	87.1
System Efficacy (lm/W)[1]	31.8	24.9	44.4	31.8	44.4	46.9	44.9	49.5	47.3	51.9	49.7
Cost ($/klm)[2]	$2.58	$2.06	$2.92	$2.58	$2.92	$2.59	$2.88	$2.38	$2.65	$2.21	$2.46
Cost ($/klm l/b/f)[3]	$24.59	$33.64	$38.67	$24.59	$38.67	$25.31	$38.09	$23.33	$35.11	$21.66	$32.61
Average Lamp Life (1000 hrs)	10	24	24.0	10.0	24.0	15.0	24.2	15.8	25.6	16.6	26.9
CRI	65	15	22	65	22	65	22	65	22	65	22
Total Installed Cost ($)	$299	$309	$294	$299	$294	$365	$294	$359	$289	$353	$285
Annual Maintenance Cost ($)	$4.68	$3.82	$3.82	$4.68	$3.82	$4.19	$3.82	$4.19	$3.82	$4.19	$3.82

[1] Losses in fixture included.

[2] Includes lamp price only.

[3] Include lamp price, ballast price, and fixture price. (l/b/f)

Commercial HID Low Bay Lighting

- The commercial HID low bay lighting characterized in this report is a is a one lamp and one ballast system in a low bay fixture with dropped lens (efficiency = 76%) that emits approximately 6,700 system lumens.
- Assumptions
  - Low efficiency unit: 175W mercury vapor lamp with magnetic ballast
  - Typical efficiency unit: 175W metal halide lamp with magnetic ballast
  - High efficiency standards compliant unit: 250W metal halide lamp with pulse start magnetic ballast
  - High efficiency unit: 70W high pressure sodium lamp with magnetic ballast.
- Low bay lighting is defined as "interior lighting where the roof trusses or ceiling height is less than 25ft. above the floor." (IESNA, 2000)
- DOE is performing a determination to see if energy conservation standards for HID lamps would be technologically feasible and economically justified, and would result in significant energy savings. The Department published a draft report for public comment, High-Intensity Discharge Lamps Analysis of Potential Energy Savings, in December 2004 .
- EPACT 2005 requires that mercury vapor lamp ballasts shall not be manufactured or imported after January 1, 2008. EISA 2007 established efficiency standards for probe start magnetic ballasts (94%) and pulse start magnetic or electronic ballasts (88%) effective January 1, 2009 which will cause currently sold probe start magnetic ballasts to become obsolete.
- California is currently undergoing a rulemaking to reduce commercial lighting by not less than 25% of 2007 levels over the next 10 years in accordance with Assembly Bill 1109. They are going to HID Metal Halide Fixtures.
- The following future improvements were assumed to occur over a 20 year period: Efficacy +10%, Life +10%, and Price -5% (NCI, 2003). Improvements can be made by using ceramic arctubes, and improved electrodes. (NCI, 2005).
- Utilities in MA, NY, OR, TX, VT, WA, WI, FL and CA offer non-regulatory incentive programs to promote energy efficient HID lighting. Incentive programs favor efficient T5 high output lamps or T8 lamps for low bay applications.
- Total installed cost includes equipment and installation costs. Annual maintenance costs and installation costs are calculated using labor rate and labor time to install/replace equipment from RS Means and the lamps ANOPR. Maintenance costs include labor only based on 3,650 operating hours per year.
- Total installation costs are $230 and annual maintenance costs are $3.94 for a 2-lamp F54T5HO low bay system.
- Total installation costs are $235 and annual maintenance costs are $3.82 for a 2-lamp F96T8HO low bay system.

Performance/Cost Characteristics Commercial Solid-State Lighting

Commercial Solid-State Lighting

	2003	2008	2010	2020	2030
	LED	LED	LED	LED	LED
Lamp Wattage	36.4	9.9	6.5	3.2	3.2
Lamp Lumens	630	630	630	630	630
System Lumens	548	548	548	548	548
Lamp Efficacy (lm/W)	17.3	63.6	97.2	195.5	195.5
System Efficacy (lm/W)[1]	15.0	55.3	84.6	170.1	170.1
Cost ($/klm)[2]	$301	$120	$74	$21	$21
Cost ($/klm l/b/f)[3]	$369	$160	$107	$47	$47
Life (1000 hours)	50	50	50	50	50
CRI	92	92	92	92	92
CCT	2700	2700	2700	2700	2700
Total Installed Cost ($)	$254	$140	$111	$78	$78
Annual Maintenance Cost ($)	$0.07	$0.07	$0.07	$0.07	$0.07

[1] Losses in fixture included.
[2] Includes lamp price only.
[3] Include lamp price, driver price, and fixture price. (l/b/f)

Commercial Solid-State Lighting

- The commercial solid-state lighting characterized is a warm white LED reflector lamp for use in a open downlight reflector can (~$12) with a fixture efficiency of 87%.
- The efficacy projection is based on the projection of efficacy of a commercial cool white luminaire in the March 2008 Solid-State Lighting Multi-Year Program Plan. Cool white LEDs are used for this analysis because it is common to create a warm white product by mixing cool white LEDs with monochromatic red LEDs..
- Current and future "typical" projections for $/klm for the LED devices are based on the March 2008 Solid-State Lighting Multi-Year Program Plan. Price projections for the LED driver, heat sink, labor and overhead are NCI estimates.
- Total installed cost includes equipment and installation costs. Annual maintenance costs and installation costs are calculated using labor rate and labor time to install/replace equipment from RS Means and the Lamps ANOPR. Maintenance costs include labor only based on 3,376 operating hours per year. (lamps ANOPR)

Commercial Supermarket Display Cases

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Cooling Capacity (Btu/hr)	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Median Store Size (ft^3)	44,000	47,500	47,500	47,500	47,500	47,500	47,500	47,500	47,500	47,500
Energy Use (kWh/yr)	21,000	22,500	21,000	17,000	21,000	17,000	21,000	17,000	21,000	17,000
Average Life (yrs)	10	10	10	10	10	10	10	10	10	10
Retail Equipment Cost	$4,200	$3,900	$4,200	$6,900	$4,200	$6,900	$4,200	$6,900	$4,200	$6,900
Total Installed Cost[1]	$6,200	$5,900	$6,200	$8,900	$6,200	$8,900	$6,200	$8,900	$6,200	$8,900
Annual Maintenance Cost[2]	$260	$260	$260	$260	$260	$260	$260	$260	$260	$260

[1] Installation cost is assumed to be about $2,000. This does not include a distribution markup.
[2] Maintenance cost includes preventative maintenance costs (cleaning evaporator coil, cleaning condensate drain, and system functionality check) and lighting replacement costs.

Commercial Supermarket Display Cases

- In 2007, the median average supermarket square footage, among the Nation's 34,967 supermarkets, was 47,500 ft^2. (FMI, 2008)
- The unit used to estimate energy use and installed cost is a vertical, open, medium temperature, remote condensing display case.
- Commercial central refrigeration systems consist of refrigerated display cases, condensing units, and centralized compressor racks.
- A typical commercial supermarket display case contains:
  - T8 electronic lighting,
  - evaporators,
  - evaporator fans, and
  - piping, insulation, valves and controls.
- The efficiency of supermarket display cases can be increased through the use of improved evaporator coils, larger evaporators, higher efficiency evaporator fan blades, high efficiency doors, LED lighting, thicker insulation, improved insulation, etc.
- A Federal energy consumption standard for commercial supermarket display cases will be in effect in 2012 and is currently being developed by DOE.
- Approximately 15 percent of the total annual electricity consumption for a large supermarket is attributable to display cases and 3 percent is attributable to condensers. (ASHRAE Handbook, 2006)

Performance/Cost Characteristics Commercial Compressor Rack Systems

Commercial Compressor Rack Systems

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Total Capacity (MBtu/hr)[1]	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
Power Input (kW)	180	200	180	160	180	160	180	160	180	160
Energy Use[2] (MWh/yr)	1,000	1,100	1,000	880	1,000	880	1,000	880	1,000	880
Average Life (yrs)	20	20	20	20	20	20	20	20	20	20
Total Installed Cost ($1000)	$110-$140	$100-$120	$110-$140	$130-$150	$110-$140	$130-$150	$110-$140	$130-$150	$110-$140	$130-$150
Annual Maintenance Cost ($1000)[3]	$30	$30	$30	$30	$30	$30	$30	$30	$30	$30

[1] A 1,050 MBtu/hr total cooling capacity is the sum of 750 MBtu/hr for medium temperature compressor racks and 300 MBtu/hr for low temperature compressor racks.
[2] Based on a duty cycle of 63% (ADL, 1996)
[3] Maintenance cost includes oil changes, bearing lubrication, filter replacement, and system functionality checks.

Commercial Compressor Rack Systems

- Commercial compressor rack systems that serve commercial supermarket display cases consist of a number of parallel-connected compressors located in a separate machine room. By modulating compressor capacity, these integrated systems provide higher efficiency and mechanical longevity.
- Rack integrators generally supply a packaged compressor rack for which much of the necessary piping, insulation, components, and controls are pre-assembled.
- A rack may have from 3 to 5 compressors serving a series of loads with nearly identical evaporator temperature.
- A typical supermarket will have 10 to 20 compressors in the 3-hp to 15-hp size range.
- The duty cycle for compressors is usually in the range 60% to 70%.
- The typical supermarket has two medium temperature and two low temperature refrigeration systems with about 200 hp total connected compressor power.
- Average compressor EER (for R404A refrigerant):
  - — Medium temperature: low (6.0); typical (7.0); high (7.8)
  - — Low temperature: low (3.8); typical (4.2); high (4.9)
- Approximately 28 percent of the total annual electricity consumption for a large supermarket is attributable to compressors. (ASHRAE Handbook, 2006)

Commercial Condensers

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Total Capacity (mBtu/hr)[1]	1,520	1,520	1,520	1,520	1,520	1,520	1,520	1,520	1,520	1,520
Power Input (kW)	25	25	22	16	22	16	22	16	22	16
Energy Use[2] (MWh/yr)	138	138	120	88	120	88	120	88	120	88
Average Life (yrs)	10	10	10	10	10	10	10	10	10	10
Total Installed Cost ($1000)	$45	$40	$45	$50	$45	$50	$45	$50	$45	$50
Annual Maintenance Cost[3]	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000

[1] Total capacity is the total heat rejected (THR) of condensers comprised of two low temperature condensers (THR_L = 240 MBtu/hr each, suction temperature = -25°F, condensing temperature 110˚F) and two medium temperature (THR_M = 520 MBtu/hr each, suction temperature = 15°F, condensing temperature = 115°F) condensers. (Ambient temperature = 95°F)
[2] Based on a 63% duty cycle. (ADL, 1996)
[3] Maintenance cost includes coil cleaning, leak checking, belt replacement as necessary, and system functionality checks.

Commercial Condensers

- Condensers are designed with multiple methods of cooling: air-cooled, water-cooled, and evaporative. These units can be single-circuit or a multiple circuit.
- Commercial condensers are remotely located, typically installed on the roof of a supermarket.
- For use with parallel compressors in supermarkets, air-cooled units are the most commonly used condensers. This analysis is based on multiple air-cooled condensers connected to a supermarket refrigeration system comprised of two low temperature condensers and two medium temperature condensers, using R-404A refrigerant.
- Each compressor rack has a dedicated condenser or a separate circuit of a single common condenser. Condenser temperatures of multiple racks are often different.
- The duty cycle for condensers is usually in the range 50 - 70%
- Approximately 3 percent of the total annual electricity consumption for a large supermarket is attributable to condensers. (ASHRAE Handbook, 2006)

Performance/Cost Characteristics Commercial Walk-In Refrigerators

Commercial Walk-In Refrigerators

	2003	2008		2010[2]		2020		2030	
	Typical[1]	Typical	High	Typical	High	Typical	High	Typical	High
Cooling Capacity[3] (Btu/hr)	44,970	26,230	26,230	26,230	26,230	26,230	26,230	26,230	26,230
Size (ft^2)	240	140	140	140	140	140	140	140	140
Energy Use (kWh/yr)	42,300	14,600	10,000	10,800	9,000	10,800	9,000	10,800	9,000
Insulated Box Average Life (yrs)	18	18	18	18	18	18	18	18	18
Compressor Average Life (yrs)	10	10	10	10	10	10	10	10	10
Retail Equipment Cost	$18,500	$13,500	$15,400	$15,000	$16,900	$15,000	$16,900	$15,000	$16,900
Total Installed Cost[4]	$22,500	$17,500	$19,400	$19,000	$20,900	$19,000	$20,900	$19,000	$20,900
Annual Maintenance Cost[5]	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000	$750-$1,000

[1] All values for 2003 are based on a typical size of 240 ft^2 since that was the typical size reported in the ADL 1996 report.
[2] EISA 2007 includes prescriptive standards for walk-in coolers (refrigerators) that go into effect in 2009. Energy savings potential and cost premiums resulting from this standard were estimated in the PG&E 2004 report.
[3] Cooling capacities listed for 2008-2030 are scaled down to a 140 ft^2 unit from the cooling capacity for the 240 ft^2 unit used in the ADL 1996 report based on a consensus of equipment sizes currently commercially available.
[4] Installation cost is assumed to be $4,000.
[5] Maintenance cost consists of checking refrigerant pressures, cleaning the heat exchanger surfaces, and system functionality checks.

Commercial Walk-In Refrigerators

- The commercial walk-in refrigerator characterized in this report has a 140 ft^2 footprint with a floor and a single door. A typical size of 240 ft^2 was used for 2003, because that was the typical size reported in the ADL 1996 report.
- A typical walk-in refrigerator includes:
  - insulated floor and wall panels
  - merchandising doors, shelving, and lighting (not included in cost estimate)
  - semi-hermetic reciprocating compressor
  - refrigerant (R404A)
  - condenser
  - evaporator
- The high efficiency unit is based on the energy savings potential and cost premiums of several advanced refrigeration technologies determined by the PG&E 2004 report.[1] These include:
  - ECM (electronically commutated motor) evaporator and condenser fan motors
  - floating heat pressure
  - ambient subcooling
  - evaporator fan shutdown
- The installation cost consists of freight and delivery costs in addition to on-site assembly.
- A Federal energy consumption standard for commercial walk-in refrigerators will be in effect in 2015 and is currently being developed by DOE.

[1] The high efficiency cost premium was scaled down to a 140 ft^2 unit from the cost premium for the 240 ft^2 unit used in the PG&E 2004 report based on a consensus of equipment sizes currently commercially available.

Commercial Walk-In Refrigerators

- The Energy Independence and Security Act (EISA) of 2007 includes prescriptive standards for walk-in refrigerators (coolers) that go into effect in 2009. These prescriptive standards state that all walk-in refrigerators manufactured after January 1, 2009 must:
  - have automatic door closers
  - have strip doors, spring hinged doors, or other method of minimizing infiltration when doors are open
  - contain wall, ceiling, and door insulation of at least R–25, except for glazed portions of doors and structural members.
  - use electronically commutated motors or 3-phase motors (for evaporator fan motors of under 1 horsepower and less than 460 volts)
  - use electronically commutated motors, permanent split capacitor-type motors, or 3-phase motors (for condenser fan motors of under 1 horsepower)
  - use light sources with an efficacy of 40 lumens per watt or more, including ballast losses (if any), except that light sources with an efficacy of 40 lumens per watt or less, including ballast losses (if any), may be used in conjunction with a timer or device that turns off the lights within 15 minutes of when the walk-in refrigerator is not occupied by people.

Performance/Cost Characteristics Commercial Walk-In Freezers

Commercial Walk-In Freezers

	2003	2008		2010[1]		2020		2030	
	Typical	Typical	High	Typical	High	Typical	High	Typical	High
Cooling Capacity (Btu/hr)	4,929	4,929	4,929	4,929	4,929	4,929	4,929	4,929	4,929
Size (ft^2)	80	80	80	80	80	80	80	80	80
Energy Use (kWh/yr)	15,600	15,600	10,500	6,900	6,500	6,900	6,500	6,900	6,500
Insulated Box Average Life (yrs)	18	18	18	18	18	18	18	18	18
Compressor Average Life (yrs)	10	10	10	10	10	10	10	10	10
Retail Equip. Cost	$7,300	$7,900	$9,800	$9,400	$11,300	$9,400	$11,300	$9,400	$11,300
Total Installed Cost[2]	$8,300	$8,900	$10,800	$10,400	$12,300	$10,400	$12,300	$10,400	$12,300
Annual Maintenance Cost[3]	$500	$500	$500	$500	$500	$500	$500	$500	$500

[1] EISA 2007 includes prescriptive standards for walk-in freezers that go into effect in 2009. Energy savings potential and cost premiums resulting from this standard were estimated in the PG&E 2004 report.

[2] Installation cost is assumed to be $1,000.

[3] Maintenance cost consists of checking refrigerant pressures, cleaning the heat exchanger surfaces, and system functionality checks.

Commercial Walk-In Freezers

- The commercial walk-in freezer characterized in this report is a self-contained, 8′ x 10′ x 7′7″ system with a floor and a single door.
- A typical walk-in freezer includes:
  - insulated floor, door, and wall panels
  - semi-hermetic reciprocating compressor
  - refrigerant (R404A)
  - condenser
  - evaporator
- The high efficiency unit is based on the energy savings potential and cost premiums of several advanced refrigeration technologies determined by the PG&E 2004 report. These include:
  - ECM (electronically commutated motor) evaporator and condenser fan motors
  - external heat rejection
  - hot gas defrost
  - evaporator fan shutdown
- A Federal energy consumption standard for commercial walk-in freezers will be in effect in 2015 and is currently being developed by DOE.

Commercial Walk-In Freezers

- The Energy Independence and Security Act (EISA) of 2007 includes prescriptive standards for walk-in freezers that go into effect in 2009. These prescriptive standards state that all walk-in freezers manufactured after January 1, 2009 must:
  - have automatic door closers
  - have strip doors, spring hinged doors, or other method of minimizing infiltration when doors are open
  - contain wall, ceiling, and door insulation of at least R–32, except for glazed portions of doors and structural members.
  - contain floor insulation of at least R–28
  - use electronically commutated motors or 3-phase motors (for evaporator fan motors of under 1 horsepower and less than 460 volts)
  - use electronically commutated motors, permanent split capacitor-type motors, or 3-phase motors (for condenser fan motors of under 1 horsepower)
  - use light sources with an efficacy of 40 lumens per watt or more, including ballast losses (if any), except that light sources with an efficacy of 40 lumens per watt or less, including ballast losses (if any), may be used in conjunction with a timer or device that turns off the lights within 15 minutes of when the walk-in freezer is not occupied by people.

Performance/Cost Characteristics Commercial Reach-In Refrigerators

Commercial Reach-In Refrigerators

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Standard[1]	High	Typical	High	Typical	High
Cooling Capacity (Btu/hr)	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Size (ft^3)	48	48	48	48	48	48	48	48	48	48
Energy Use (kWh/yr)	3,800	3,100	2,500	1,500	2,497	1,500	2,400	1,500	2,400	1,500
Average Life (yrs)	8	8	8	8	8	8	8	8	8	8
Retail Equip. Cost	$2,700	$2,400	$2,500	$2,600	$2,500	$2,600	$2,500	$2,600	$2,500	$2,600
Total Installed Cost[2]	$2,850	$2,550	$2,650	$2,750	$2,650	$2,750	$2,650	$2,750	$2,650	$2,750
Annual Maintenance Cost[3]	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

[1] EPACT 2005 standard in effect (based on a 48 cubic foot solid door reach-in refrigerator)
[2] The installation cost consists of delivery, which can vary from $75 to $150 depending on shipment location.
[3] Maintenance is only performed if there is a problem with the equipment.

Commercial Reach-In Refrigerators

- The Energy Policy Act of 2005 (EPACT 2005) sets maximum daily energy consumption levels, in kWh/day, for commercial reach-in refrigerators manufactured and/or sold in the United States on or after January 1, 2010. The daily energy consumption is based on the volume of the unit (V).
  - Refrigerators with solid doors 0.10xV + 2.04
  - Refrigerators with transparent doors 0.12xV + 3.34
- Energy Star® and the Consortium for Energy Efficiency (CEE) offer voluntary specifications for commercial reach-in refrigerators. California, Connecticut, Maryland, Massachusetts, Oregon, and Washington require minimum performance standards for these units. Arizona, New Jersey, New York, and Rhode Island have enacted similar energy use standards that will take effect in upcoming years.
- California Energy Commission Tier 4 appliance efficiency regulation went into effect in 2007.
  - Refrigerators with solid doors 0.10xV + 2.04
  - Refrigerators with transparent doors 0.12xV + 3.34
- The most common solid-door commercial reach-in refrigerator is a 48 cubic foot two-door unit.
- The Beverage-Air KR48-1AS commercial reach-in refrigerator has a capacity of about 48 cubic feet and consumes approximately 1,500 kWh/yr.
- The efficiency of commercial reach-in refrigerators can be increased through the use of efficient compressors, efficient evaporator fans, efficient condenser fans, electric defrost, and more efficient lighting.
- There are approximately 1.3 million commercial reach-in refrigerators in use today. (CBECS, 2003; NCI analysis)
- In 2007, there were approximately 263,000 commercial reach-in refrigerators sold in the United States each year (Appliance Magazine, May 2008).[1] True accounts for 42% of the total market, while Traulsen has 9%, Victory has 9%, Beverage Air has 6%, Delfield has 5%, Continental has 4%, and Northland has 1%. The remaining 24% is comprised of various other manufacturers. (Appliance Magazine, September 2007)

[1] 85% of Appliance Magazine's reported total of 309,375 units to account for exclusion of pass-throughs, roll-throughs, and roll-ins.

Performance/Cost Characteristics Commercial Reach-In Freezers

Commercial Reach-In Freezers

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Standard[1]	High	Typical	High	Typical	High
Cooling Capacity (Btu/hr)	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
Size (ft^3)	24	24	24	24	24	24	24	24	24	24
Energy Use (kWh/yr)	4,600	4,500	4,000	2,500	4,008	2,500	4,000	2,500	4,000	2,500
Average Life (yrs)	8	8	8	8	8	8	8	8	8	8
Retail Equip. Cost	$2,400	$2,400	$2,500	$2,700	$2,500	$2,700	$2,500	$2,700	$2,500	$2,700
Total Installed Cost[2]	$2,550	$2,550	$2,650	$2,850	$2,650	$2,850	$2,650	$2,850	$2,650	$2,850
Annual Maintenance Cost[3]	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

[1] EPACT 2005 standard in effect (based on a 24 cubic foot sold door reach-in freezer)
[2] The installation cost consists of delivery, which can vary from $75 to $150 depending on shipment location.
[3] Maintenance is only performed if there is a problem with the equipment.

Commercial Reach-In Freezers

- EPACT 2005 sets maximum daily energy consumption levels, in kWh/day, for commercial reach-in freezers manufactured and/or sold in the United States on or after January 1, 2010. The daily energy consumption is based on the volume of the unit (V).
  - Freezers with solid doors 0.40xV + 1.38
  - Freezers with transparent doors 0.75xV + 4.10
- Energy Star® and the Consortium for Energy Efficiency (CEE) offer voluntary specifications for commercial reach-in freezers. California, Connecticut, Maryland, Massachusetts, Oregon, and Washington require minimum performance standards for these units. Arizona, New Jersey, New York, and Rhode Island have enacted similar energy use standards that will take effect in upcoming years.
- California Energy Commission Tier 4 appliance efficiency regulation went into effect in 2007.
  - Freezers with solid doors 0.40xV + 1.38
  - Freezers with transparent doors 0.75xV + 4.10
- The most common solid-door commercial reach-in freezer is a 24 cubic foot one-door unit.
- The Beverage Air EF24-5BS-02-88 commercial reach-in freezer has a capacity of 22 cubic feet and consumes approximately 2,500 kWh/yr.
- The efficiency of commercial reach-in freezers can be increased through the use of efficient compressors, efficient evaporator fans, efficient condenser fans, electric defrost, and more efficient lighting.
- There are approximately 0.9 million commercial reach-in freezers in use today. (CBECS 2003, NCI analysis)
- There are approximately 47,000 commercial reach-in freezers sold in the United States each year (Appliance Magazine, May 2008).[1]

[1] 90% of Appliance Magazine's reported total of 309,375 units to account for exclusion of pass-throughs, roll-throughs, and roll-ins.

Performance/Cost Characteristics Commercial Ice Machines

Commercial Ice Machines

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Standard[1]	High	Typical	High	Typical	High
Output (lbs/day)	500	500	500	500	500	500	500	500	500	500
Water Use (gal/100 lbs)	24	27	20	18	24	18	20	18	20	18
Energy Use (kWh/100 lbs)	7.0	7.0	6.0	5.5	6.3	5.5	6.3	5.5	6.3	5.5
Energy Use (kWh/yr)[2]	4,375	4,400	3,750	3,440	3,940	3,440	3,750	3,440	3,750	3,440
Average Life (yrs)	8	8	8	8	8	8	8	8	8	8
Retail Equip. Cost	$2,200	$2,200	$2,500	$3,300	$2,400	$3,300	$2,500	$3,300	$2,500	$3,300
Total Installed Cost (with Bin)[3]	$2,400	$2,400	$2,700	$3,500	$2,600	$3,500	$2,700	$3,500	$2,700	$3,500
Annual Maint. Cost[4]	$200-$300	$200-$300	$200-$300	$200-$300	$200-$300	$200-$300	$200-$300	$200-$300	$200-$300	$200-$300

[1] EPACT 2005 energy use standard in effect (based on a 500 lbs/24 hrs air-cooled ice making head). Condenser water use for air-cooled ice making heads not regulated.

[2] Assuming 3000 hours per year of use.

[3] Installation cost is assumed to be about $200.

[4] Maintenance cost includes cleaning/sanitizing the bin and water system, cleaning the heat exchanger surfaces, and system functionality checks.

Commercial Ice Machines

- The commercial ice machine characterized in this report is an air-cooled ice machine with an approximate output of 500 lbs/day. Commercial ice machines are typically integrated with an insulated ice storage bin or mounted on top of a separate storage bin. The retail equipment cost includes the ice making head and the integrated storage bin.
- Due to competition between commercial ice machine manufacturers, there is little variation in equipment price although equipment efficiencies vary.
- There are two voluntary specifications available for commercial ice machines. The Federal Energy Management Program (FEMP) created standards in 1996 and updated them in 1999. The Consortium for Energy Efficiency (CEE) developed a two-tiered specification in 2002 and updated them to a three-tiered system in 2006.
- Several states, including California, Arizona, New York, Oregon, Rhode Island, and Washington, have passed state energy efficiency standards for commercial ice machines that have taken effect or will take effect in upcoming years.
- Commercial ice machine condensers are either air-cooled or water-cooled. Approximately 80% of all units are the air-cooled type.
- Commercial ice machine maintenance includes periodic (every 2 to 6 weeks) cleaning to remove lime and scale and sanitization to kill bacteria. Some ice machines are self-cleaning/sanitizing. Manitowoc offers an automatic cleaning system that costs approximately $600.
- In 2007, approximately 195,000 ice machines were shipped in the United States (Appliance Magazine, May 2008). Market shares are as follows: Manitowoc, 45%; Enodis, 31%; Hoshizaki, 20%; and Cornelius, 4%. (Appliance Magazine, September 2005)

Commercial Ice Machines: EPACT 2005

- EPACT 2005 issued standard levels for commercial ice machines with capacities between 50 and 2500 pounds per 24-hour period manufactured and/or sold in the United States on or after January 1, 2010. The energy consumption is based on the harvest rate in pounds per 24 hours (H).

Equipment Type	Type of Cooling	Harvest Rate (lbs ice/24 hrs)	Maximum Energy Use (kWh/100 lbs ice)	Maximum Condenser Water Use (gal/100 lbs ice)
Ice Making Head	Water	<500	7.80-0.0055H	200-0.022H
		≥500 and <1436	5.58-0.0011H	200-0.022H
		≥1436	4.0	200-0.022H
Ice Making Head	Air	<450	10.26-0.0086H	Not Applicable
		≥450	6.89-0.0011H	Not Applicable
Remote Condensing (but not remote compressor)	Air	<1000	8.85-0.0038H	Not Applicable
		≥1000	5.10	Not Applicable
Remote Condensing and Remote Compressor	Air	<934	8.85-0.0038H	Not Applicable
		≥934	5.3	Not Applicable
Self Contained	Water	<200	11.40-0.019H	191-0.0315H
		≥200	7.60	191-0.0315H
Self Contained	Air	<175	18.0-0.0469H	Not Applicable
		≥175	9.80	Not Applicable

Water use is for the condenser only and does not include potable water used to make ice.

Performance/Cost Characteristics Commercial Beverage Merchandisers

Commercial Beverage Merchandisers

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Standard[1]	High	Typical	High	Typical	High
Cooling Capacity (Btu/hr)	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Size (ft^3)	27	27	27	27	27	27	27	27	27	27
Energy Use (kWh/yr)	3,900	3,500	3,000	1,650	2,523	1,650	2,400	1,650	2,400	1,650
Average Life (yrs)	8	8	8	8	8	8	8	8	8	8
Retail Equip. Cost	$1,400	$1,200	$1,400	$1,900	$1,500	$1,900	$1,500	$1,900	$1,500	$1,900
Total Installed Cost[2]	$1,550	$1,350	$1,550	$2,050	$1,650	$2,050	$1,650	$2,050	$1,650	$2,050
Annual Maintenance Cost[3]	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

[1] EPACT 2005 standard in effect (based on a 27 cubic foot transparent door beverage merchandiser)
[2] The installation cost consists of delivery, which can vary from $75 to $150 depending on shipment location.
[3] Maintenance is only performed if there is a problem with the equipment.

Commercial Beverage Merchandisers

- EPACT 2005 sets maximum daily energy consumption levels, in kWh/day, for commercial refrigerators with a self-contained condensing unit designed for pull-down temperature applications and transparent doors (i.e., beverage merchandisers) manufactured and/or sold in the United States on or after January 1, 2010. The daily energy consumption is based on the volume of the unit (V).
  - Beverage merchandisers with transparent doors 0.126xV + 3.51
- The typical commercial beverage merchandiser characterized in this report is a 27 cubic foot cooler with a single hinged, transparent door, bright lighting, and shelving.
- Several states have issued maximum energy use standards for commercial beverage merchandisers. California, Connecticut, Maryland, Massachusetts, Oregon, and Washington require minimum performance standards for these units. Arizona, New Jersey, New York, and Rhode Island have enacted similar energy use standards that will take effect in upcoming years.
- The high efficiency unit is the True GDM-26, which has a capacity of 26 cubic feet, an approximate energy use of 4.57 kWh/day, and costs approximately $1,850.
- The future typical efficiency units incorporate more efficient compressors and fluorescent lighting with electronic ballasts.

Performance/Cost Characteristics Commercial Refrigerated Vending Machines

Commercial Refrigerated Vending Machines

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Cooling Capacity (Btu/hr)	700	700	700	700	700	700	700	700	700	700
Can Capacity	500	650	650	650	650	650	650	650	650	650
Energy Use[1] (kWh/yr)	3,000	3,400	2,400	1,700	2,400	1,700	2,400	1,700	2,400	1,700
Average Life (yrs)	14	14	14	14	14	14	14	14	14	14
Retail Equip. Cost	$1,700	$1,500	$1,600	$1,800	$1,600	$1,800	$1,600	$1,800	$1,600	$1,800
Total Installed Cost[2]	$1,772	$1,572	$1,672	$1,872	$1,672	$1,872	$1,672	$1,872	$1,672	$1,872
Annual Maintenance Cost[3]	$165	$165	$165	$165	$165	$165	$165	$165	$165	$165

[1] Energy use is based on a zone-cooled machine tested in 75°F steady state ambient conditions.
[2] The installation cost includes overhead and profit and is assumed to be $72.
[3] Maintenance cost includes preventative maintenance costs and an annualized cost for refurbishments, assuming two refurbishments over the life of the machine at a cost of about $930 each.

Commercial Refrigerated Vending Machines

- EPACT 2005 requires that a federal energy efficiency standard for refrigerated vending machines be developed by 2009. Energy Star® currently offers voluntary specifications, where the daily energy consumption is based on the vendible capacity (C):
  - Refrigerated Vending Machines 0.45[8.66 + (0.009 x C)]
- A Federal energy consumption standard for beverage vending machines will be in effect in 2012 and is currently being developed by DOE.
- As of January 1, 2006, the California Energy Commission (CEC) required that refrigerated vending machines meet energy efficiency standards. The maximum energy use for 500-can vending machine will be 7.24 kWh/day (2642 kWh/yr).
- The Royal Vendors RVCDE 650-12 has a capacity of 650 cans and uses approximately 4.8 kWh/day.
- The CEC requires the installation of hard wired controllers or software capable of automatically placing the refrigerated vending machine into a low power mode and automatically returning to the normal operating conditions at the conclusion of the low power mode. This applies to refrigerated vending machines manufactured on or after January 1, 2006.
- In 2006, there were approximately 3.36 million refrigerated packaged beverage vending machines installed in the United States. These machines accounted for nearly 51% of all vending machine revenue that year, collecting almost $24 billion. (Vending Times, 2007)
- USA Technologies manufactures the Vending Miser, an attachment which turns the vending machine off if no one is near it for 15 minutes. The machine will turn on every 1-3 hours to ensure the drinks remain cold. The Vending Miser costs approximately $180 and can reduce vending machine energy use by up to 46%.
- The annual maintenance cost is representative of typical preventive maintenance including replacement of lighting and routine machine checks. Machines are refurbished about once every three to five years at a cost of approximately $930.

Commercial Constant Air Volume Ventilation

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Primary Airflow (CFM)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Fan Power Input (Watts)	800	1,500	800	400	800	400	750	400	650	400
Energy Use (kWh/yr)[1]	3,040	5,700	3,040	1,520	3,040	1,520	2,850	1,520	2,500	1,520
Average Life (yrs)	20	20	20	20	20	20	20	20	20	20
Total Installed Cost[2]	$8,600	$8,275	$8,600	$9,275	$8,600	$9,275	$8,600	$9,275	$8,600	$9,275
Annual Maintenance Cost[3]	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

[1] Based on 3800 effective full load hours per year (ADL, 1999)
[2] Total installed cost of one fan-powered constant air volume (CAV) terminal box, cooling only (no reheat coil), with actuator/controls and associated insulation and ductwork.
[3] Filters must be periodically changed in CAV terminals, however these costs are very small.

Commercial Constant Air Volume Ventilation

- Constant air volume (CAV) ventilation systems are the most common, inexpensive, and straightforward ventilation systems. These systems provide a constant amount of air, of varying temperatures, to a zone regardless of fluctuating airflow requirements.
- The unit characterized in this report is a CAV terminal box without reheat, and is therefore suitable for use where no heating is required. A comparable CAV terminal box with a reheat coil can be installed for approximately $10,550. CAV terminals with reheat are inefficient because they heat air that has already been mechanically cooled. However, CAV with reheat does closely control the zone temperature, resulting in excellent zone comfort.
- The average commercial building is approximately 15,000 square feet (CBECS 2003 and BED 2007). In general, 1 CFM is needed per square foot of floor area, requiring a 15,000 CFM rooftop air handling unit. A 15,000 CFM CAV rooftop air handling unit with cooling and heating coils can be installed for approximately $42,400 (RS Means 2008).
- Approximately 7 percent of U.S. commercial building floor space is conditioned using central constant air volume systems. (ADL, 1999)
- ASHRAE Standard 62-2001, which has been adopted by most states, mandates an outdoor air requirement of 20 cfm/person in office buildings.

Performance/Cost Characteristics Commercial Variable Air Volume Ventilation

Commercial Variable Air Volume Ventilation

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Primary Airflow (CFM)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Fan Power Input (Watts)	700	1,400	700	270	700	270	650	270	650	270
Fan Energy Use (kWh/yr)[1]	1,300	2,700	1,300	510	1,300	510	1,200	510	1,200	510
Average Life (yrs)	20	20	20	20	20	20	20	20	20	20
Total Installed Cost[2]	$8,325	$8,000	$8,325	$9,000	$8,325	$9,000	$8,500	$9,000	$8,500	$9,000
Annual Maintenance Cost[3]	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

[1] Based on 1900 effective full load hours per year (ADL, 1999)
[2] Total installed cost of one fan-powered variable air volume (VAV) terminal box, cooling only (no reheat coil), with actuator/controls and associated insulation and ductwork.
[3] Filters must be periodically changed in VAV terminals, however these costs are very small.

Commercial Variable Air Volume Ventilation

- Variable air ventilation (VAV) systems meet fluctuating load requirements by changing the amount of conditioned air that flows into the zone, saving fan energy as a result of the reduced airflow.
- Over 80 percent of VAV systems use single duct cooling, which consists of one central air handler and several local VAV boxes, one for each thermal control zone. The air handler delivers air to each VAV box through a single duct. Each VAV box then provides the appropriate amount of air to maintain the desired sensible temperature in each zone.
- While most VAV terminal boxes are valve boxes with a damper for airflow control, the unit characterized in this report is a fan powered VAV terminal box. This box does not have reheat, and is therefore suitable for use where no heating is required (e.g. building interior zones). A comparable fan powered VAV terminal box with a reheat coil can be installed for approximately $10,550.
- Fan powered VAV terminal boxes typically use a centrifugal type, forward curved fan blade design and PSC motors.
- The average commercial building is approximately 15,000 square feet (CBECS 2003 and BED 2007). In general, 1 CFM is needed per square foot of floor area, requiring a 15,000 CFM rooftop air handling unit. A 15,000 CFM VAV rooftop air handling unit with cooling and heating coils can be installed for approximately $44,500 (RS Means 2008).
- Approximately 11 percent of U.S. commercial building floor space is conditioned using central variable air volume systems. (ADL, 1999)

Performance/Cost Characteristics Commercial Fan Coil Units

Commercial Fan Coil Units

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Total Cooling Capacity (Btu/hr)	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Sensible Cooling Capacity[1] (Btu/hr)	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
Power Input (Watts)	315	530	315	120	315	120	315	110	315	110
Energy Use[2] (kWh/yr)	700	1,200	700	270	700	270	700	250	700	250
Average Life (yrs)	20	20	20	20	20	20	20	20	20	20
Total Installed Cost	$3,425	$3,000	$3,425	$3,800	$3,425	$3,800	$3,425	$3,900	$3,425	$3,900
Annual Maintenance Cost[3]	$50-$100	$50-$100	$50-$100	$50-$100	$50-$100	$50-$100	$50-$100	$50-$100	$50-$100	$50-$100

[1] The capacity associated with the change in dry-bulb temperature
[2] Based on 2250 effective full load hours per year (ADL, 1999)
[3] Filters must be changed and drain systems must be flushed periodically.

Commercial Fan Coil Units

- Commercial fan coil units (FCUs) are self-contained, mass-produced assemblies that provide cooling, heating, or cooling and heating, but do not include the source of cooling or heating. The unit characterized in this report is a cooling only, cabinet mounted, two-pipe unit with controls.
- Four-pipe units have separate circuits for heating and cooling. Two-pipe units with electric heat are a low-cost alternative to four-pipe units but may use more energy.
- Approximately 6 percent of U.S. commercial floor space is conditioned using central fan coil units (ADL, 1999).
- According to manufacturer literature, the typical airflow of a 2-ton FCU is between 800 and 1000 CFM.
- Fan coil motors can be shaded pole, a single phase AC motor with offset start winding and no capacitor; PSC, a single phase AC motor with offset start winding with capacitor; or EC, an AC electrically commutated permanent magnet DC motor. PSC motors are the most common motor type in FCUs.
- Fan coil units have higher maintenance costs than central air systems. Filters must be changed and drain systems must be flushed periodically.

Appendix A
Data Sources

September 2008

Navigant Consulting, Inc.
1801 K Street, NW, Suite 500
Washington, D.C. 20006
(202) 973-2400

www.navigantconsulting.com

Data Sources Residential Incandescent Lighting

Residential Incandescent Lighting

	2005	2008	2013/2014
	Typical	**Typical/High**	**Typical/High**
Typical Wattage	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)		EISA 2007
Lumens			
Efficacy (lm/W)	Calculated		
Average Life (hrs)	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)		EISA 2007
Lamp price ($)	Distributor Websites		NCI Analysis, 2008
Cost ($/klm)	Calculated		
CRI	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)		

Data Sources Residential Reflector Lamps

Residential Reflector Lamps

	2005	2008			2010			2020			2030		
	Typical	Inc.	Hal.	CFL	Inc.	Hal.	CFL	Inc.	Hal.	CFL	Inc.	Hal.	CFL
Typical Wattage	DOE, 2008				NCI, 2006								
Lumens													
Efficacy (lm/W)	Calculated												
Lamp Price ($)	DOE, 2008												
Lamp Cost ($/klm)	Calculated												
Average Life (1000 hrs)	DOE, 2008												
CRI	DOE, 2008												

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Data Sources Residential Compact Fluorescent Lighting

Residential Compact Fluorescent Lighting

	2005	2008		2010		2020		2030	
	Typical	Typical	High	Typical/ Standard	High	Typical/ Standard	High	Typical/ Standard	High
Typical Wattage	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)			NCI, 2006					
Lumens									
Efficacy (lm/W)	Calculated								
Average Life (hrs)	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)								
Lamp price ($)	Distributor Websites								
Cost ($/klm)	Calculated								
CRI	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)								

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Data Sources Residential Torchieres

Residential Torchieres

	2005	2008			2010		2020		2030	
	Typical	Inc.	Hal.	CFL	Inc.	Hal.	CFL	Inc.	Hal.	CFL
Typical Wattage	DOE Priority Setting FY 2005, EPACT 2005				NCI, 2006					
Lumens										
Efficacy (lm/W)	Calculated									
Average Life (1000 hrs)	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)									
Lamp price ($)	Distributor Websites									
Cost ($/klm)	Calculated									
CRI	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)									

Data Sources Residential Linear Fluorescent Lighting

Residential Linear Fluorescent Lighting (2-lamp system)

<table>
<tr><th></th><th>2005</th><th colspan="3">2008</th><th colspan="2">2010</th><th colspan="2">2020</th><th colspan="2">2030</th></tr>
<tr><th></th><th>F32T8</th><th>F40T12</th><th>F32T8</th><th>F28T5</th><th>F32T8</th><th>F28T5</th><th>F32T8</th><th>F28T5</th><th>F32T8</th><th>F28T5</th></tr>
<tr><td>Lamp Wattage</td><td colspan="4" rowspan="4">DOE, 2008; Manufacturer Catalogs (GE, OSRAM, Philips, 2008)</td><td colspan="6" rowspan="11">NCI, 2006</td></tr>
<tr><td>Lamp Lumens</td></tr>
<tr><td>System Wattage</td></tr>
<tr><td>System Lumens</td></tr>
<tr><td>Lamp Efficacy (lm/W)</td><td colspan="4" rowspan="2">Calculated</td></tr>
<tr><td>System Efficacy (lm/W)</td></tr>
<tr><td>Lamp price ($)</td><td colspan="4" rowspan="2">DOE, 2008; Distributor Websites</td></tr>
<tr><td>Ballast Price ($)</td></tr>
<tr><td>Cost ($/klm)</td><td colspan="4">Calculated</td></tr>
<tr><td>Average Lamp Life (1000 hrs)</td><td colspan="4" rowspan="2">DOE, 2008; Manufacturer Catalogs (GE, OSRAM, Philips, 2008)</td></tr>
<tr><td>CRI</td></tr>
</table>

Data Sources Residential Solid State Lighting

Residential Solid-State Lighting

	2005	2008	2010	2020	2030
	LED	LED	LED	LED	LED
Typical Wattage	NCI, 2008		NCI, 2008		
Lumens					
Efficacy (lm/W)	Calculated				
Average Life (1000 hrs)	NCI, 2008				
Lamp price ($)	NCI, 2008, NCI Estimate				
Cost ($/klm)	Calculated				
CRI	Manufacturer Catalogs (CREE, 2008)				
CCT					

Data Sources Commercial Incandescent Lighting

Commercial Incandescent Lighting

	2003	2008	2012
	100W Inc	100W Inc	100W Inc
Typical Wattage	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)		EISA 2007
Lumens			
Efficacy (lm/W)	Calculated		
Average Life (hrs)	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)		EISA 2007
Cost ($/klm)	Distributor Websites, NCI, Calculated		
Cost ($/klm l/f)			
CRI	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)		
Total Installed Cost ($)	RS Means, Lamps ANOPR		
Annual Maintenace Cost ($)			

Data Sources Commercial Compact Fluorescent Lighting

Commercial Compact Fluorescent Lighting

	2003		2008		2010		2020		2030	
	26W CFL	42W CFL	26W CFL	42W CFL	26W CFL	42W CFL	26W CFL	42W CFL	26W CFL	42W CFL
Typical Wattage	Manufacturer Catalogs (GE, OSRAM, Philips, 2008), IESNA Lighting Handbook				NCI, 2006					
Lumens										
Efficacy (lm/W)	Calculated									
Average Life (1000 hrs)	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)									
Cost ($/klm l)	Distributor Websites, NCI, Calculated									
Cost ($/klm l/f)										
CRI	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)									
Total Installed Cost ($)	RS Means, NCI, Calculated									
Annual Maintenance Cost ($)										

Data Sources Commercial Halogen Lighting

Commercial Halogen Lighting – General and Quartz

	2003		2008		2010		2020		2030	
	90W Halogen	70W HIR	90W Halogen	70W HIR	90W Halogen	70W HIR	90W Halogen	70W HIR	90W Halogen	70W HIR
Typical Wattage	DOE, 2008; Manufacturer Catalogs (GE, OSRAM, Philips, 2008), IESNA Lighting Handbook				NCI, 2006					
Lumens	DOE, 2008; Manufacturer Catalogs (GE, OSRAM, Philips, 2008), IESNA Lighting Handbook				NCI, 2006					
Efficacy (lm/W)	Calculated				NCI, 2006					
Average Life (1000 hrs)	DOE, 2008; Manufacturer Catalogs (GE, OSRAM, Philips, 2008)				NCI, 2006					
Cost ($/klm l)	DOE, 2008; Distributor Websites, NCI, Calculated				NCI, 2006					
Cost ($/klm l/f)	DOE, 2008; Distributor Websites, NCI, Calculated				NCI, 2006					
CRI	DOE, 2008; Manufacturer Catalogs (GE, OSRAM, Philips, 2008)				NCI, 2006					
Total Installed Cost ($)	RS Means, DOE, 2008, Calculated				NCI, 2006					
Annual Maintenance Cost ($)	RS Means, DOE, 2008, Calculated				NCI, 2006					

Data Sources Commercial Linear Fluorescent Lighting T5

Commercial Linear Fluorescent Lighting – T5 (2-lamp system)

	2003	2008	2010	2020	2030
	F28T5/ F54T5HO	F28T5/ F54T5HO	F28T5/F54T5HO	F28T5/F54T5HO	F28T5/F54T5HO
System Wattage	Manufacturer Catalogs (GE, OSRAM, Philips, 2008), IESNA Lighting Handbook		NCI, 2006		
System Lumens					
Lamp Efficacy (lm/W)	Calculated				
System Efficacy (lm/W)					
Cost ($/klm)[1]	Distributor Websites, NCI, Calculated				
Cost ($/klm l/b/f)[2]					
Average Lamp Life (1000 hrs)	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)				
CRI					
Total Installed Cost ($)	RS Means, DOE, 2008, Calculated				
Annual Maintenance Cost ($)					

Data Sources Commercial Linear Fluorescent Lighting > 4ft. T8-T12

Commercial Linear Fluorescent Lighting – > 4 ft. T8/T12 (2-lamp system)

	2003	2008	2010	2020	2030
	F96T12/F96T8	F96T12/F96T8	F96T8	F96T8	F96T8
System Wattage	Manufacturer Catalogs (GE, OSRAM, Philips, 2008), IESNA Lighting Handbook		NCI, 2006		
System Lumens					
Lamp Efficacy (lm/W)	Calculated				
System Efficacy (lm/W)					
Cost ($/klm)[1]	Distributor Websites, NCI, Calculated				
Cost ($/klm l/b/f)[2]					
Average Lamp Life (1000 hrs)	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)				
CRI					
Total Installed Cost ($)	RS Means, DOE, 2008, Calculated				
Annual Maintenance Cost ($)					

Data Sources Commercial Linear Fluorescent Lighting ≤ 4ft. T8/T12

Commercial Linear Fluorescent Lighting – ≤ 4 ft. T8/T12 (2-lamp system)

	2003	2008	2010	2020	2030
	F34T12/F32T8	F34T12/F32T8	F32T8	F32T8	F32T8
System Wattage	Manufacturer Catalogs (GE, OSRAM, Philips, 2008), IESNA Lighting Handbook		NCI, 2006		
System Lumens					
Lamp Efficacy (lm/W)	Calculated				
System Efficacy (lm/W)					
Cost ($/klm)[1]	Distributor Websites, NCI, Calculated				
Cost ($/klm l/b/f)[2]					
Average Lamp Life (1000 hrs)	Manufacturer Catalogs (GE, OSRAM, Philips, 2008), Lutron Website				
CRI					
Total Installed Cost ($)	RS Means, DOE, 2008, Calculated				
Annual Maintenance Cost ($)					

Commercial HID High Bay Lighting

<table>
<tr><th></th><th colspan="3">2003</th><th colspan="2">2008</th><th colspan="2">2010</th><th colspan="2">2020</th><th colspan="2">2030</th></tr>
<tr><th></th><th>400W MV</th><th>250W MH</th><th>150W HPS</th><th>250W MH</th><th>150W HPS</th><th>250W MH</th><th>150W HPS</th><th>250W MH</th><th>150W HPS</th><th>250W MH</th><th>150W HPS</th></tr>
<tr><td>System Wattage</td><td colspan="5" rowspan="2">Manufacturer Catalogs
(GE, OSRAM, Philips, 2008),
IESNA Lighting Handbook,
DOE HID Determination Draft, 2004</td><td colspan="6" rowspan="10">NCI, 2006; EISA 2007</td></tr>
<tr><td>System Lumens</td></tr>
<tr><td>Lamp Efficacy (lm/W)</td><td colspan="5" rowspan="2">Calculated</td></tr>
<tr><td>System Efficacy (lm/W)</td></tr>
<tr><td>Cost ($/klm)[1]</td><td colspan="5" rowspan="2">Distributor Websites,
NCI, Calculated</td></tr>
<tr><td>Cost ($/klm l/b/f)[2]</td></tr>
<tr><td>Average Lamp Life (1000 hrs)</td><td colspan="5" rowspan="2">Manufacturer Catalogs
(GE, OSRAM, Philips, 2008)</td></tr>
<tr><td>CRI</td></tr>
<tr><td>Total Installed Cost ($)</td><td colspan="5" rowspan="2">RS Means, DOE, 2008, Calculated</td></tr>
<tr><td>Annual Maintenance Cost ($)</td></tr>
</table>

Data Sources Commercial HID Low Bay Lighting

Commercial HID Low Bay Lighting

	2003		2008		2010		2020		2030	
	MH 175	MV175	MH 175	HPS70	MH 175	HPS70	MH 175	HPS70	MH 175	HPS70
System Wattage	Manufacturer Catalogs (GE, OSRAM, Philips, 2008), IESNA Lighting Handbook, DOE HID Determination Draft, 2004.				NCI, 2006; EISA, 2007					
System Lumens										
Lamp Efficacy (lm/W)	Calculated									
System Efficacy (lm/W)										
Cost ($/klm)[1]	Distributor Websites, NCI, Calculated									
Cost ($/klm l/b/f)[2]										
Average Lamp Life (1000 hrs)	Manufacturer Catalogs (GE, OSRAM, Philips, 2008)									
CRI										
Total Installed Cost ($)	RS Means, NCI, Calculated									
Annual Maintenance Cost ($)										

Commercial Solid-State Lighting

	2003	2008	2010	2020	2030
	LED	LED	LED	LED	LED
Lamp Wattage	NCI, 2008		NCI, 2008, NCI Estimate		
Lamp Lumens					
System Lumens	DOE, CAliPER 2008				
Lamp Efficacy (lm/W)	Calculated				
System Efficacy (lm/W)[1]					
Cost ($/klm)[2]	NCI, 2008, NCI Estimate				
Cost ($/klm l/b/f)[3]					
Life (1000 hours)	NCI, 2008				
CRI	Manufacturer Catalogs (CREE, 2008)				
CCT					
Total Installed Cost ($)	RS Means, DOE 2008, Calculated				
Annual Maintenance Cost ($)					

Data Sources Commercial Supermarket Display Cases

Commercial Supermarket Display Cases

	2003	2008		2010		2020		2030	
	Typical	Typical	High	Typical	High	Typical	High	Typical	High
Cooling Capacity (Btu/hr)	DOE, 2008 / NCI Analysis, 2008			NCI Analysis, 2008 / FMI, 2008 / DOE, 2008					
Median Store Size (ft³)	Food Marketing Institute (FMI), 2008								
Energy Use (kWh/yr)	DOE, 2008 / NCI Analysis, 2008								
Average Life (yrs)	DOE, 2008 / NCI Analysis, 2008								
Retail Equipment Cost	DOE, 2008 / NCI Analysis, 2008								
Total Installed Cost	DOE, 2008 / NCI Analysis, 2008								
Annual Maintenance Cost	DOE, 2008 / NCI Analysis, 2008								

Data Sources Commercial Compressor Rack Systems

Commercial Compressor Rack Systems

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Total Capacity (MBtu/hr)	ADL, 1996				NCI Analysis, 2008 / ADL, 1996 / Distributor Web Sites					
Power Input (kW)	Copeland, 2008									
Energy Use (MWh/yr)	ADL, 1996 / NCI Analysis, 2008									
Average Life (yrs)	Kysor-Warren, 2008									
Total Installed Cost	Distributor Web Sites / NCI Analysis, 2008									
Annual Maintenance Cost	ADL, 1996 / NCI Analysis, 2008									

Commercial Condensers

<table>
<tr><th></th><th>2003</th><th colspan="3">2008</th><th colspan="2">2010</th><th colspan="2">2020</th><th colspan="2">2030</th></tr>
<tr><th></th><th>Typical</th><th>Low</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th></tr>
<tr><td>Total Capacity (mBtu/hr)</td><td colspan="4">NCI Analysis, 2008 / Heatcraft, 2008 / ADL, 1996</td><td colspan="6" rowspan="6">NCI Analysis, 2008</td></tr>
<tr><td>Power Input (kW)</td><td colspan="4">NCI Analysis, 2008 / Heatcraft, 2008 / ADL, 1996</td></tr>
<tr><td>Energy Use (MWh/yr)</td><td colspan="4">NCI Analysis, 2008 / ADL, 1996</td></tr>
<tr><td>Average Life (yrs)</td><td colspan="4">ADL, 1996 / NCI Analysis, 2008</td></tr>
<tr><td>Total Installed Cost ($1000)</td><td colspan="4">NCI Analysis, 2008 / Heatcraft, 2008 / RS Means, 2007</td></tr>
<tr><td>Annual Maintenance Cost</td><td colspan="4">NCI Analysis, 2008</td></tr>
</table>

Data Sources Commercial Walk-In Refrigerators

Commercial Walk-In Refrigerators

<table>
<tr><th rowspan="2"></th><th>2003</th><th colspan="2">2008</th><th colspan="2">2010</th><th colspan="2">2020</th><th colspan="2">2030</th></tr>
<tr><th>Typical</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th></tr>
<tr><td>Cooling Capacity (Btu/hr)</td><td colspan="3">ADL, 1996 / NCI Analysis, 2008</td><td colspan="6" rowspan="8">NCI Analysis, 2008 / ADL, 1996 / PG&E, 2004 / FMI, 2005</td></tr>
<tr><td>Size (ft^2)</td><td>ADL, 1996 / NCI Analysis, 2008</td><td colspan="2" rowspan="2">Emerson, 2006 / NCI Analysis, 2008</td></tr>
<tr><td>Energy Use (kWh/yr)</td><td>ADL, 1996 / PG&E, 2004 / NCI Analysis, 2008</td></tr>
<tr><td>Insulated Box Average Life (yrs)</td><td colspan="3">ADL, 1996 / PG&E, 2004</td></tr>
<tr><td>Compressor Average Life (yrs)</td><td colspan="3">ADL, 1996 / PG&E, 2004</td></tr>
<tr><td>Retail Equip. Cost</td><td colspan="3">ADL, 1996 / Distributor Web Sites / NCI Analysis, 2008</td></tr>
<tr><td>Total Installed Cost</td><td colspan="3">ADL, 1996 / Distributor Web Sites / NCI Analysis, 2008</td></tr>
<tr><td>Annual Maintenance Cost</td><td colspan="3">ADL, 1996 / FMI, 2005 / NCI Analysis, 2008</td></tr>
</table>

Data Sources Commercial Walk-In Freezers

Commercial Walk-In Freezers

<table>
<tr><th rowspan="2"></th><th>2003</th><th colspan="2">2008</th><th colspan="2">2010</th><th colspan="2">2020</th><th colspan="2">2030</th></tr>
<tr><th>Typical</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th></tr>
<tr><td>Cooling Capacity (Btu/hr)</td><td colspan="3">ADL, 1996 / NCI Analysis, 2008</td><td colspan="6" rowspan="8">NCI Analysis, 2008 / ADL, 1996 / PG&E, 2004 / Distributor Web Sites</td></tr>
<tr><td>Size (ft^2)</td><td colspan="3">ADL, 1996</td></tr>
<tr><td>Energy Use (kWh/yr)</td><td>ADL, 1996 / PG&E, 2004</td><td colspan="2">ADL, 1996 / NCI Analysis, 2008</td></tr>
<tr><td>Insulated Box Average Life (yrs)</td><td colspan="3">ADL, 1996 / PG&E, 2004</td></tr>
<tr><td>Compressor Average Life (yrs)</td><td colspan="3">ADL, 1996 / PG&E, 2004</td></tr>
<tr><td>Retail Equip. Cost</td><td colspan="3">ADL, 1996 / PG&E, 2004 / Distributor Web Sites / NCI Analysis, 2008</td></tr>
<tr><td>Total Installed Cost</td><td colspan="3">ADL, 1996 / Distributor Web Sites / NCI Analysis, 2008</td></tr>
<tr><td>Annual Maintenance Cost</td><td colspan="3">NCI Analysis, 2008</td></tr>
</table>

Data Sources Commercial Reach-In Refrigerators

Commercial Reach-In Refrigerators

<table>
<tr><th></th><th>2003</th><th colspan="3">2008</th><th colspan="2">2010</th><th colspan="2">2020</th><th colspan="2">2030</th></tr>
<tr><th></th><th>Typical</th><th>Low</th><th>Typical</th><th>High</th><th>Standard</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th></tr>
<tr><td>Cooling Capacity (Btu/hr)</td><td colspan="10">ADL, 1996 / NCI Analysis, 2008</td></tr>
<tr><td>Size (ft^3)</td><td colspan="4">ADL, 1996 / Distributor Web Sites</td><td colspan="6" rowspan="6">NCI Analysis, 2008 / EPACT 2005 / Distributor Web Sites</td></tr>
<tr><td>Energy Use (kWh/yr)</td><td>ADL, 1996 / NCI Analysis, 2008</td><td colspan="3">CEE, 2008 / ENERGY STAR, 2008 / CEC, 2008 / NCI Analysis 2008</td></tr>
<tr><td>Average Life (yrs)</td><td colspan="4">ACEEE, 2002</td></tr>
<tr><td>Retail Equip. Cost</td><td>ADL, 1996/ Distributor Web Sites / NCI Analysis, 2008</td><td colspan="3">Distributor Web Sites / NCI Analysis, 2008</td></tr>
<tr><td>Total Installed Cost</td><td colspan="4">Distributor Web Sites / NCI Analysis, 2008</td></tr>
<tr><td>Annual Maintenance Cost</td><td colspan="4">NCI Analysis, 2008</td></tr>
</table>

Data Sources Commercial Reach-In Freezers

Commercial Reach-In Freezers

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Standard	High	Typical	High	Typical	High
Cooling Capacity (Btu/hr)	ADL, 1996 / NCI Analysis, 2008									
Size (ft^3)	ADL, 1996 / Distributor Web Sites				NCI Analysis, 2008 / EPACT 2005 / Distributor Web Sites					
Energy Use (kWh/yr)	ADL, 1996 / NCI Analysis, 2008	ENERGY STAR, 2008 / Fisher-Nickel, 2004 / CEC, 2008 / NCI Analysis, 2008								
Average Life (yrs)	ACEEE, 2002									
Retail Equip. Cost	ADL, 1996/ Distributor Web Sites / NCI Analysis, 2008	CEE, 2008 / ENERGY STAR, 2008 / Distributor We Sites / NCI Analysis, 2008								
Total Installed Cost	Distributor Web Sites / NCI Analysis, 2008									
Annual Maintenance Cost	NCI Analysis, 2008									

Data Sources Commercial Ice Machines

Commercial Ice Machines

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Standard	High	Typical	High	Typical	High
Output (lbs/day)	ADL, 1996 / RS Means 2005				NCI Analysis, 2008 / EPACT 2005 / Distributor Web Sites					
Water Use (kWh/100 lbs)	DOE, 2004 / ARI, 2005 / ADL, 1996 / NCI Analysis, 2008	ARI, 2008 / CEC, 2008 / ENERGY STAR, 2008 / NCI Analysis, 2008								
Energy Use (kWh/100 lbs)										
Energy Use (kWh/yr)	FEMP, 2005 / NCI Analysis, 2008									
Average Life (yrs)	ACEEE, 2002									
Retail Equip. Cost	Distributor Web Sites / NCI Analysis, 2008									
Total Installed Cost (with Bin)	Distributor Web Sites / RS Means 2005 / NCI Analysis, 2008									
Annual Maint. Cost	Distributor Web Sites / NCI Analysis, 2008									

Data Sources Commercial Beverage Merchandisers

Commercial Beverage Merchandisers

<table>
<tr><th></th><th>2003</th><th colspan="3">2008</th><th colspan="2">2010</th><th colspan="2">2020</th><th colspan="2">2030</th></tr>
<tr><th></th><th>Typical</th><th>Low</th><th>Typical</th><th>High</th><th>Standard</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th></tr>
<tr><td>Cooling Capacity (Btu/hr)</td><td colspan="10">ADL, 1996 / NCI Analysis, 2008</td></tr>
<tr><td>Size (ft^3)</td><td colspan="4">ADL, 1996 / Distributor Web Sites</td><td colspan="6" rowspan="6">CEC, 2008 / ENERGY STAR, 2008 / EPACT 2005 / Distributor Wed Sites / NCI Analysis, 2008</td></tr>
<tr><td>Energy Use (kWh/yr)</td><td>ADL, 1996 / NCI Analysis, 2008</td><td colspan="3">CEC, 2008 / ENERGY STAR, 2008 / NCI Analysis, 2008</td></tr>
<tr><td>Average Life (yrs)</td><td colspan="4">ACEEE, 2002</td></tr>
<tr><td>Retail Equip. Cost</td><td>ADL, 1996 / Distr. Web Sites</td><td colspan="3">NCI Analysis, 2008 / Distributor Web Sites</td></tr>
<tr><td>Total Installed Cost</td><td colspan="4">Distributor Web Sites / NCI Analysis, 2008</td></tr>
<tr><td>Annual Maintenance Cost</td><td colspan="4">NCI Analysis, 2008</td></tr>
</table>

Data Sources Commercial Refrigerated Vending Machines

Commercial Refrigerated Vending Machines

<table>
<tr><th rowspan="2"></th><th>2003</th><th colspan="3">2008</th><th colspan="2">2010</th><th colspan="2">2020</th><th colspan="2">2030</th></tr>
<tr><th>Typical</th><th>Low</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th><th>Typical</th><th>High</th></tr>
<tr><td>Cooling Capacity (Btu/hr)</td><td colspan="10">DOE, 2008 / NCI Analysis, 2008</td></tr>
<tr><td>Can Capacity</td><td>CEC, 2005 / NREL, 2003 / FEMP, 2004</td><td colspan="3">DOE, 2008</td><td colspan="6" rowspan="7">NCI Analysis, 2008 / Distributor Web Sites</td></tr>
<tr><td>Energy Use (kWh/yr)</td><td>ADL, 1996 / CEC, 2008 / NREL, 2003</td><td colspan="3">DOE, 2008 / CEC, 2008 / ENERGY STAR, 2008</td></tr>
<tr><td>Average Life (yrs)</td><td colspan="4">DOE, 2008</td></tr>
<tr><td>Retail Equip. Cost</td><td colspan="4">Distributor Web Sites / NCI Analysis, 2008 / DOE, 2008</td></tr>
<tr><td>Total Installed Cost</td><td colspan="4">Distributor Web Sites / NCI Analysis, 2008 / DOE, 2008</td></tr>
<tr><td>Annual Maintenance Cost</td><td colspan="4">DOE, 2008</td></tr>
</table>

Data Sources Commercial Constant Air Volume Ventilation

Commercial Constant Air Volume Ventilation

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Primary Airflow (CFM)	NCI Analysis, 2008				NCI Analysis, 2008 / ARI, 2008 / RS Means 2008 / ASHRAE, 2000					
Fan Power Input (Watts)										
Energy Use (kWh/yr)	ADL, 1999 / NCI Analysis, 2008									
Average Life (yrs)	ASHRAE, 2000									
Total Installed Cost	RS Means 2008 / NCI Analysis, 2008									
Annual Maintenance Cost	NCI Analysis, 2008									

Commercial Variable Air Volume Ventilation

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Primary Airflow (CFM)	ARI, 2008 / NCI Analysis, 2008				NCI Analysis, 2008 / ARI, 2008 / RS Means 2008 / ASHRAE, 2000					
Fan Power Input (Watts)										
Energy Use (kWh/yr)	ADL, 1999 / NCI Analysis, 2008									
Average Life (yrs)	ASHRAE, 2000									
Total Installed Cost	RS Means 2008 / NCI Analysis, 2008									
Annual Maintenance Cost	NCI Analysis, 2008									

Commercial Fan Coil Units

	2003	2008			2010		2020		2030	
	Typical	Low	Typical	High	Typical	High	Typical	High	Typical	High
Total Cooling Capacity (Btu/hr)	ARI, 2008 / ADL, 1999 / NCI Analysis, 2008				NCI Analysis, 2008 / ARI, 2008 / RS Means 2008 / ASHRAE, 2000					
Sensible Cooling Capacity (Btu/hr)										
Power Input (Watts)										
Energy Use (kWh/yr)	ADL, 1999 / NCI Analysis, 2008									
Average Life (yrs)	ASHRAE, 2000									
Total Installed Cost	RS Means 2008 / NCI Analysis, 2008									
Annual Maintenance Cost	ASHRAE, 2000 / NCI Analysis, 2008									

Appendix B
References

September 2008

Navigant Consulting, Inc.
1801 K Street, NW, Suite 500
Washington, D.C. 20006
(202) 973-2400

www.navigantconsulting.com

References

ACEEE

Kubo, Turo and Steven Nadel. Commercial Packaged Refrigeration: An Untapped Lode for Energy Efficiency. American Council for an Energy-Efficient Economy, report number A015. May 2002.

Nadel, Steven. Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers. American Council for an Energy-Efficient Economy, report number A022. December 2002.

ADL

Westphalen, Detlef, Robert A. Zogg, Anthony F. Varone, and Matthew A. Foran. Energy Savings Potential for Commercial Refrigeration Equipment, prepared for the U.S. Department of Energy by Arthur D. Little. June, 1996.

Westphalen, Detlef and Scott Koszalinski. Energy Consumption Characteristics of Commercial Building HVAC Systems Volume II: Thermal Distribution, Auxiliary Equipment, and Ventilation, prepared for the U.S. Department of Energy by Arthur D. Little. October, 1999.

Appliance Magazine

30th Annual Portrait of the U.S. Appliance Industry, Appliance Magazine. September 2007.

A Portrait of the U.S. Appliance Industry 2005, Appliance Magazine, September 2005.

Statistical Review: 54th Annual Report, Appliance Magazine. May 2008.

References

ARI
Directory of Certified Automatic Commercial Ice-Cube Machines and Ice Storage Bins, Air-Conditioning and Refrigeration Institute, 2005.

Directory of Certified Automatic Commercial Ice-Cube Machines and Ice Storage Bins, Air-Conditioning and Refrigeration Institute, 2008.

Directory of Certified Room Fan Coil Air Conditioners, Air-Conditioning and Refrigeration Institute, 2008.

Directory of Certified Variable Air Volume (VAV) Terminals – Fan Powered, Air-Conditioning and Refrigeration Institute, 2008.

ASHRAE
2000 ASHRAE Systems and Equipment Handbook, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 2000.

CBECS
Commercial Building Energy Consumption Survey, Energy Information Administration, 2003.

CEC
2005 Building Energy Efficiency Standards For Residential And Nonresidential Buildings. Title 24. September 2004.

Appliance Efficiency Database, California Energy Commission, June 2008.

Appliance Efficiency Regulations, California Energy Commission, June 2008.

References

CEE
CEE Commercial Glass Door Refrigerator Tier 1 and Tier 2 Qualifying Lists (http://www.cee1.org/com/com-ref/com-ref-main.php3). March 7, 2008.

Copeland
Copeland Compressor Performance Calculator (http://www.emersonclimate.com/contractor/tools), Emerson Climate Technologies. June 17, 2008.

Department of Energy
Annual Energy Outlook, U.S. Department of Energy. 2008.

Buildings Energy Data Book, U.S. Department of Energy. 2007.

Refrigerated Beverage Vending Machines Energy Conservation Standard Advance Notice of Proposed Rulemaking, U.S. Department of Energy. June 2008.

Commercial Refrigeration Equipment Energy Conservation Standard Notice of Proposed Rulemaking, U.S. Department of Energy. August 2008.

DOE Solid-State Lighting CALiPER Program: Summary of Results: Round 5 of Product Testing. June 2008.

High-Intensity Discharge Lamps Analysis of Potential Energy Savings, Draft Report. December 2004.

Fluorescent and Incandescent Lamp Advance Notice of Proposed Rulemaking. Technical Support Document. March 2008.

FY 2005 Draft Priority-Setting Data Sheets for "Non-Covered" Products. Appendix C: Technical Support Document. 2004.

References

Department of Energy (continued)
FY 2005 Preliminary Priority-Setting Summary Report. Appendix A: Technical Support Document. 2004.

Emerson
Energy-Saving Incentives for High-Efficiency Scroll Compressors in Walk-In Coolers, Emerson Climate Technologies. November 2006.

ENERGY STAR
EPA and DOE ENERGY STAR databases (www.energystar.gov, June 2008).

Winter 2008 ENERGY STAR News (http://www.energystar.gov/index.cfm?c=news.nr, Winter 2008)

FEMP
How to Lease an Energy-Efficient Beverage Vending Machine. U.S. Department of Energy Federal Energy Management Program. June 2004.

Online Energy Cost Calculator for Commercial Ice Machines. U.S. Department of Energy Federal Energy Management Program. May 2005.

Fisher-Nickel
Food Service Technology Center Report, Fisher-Nickel, Inc. March 2004.

Food Marketing Institute (FMI)
Food Marketing Institute Facts and Figures web site (www.fmi.org, June 2008).

References

General Electric (GE)
GE Press Release: GE Announces Advancement in Incandescent Technology; New High-Efficiency Lamps Targeted for Market by 2010. February 23, 2007. http://www.businesswire.com/portal/site/ge/

Heatcraft
Personal communication with a Heatcraft representative. July 18, 2008.

IESNA
The IESNA Lighting Handbook: Reference and Application, 9th Edition. M.S. Rea. Illuminating Engineering Society of North America. New York. 2000

Kysor-Warren
Personal communication with a Kysor-Warren representative. June 16, 2008.

LRC
Bill VonNeida, Dorene Maniccia, Allan Tweed. An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems, Lighting Research Center and US Environmental Protection Agency. 2000

Lutron website
www.lutron.com

Manufacturer Catalogs
Lighting Catalogs from GE, OSRAM, and Philips. 2008

NCI
U.S. Lighting Market Characterization Volume I: National Lighting Inventory and Energy Consumption Estimate. Prepared by Navigant Consulting, Inc. for the Department of Energy. Washington D.C. September 2002.

Energy Savings Potential of Solid-State Lighting in General Illumination Applications. Prepared by Navigant Consulting, Inc. for the Department of Energy. Washington D.C. November 2006.

References

NCI (continued)
U.S. Lighting Market Characterization Volume II: Energy Efficient Lighting Technology Options. Prepared by Navigant Consulting, Inc. for the Department of Energy. Washington D.C. October 2005.

NEMA
"NEMA A-line Statistical Wattage Survey." *California Energy Commission, Appliance Rulemaking 1*, Docket # 05-AAER-2. http://www.energy.ca.gov/appliances/2006rulemaking1/documents/2006-03-10_NEMA_A-INE_SURVEY_REPONSE_12-14-2005.PDF.

National Electrical Manufacturers Association. 2006. "Special Statistical Bulletin for the Lamps Section." *Energy Conservation Program for Commercial and Industrial Equipment: Fluorescent and Incandescent Lamps Rulemaking*, No. 12 at p. 7. This written comment, document number 12, is available in Docket # EE–2006–STD–0131.

NETL
Application of Best Industry Practices to the Design of Commercial Refrigerators, prepared for the National Energy Technology Laboratory, U.S. Department of Energy, by TIAX, LLC. June 2002.

NREL
Deru, M., P. Torcellini, K. Bottom, and R. Ault. Analysis of NREL Cold-Drink Vending Machines for Energy Savings. National Renewable Energy Laboratory. June 2003.

PG&E
Analysis of Standard Options for Walk-in Coolers (Refrigerators) and Freezers, Pacific Gas and Electric Company. May 2004.

RLW Analytics, Inc.
RLW Analytics, Inc. "California Statewide Residential Lighting and Appliance Efficiency Saturation Survey." Sonoma, CA: RLW Analytics, Inc. http://www.calresest.com/index.cfm 2005a.

RLW Analytics, Inc. "SMUD Residential Lighting and Appliance Efficiency Saturation Survey." Sonoma, CA: RLW Analytics, Inc. http://www.calresest.com/index.cfm. 2005b.

References

RLW Analytics, Inc. "California Statewide Residential Lighting Database." Sonoma, CA: RLW Analytics, Inc. http://www.calresest.com/index.cfm. 2005c.

RLW Analytics, Inc. "SMUD Residential Lighting Database." Sonoma, CA: RLW Analytics, Inc. http://www.calresest.com/index.cfm. 2005d.

RS Means
2007 RS Means Electrical Cost Data, 30th Annual Edition, Kingston, Massachusetts, 2007.

Means Mechanical Cost Data, 28th Annual Edition, Means Southern Construction Information Network, 2005.

Means Mechanical Cost Data, 31st Annual Edition, RS Means, 2008.

Various Distributor Web Sites
Retail prices from various distributor web sites, June 2008.

Vending Times
Census of the Industry. Vending Times, 2007.

SUBJECT: DSM

REFERENCE: CAC/MH I-023f

QUESTION:

Please provide efficiencies (lumens/watt) and other characteristics of the LED 2010 and the LED 2020 lamps used in the potential study.

RESPONSE:

The following response is provided by EnerNOC Utility Solutions.

Residential				
	Price	**Lumens**	**Watts**	**Lm/W**
LED 2010	$47	630	7	96.9
LED 2020	$13	630	3	196.9
Commercial / Industrial:				
	Price	**Lumens**	**Watts**	**Lm/W**
LED 2010	$40.55	548	10	55.4
LED 2020	$11.51	548	3	171.3

SUBJECT: Demand response (DR)

REFERENCE: CAC/MH I-031a

PREAMBLE: In response to question CAC_GAC/MH I-031a, Manitoba Hydro stated, "Manitoba Hydro has not prepared documents comparing its current demand response offerings (Curtailable Rates Program) to those of other jurisdictions."

QUESTION:

Has Manitoba Hydro had any internal documents comparing its current Demand Response offerings to any other jurisdictions? If so, please provide documents related to this comparison. If not, please explain why not.

RESPONSE:

Manitoba Hydro has not undertaken a comparison of the demand response offerings of other jurisdictions, although the Corporation does monitor other utility rate offerings based on information provided on their websites. Each utility is unique in its ability to offer such programs, as there are many underlying factors that go into the development of a demand response offering, such as:

- The composition and availability of a utility's resources;
- The costs associated with alternate capacity-based resources;
- The utility's obligation to provide ancillary services such as reserve obligations;
- The utility's obligation to serve its export markets (if any);
- The type of customers being served; and,
- The customer's ability to take advantage of the demand response program being offered.

REFERENCE: CAC/MH I-031a

PREAMBLE: In response to question CAC_GAC/MH I-031a, Manitoba Hydro stated, "Manitoba Hydro has not prepared documents comparing its current demand response offerings (Curtailable Rates Program) to those of other jurisdictions."

QUESTION:

Has Manitoba Hydro conducted any benchmarking exercises to compare its current Demand Response offerings to any other jurisdiction (even in the absence of any internal or external document)? If so, please submit a summary of main findings.

RESPONSE:

Please see Manitoba Hydro's response to GAC_CAC/MH II-008(a).

SUBJECT: DSM

REFERENCE: CAC/MH I-014b and CAC/MH I-014c

QUESTION:

Were there significant differences – understood to be an increase or decrease of 10% or more – in results between the Dec. 2012 version and the version submitted to the PUB?

RESPONSE:

The following response was provided by EnerNOC Utility Solutions.

The first version of results was sent to Manitoba Hydro in December 2012. These results provided a proof-of-concept and allowed EnerNOC to share the full modeling framework with Manitoba Hydro. EnerNOC considers these results to be pre-preliminary; preliminary results would be closer to final than these results.

The first version of the results included results for only one residential model (the study has 5 model files to cover the 29 residential segments in the study). After running this residential model EnerNOC advised Manitoba Hydro staff that the results were exceedingly low and determined that the input data needed to be reviewed. The results were not shared with Manitoba Hydro at that time. The data was revisited and the residential sector was re-run in January 2013 again including only one residential model and the results were provided to Manitoba Hydro.

The following tables outline the results from the January 2013 residential run and compares them to the November 2013 report, all shown with the single residential model.

	January 2013 Version					November 2013 Version					Difference (January 2013 - November 2013)				
	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32
Baseline Projection (GWh)	**3,700**	**3,669**	**3,814**	**4,129**	**4,465**	**3,726**	**3,756**	**3,956**	**4,308**	**4,668**	**1%**	**2%**	**4%**	**4%**	**5%**
Energy Savings (GWh)															
Achievable Potential	10	66	119	273	392	0	81	129	206	271	-99%	22%	8%	-25%	-31%
Market Potential	17	277	527	835	1,025	3	221	344	505	606	-81%	-20%	-35%	-40%	-41%
Economic Potential	113	536	870	1,201	1,406	110	438	606	788	906	-2%	-18%	-30%	-34%	-36%
Technical Potential	169	755	1,113	1,437	1,643	164	701	995	1,269	1,455	-3%	-7%	-11%	-12%	-11%
Energy Savings (% of Baseline)															
Achievable Potential	0.3%	1.8%	3.1%	6.6%	8.8%	0.004%	2.1%	3.3%	4.8%	5.8%					
Market Potential	0.5%	7.5%	13.8%	20.2%	23.0%	0.1%	5.9%	8.7%	11.7%	13.0%					
Economic Potential	3.0%	14.6%	22.8%	29.1%	31.5%	3.0%	11.7%	15.3%	18.3%	19.4%					
Technical Potential	4.6%	20.6%	29.2%	34.8%	36.8%	4.4%	18.7%	25.2%	29.4%	31.2%					

The following tables outline the results from the initial commercial and industrial runs that were provided to Manitoba Hydro in January 2013 and compares them to the November 2013 report.

Commercial Sector	January 2013 Version					November 2013 Version					Difference (January 2013 - November 2013)				
	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32
Baseline Projection (GWh)	**5,729**	**6,053**	**6,789**	**7,119**	**7,438**	**5,688**	**5,590**	**5,858**	**6,236**	**6,581**	**-1%**	**-8%**	**-14%**	**-12%**	**-12%**
Energy Savings (GWh)															
Achievable Potential	0.01	395	1,265	1,573	1,675	25	327	629	974	1,123	410866%	-17%	-50%	-38%	-33%
Market Potential	0.11	762	1,644	1,987	2,105	114	572	1,241	1,696	1,892	107493%	-25%	-25%	-15%	-10%
Economic Potential	473	1,439	2,693	3,183	3,369	493	1,169	1,986	2,485	2,699	4%	-19%	-26%	-22%	-20%
Technical Potential	549	1,686	3,076	3,606	3,822	538	1,311	2,191	2,727	2,976	-2%	-22%	-29%	-24%	-22%
Energy Savings (% of Baseline)															
Achievable Potential	0.0001%	6.5%	18.6%	22.1%	22.5%	0.4%	5.8%	10.7%	15.6%	17.1%					
Market Potential	0.002%	12.6%	24.2%	27.9%	28.3%	2.0%	10.2%	21.2%	27.2%	28.8%					
Economic Potential	8.3%	23.8%	39.7%	44.7%	45.3%	8.7%	20.9%	33.9%	39.8%	41.0%					
Technical Potential	9.6%	27.8%	45.3%	50.7%	51.4%	9.5%	23.5%	37.4%	43.7%	45.2%					

Industrial Sector	January 2013 Version					November 2013 Version					Difference (January 2013 - November 2013)				
	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32
Baseline Projection (GWh)	**8,122**	**8,462**	**8,910**	**9,392**	**9,687**	**7,978**	**8,177**	**8,556**	**9,016**	**9,304**	**-2%**	**8,177**	**8,556**	**9,016**	**9,304**
Energy Savings (GWh)															
Achievable Potential	0.01	104	252	328	370	7	54	132	206	250	114971%	-48%	-48%	-37%	-32%
Market Potential	1	268	575	729	812	28	282	538	736	822	2700%	5%	-6%	1%	1%
Economic Potential	44	389	711	895	992	73	478	890	1,166	1,274	66%	23%	25%	30%	28%
Technical Potential	57	425	807	1,070	1,233	84	513	981	1,315	1,463	47%	21%	22%	23%	19%
Energy Savings (% of Baseline)															
Achievable Potential	0.0001%	1.2%	2.8%	3.5%	3.8%	0.1%	0.7%	1.5%	2.3%	2.7%					
Market Potential	0.01%	3.2%	6.5%	7.8%	8.4%	0.4%	3.5%	6.3%	8.2%	8.8%					
Economic Potential	0.5%	4.6%	8.0%	9.5%	10.2%	0.9%	5.8%	10.4%	12.9%	13.7%					
Technical Potential	0.7%	5.0%	9.1%	11.4%	12.7%	1.1%	6.3%	11.5%	14.6%	15.7%					

The first time that all sectors were run together, including the full residential sector, and the full results were presented to Manitoba Hydro was in March 2013. The following tables outline the results from that run and compares them to the November 2013 report. A comparison of the savings potential are not presented by measure as this level of detail would take longer to prepare than is allowed by the hearing timeline.

Summary of Electricity Potential

	March 2013 Version					November 2013 Version					Difference (March 2013 - November 2013)				
	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32
Baseline Projection (GWh)	**21,248**	**22,456**	**24,282**	**25,880**	**27,227**	**20,621**	**20,935**	**22,007**	**23,466**	**24,716**	**-3%**	**-7%**	**-9%**	**-9%**	**-9%**
Energy Savings (GWh)															
Achievable Potential	0.02	563	1,586	2,058	2,309	48	542	1,038	1,615	1,943	234790%	-4%	-35%	-22%	-16%
Market Potential	42	1,556	3,455	4,405	4,896	166	1,292	2,513	3,507	4,014	292%	-17%	-27%	-20%	-18%
Economic Potential	420	2,654	5,081	6,340	6,975	766	2,533	4,249	5,507	6,125	82%	-5%	-16%	-13%	-12%
Technical Potential	681	3,306	6,131	7,685	8,528	895	3,180	5,244	6,740	7,474	31%	-4%	-14%	-12%	-12%
Energy Savings (% of Baseline)															
Achievable Potential	0.0001%	2.5%	6.5%	8.0%	8.5%	0.2%	2.6%	4.7%	6.9%	7.9%					
Market Potential	0.2%	6.9%	14.2%	17.0%	18.0%	0.8%	6.2%	11.4%	14.9%	16.2%					
Economic Potential	2.0%	11.8%	20.9%	24.5%	25.6%	3.7%	12.1%	19.3%	23.5%	24.8%					
Technical Potential	3.2%	14.7%	25.2%	29.7%	31.3%	4.3%	15.2%	23.8%	28.7%	30.2%					

Summary of Achievable Potential by Sector

	March 2013 Version					November 2013 Version					Difference (March 2013 - November 2013)				
	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32
Residential	0.02	189	379	601	748	16	162	277	435	570	78197%	-14%	-27%	-28%	-24%
Commercial	0.00	320	1,074	1,252	1,314	25	327	629	974	1,123	130894241401805%	2%	-41%	-22%	-15%
Industrial	-	54	133	205	247	7	54	132	206	250	-	-0.1%	-1%	0.3%	1%
Total	**0.02**	**563**	**1,586**	**2,058**	**2,309**	**48**	**542**	**1,038**	**1,615**	**1,943**	234790%	-4%	-35%	-22%	-16%

Summary of Potential by Sector

Residential Sector	March 2013 Version					November 2013 Version					Difference (March 2013 - November 2013)				
	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32
Baseline Projection (GWh)	**6,951**	**7,258**	**7,724**	**8,367**	**8,987**	**6,955**	**7,168**	**7,592**	**8,215**	**8,831**	**0%**	**-1%**	**-2%**	**-2%**	**-2%**
Energy Savings (GWh)															
Achievable Potential	0.02	189	379	601	748	16	162	277	435	570	78197%	-14%	-27%	-28%	-24%
Market Potential	0.35	412	819	1,233	1,480	24	438	735	1,075	1,299	6685%	6%	-10%	-13%	-12%
Economic Potential	136	831	1,444	1,975	2,305	192	886	1,373	1,855	2,152	41%	7%	-5%	-6%	-7%
Technical Potential	212	1,129	1,879	2,498	2,864	273	1,356	2,073	2,697	3,035	29%	20%	10%	8%	6%
Energy Savings (% of Baseline)															
Achievable Potential	0.0003%	2.6%	4.9%	7.2%	8.3%	0.2%	2.3%	3.6%	5.3%	6.5%					
Market Potential	0.01%	5.7%	10.6%	14.7%	16.5%	0.3%	6.1%	9.7%	13.1%	14.7%					
Economic Potential	2.0%	11.4%	18.7%	23.6%	25.6%	2.8%	12.4%	18.1%	22.6%	24.4%					
Technical Potential	3.1%	15.6%	24.3%	29.9%	31.9%	3.9%	18.9%	27.3%	32.8%	34.4%					

Commercial Sector	March 2013 Version					November 2013 Version					Difference (March 2013 - November 2013)				
	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32
Baseline Projection (GWh)	**6,319**	**7,021**	**8,001**	**8,497**	**8,936**	**5,688**	**5,590**	**5,858**	**6,236**	**6,581**	**-10%**	**-20%**	**-27%**	**-27%**	**-26%**
Energy Savings (GWh)															
Achievable Potential	0.00	320	1,074	1,252	1,314	25	327	629	974	1,123	130894241401805%	2%	-41%	-22%	-15%
Market Potential	14.42	860	2,094	2,439	2,607	114	572	1,241	1,696	1,892	691%	-34%	-41%	-30%	-27%
Economic Potential	213	1,344	2,747	3,210	3,423	493	1,169	1,986	2,485	2,699	132%	-13%	-28%	-23%	-21%
Technical Potential	383	1,658	3,261	3,861	4,189	538	1,311	2,191	2,727	2,976	40%	-21%	-33%	-29%	-29%
Energy Savings (% of Baseline)															
Achievable Potential	0.00%	4.6%	13.4%	14.7%	14.7%	0.4%	5.8%	10.7%	15.6%	17.1%					
Market Potential	0.2%	12.3%	26.2%	28.7%	29.2%	2.0%	10.2%	21.2%	27.2%	28.8%					
Economic Potential	3.4%	19.1%	34.3%	37.8%	38.3%	8.7%	20.9%	33.9%	39.8%	41.0%					
Technical Potential	6.1%	23.6%	40.8%	45.4%	46.9%	9.5%	23.5%	37.4%	43.7%	45.2%					

Industrial Sector	March 2013 Version					November 2013 Version					Difference (March 2013 - November 2013)				
	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32	2012/13	2017/18	2022/23	2027/28	2031/32
Baseline Projection (GWh)	**7,978**	**8,177**	**8,556**	**9,016**	**9,304**	**7,978**	**8,177**	**8,556**	**9,016**	**9,304**	**-0.005%**	**8,177**	**8,556**	**9,016**	**9,304**
Energy Savings (GWh)															
Achievable Potential	-	54	133	205	247	7	54	132	206	250	-	0%	-1%	0%	1%
Market Potential	28	284	542	732	808	28	282	538	736	822	2%	-1%	-1%	1%	2%
Economic Potential	72	479	890	1,154	1,247	73	478	890	1,166	1,274	1%	0%	0%	1%	2%
Technical Potential	85	519	990	1,326	1,475	84	513	981	1,315	1,463	-2%	-1%	-1%	-1%	-1%
Energy Savings (% of Baseline)															
Achievable Potential	0.00%	0.7%	1.6%	2.3%	2.7%	0.1%	0.7%	1.5%	2.3%	2.7%					
Market Potential	0.3%	3.5%	6.3%	8.1%	8.7%	0.4%	3.5%	6.3%	8.2%	8.8%					
Economic Potential	0.9%	5.9%	10.4%	12.8%	13.4%	0.9%	5.8%	10.4%	12.9%	13.7%					
Technical Potential	1.1%	6.3%	11.6%	14.7%	15.9%	1.1%	6.3%	11.5%	14.6%	15.7%					

Many modeling assumptions changed between December 2012 and November 2013 as the analysis was finalized. The number of changes and their magnitude on the results is typical for potential studies EnerNOC performs. They reflect refinement of modeling assumptions as the EnerNOC team and Manitoba Hydro staff came to common understanding of the input data assumptions and exactly how they are applied in the modeling framework. This is a process EnerNOC goes through with each client. The changes that were made are also typical of EnerNOC studies summarized as follows. The assumptions driving the baseline projection were refined as needed. The measure list was reviewed again and some measures were excluded because they were not applicable to Manitoba (e.g., duct repair and ceiling) as they were missed in the first pass in measure identification. Market adoption rates (MARs) and program implementation factors (PIFs) were adjusted to better reflect past program results and expected program savings in the future. Algorithms to calculate heating and cooling interactive effects for equipment measures were added to LoadMAP in late spring 2013.

SUBJECT: DSM

REFERENCE: CAC/MH I-014b and CAC/MH I-014c

QUESTION:

If so, please specify the differences, with quantitative results for each version, for specific measures (for which potentials increased or decreased by more than 10%).

RESPONSE:

Please see the response to GAC_CAC/MH II-009a.

SUBJECT: DSM

REFERENCE: CAC/MH I-014b and CAC/MH I-014c

QUESTION:

If so, please specify the differences, with quantitative results for each version, for sector-level potentials (if said potentials increased or decreased by more than 10%).

RESPONSE:

Please see the response to GAC_CAC/MH II-009a.

SUBJECT: DSM

REFERENCE: CAC/MH I-014b and CAC/MH I-014c

QUESTION:

If so, please specify the differences, with quantitative results for each version, for other significant changes between the versions.

RESPONSE:

Please see the response to GAC_CAC/MH II-009a.

SUBJECT: DSM

REFERENCE: CAC/MH I-029b

QUESTION:

Has Manitoba Hydro conducted an internal assessment of the impact of achieving 4x more DSM than currently achieved and/or planned?

RESPONSE:

As outlined in Manitoba Hydro's responses to PUB/MH I-257 and CAC/GAC/MH I-018(b), DSM is a resource option considered as part of Manitoba Hydro's integrated resource planning process. Manitoba Hydro had intended to undertake a full DSM Market Potential Study, and then utilize the resulting information to perform an evaluation of DSM utilizing different levels of DSM in conjunction with different generation plans and exports. Unfortunately the study took longer to complete than expected and planned. As a result, the generation plan evaluations with the different levels of DSM could not be undertaken in time for the August 16, 2013 filing of the NFAT submission required by the NFAT schedule. Through the sensitivity analyses outlined in Chapter 12 of the submission, Manitoba Hydro did however assess the attractiveness of the Preferred Development Plan under increased levels of DSM, regardless of the cost of achieving the increased DSM savings. The DSM sensitivity and stress test indicated that in general the development plans analyzed benefit from increased levels of DSM. The Preferred Plan and Plan 4 (K19/Gas30/250MW) derive greater benefits from higher levels of DSM than the K23/Gas plan. Please also see Manitoba Hydro's response to CAC/MH I-225(a). As concluded in Chapter 12 of the submission: "analysis shows that the economic ranking of development plans remain the same under higher levels of DSM".

With the completion and subsequent filing of the DSM Market Potential Study with the August 16, 2013 submission, Manitoba Hydro had communicated that it intends to undertake prior to the NFAT hearing a generation plan study with two levels of DSM, the timing and extent of which will be dependent upon other demands on staff time in the process, including the need to respond to Information Requests. Manitoba Hydro continues to work toward this goal.

SUBJECT: DSM

REFERENCE: CAC/MH I-029b

QUESTION:

If so, please provide the full assumptions used, including: cost ($M), savings (GWh and MW, both on an annual basis), average savings lives accounted for in economic and supply/demand models, average $/kWh and $/kW unit cost of savings, discount rate and treatment of risk.

RESPONSE:

Please see Manitoba Hydro’s response to GAC_CAC/MH II-010a.

SUBJECT: DSM

REFERENCE: CAC/MH I-029b

QUESTION:

Please expand in particular on the unit cost assumptions, and provide substantiation for the assumptions made as they relate, at least in part, to Manitoba Hydro's own DSM history and experience with DSM in other regions.

RESPONSE:

Please see Manitoba Hydro's response to GAC_CAC/MH II-010a.

SUBJECT: DSM

REFERENCE: CAC/MH I-029b

QUESTION:

If Manitoba Hydro were directed to achieve the 4x scenario (i.e. somewhat lower than the relative savings required of utilities in neighbouring Minnesota), what, if any, organizational changes does Manitoba Hydro believe would be needed to deliver? Specifically, would Manitoba Hydro be able to deliver with its internal Power Smart team? Alternatively, would it consider recourse to third-party delivery agents, and/or would it recommend transferring responsibility to an independent body? Please justify your answers.

RESPONSE:

If Manitoba Hydro were directed to achieve the 4x scenario and notwithstanding any consideration for cost effectiveness, no significant organizational changes would be envisioned. Manitoba Hydro is well positioned to pursue energy savings through demand side management (DSM) based upon its extensive history and experience with DSM, its position as an integrated energy service provider (electricity and natural gas), its existing relationships with customers as an energy services provider through its customer care activities and account managers, its ability to leverage billing systems and customer account information, and the significant recognition and value of the Power Smart Brand. The best approach to achieving the 4x scenario would need to be assessed and decisions on internal resource requirements and contracting to third parties would be made after undertaking an assessment of varying program design options. This is consistent with the approach undertaken today where internal resources are adjusted according to changing requirements and third parties are utilized when this approach is deemed to be more effective and efficient. In the latter case, examples include:

- The Water and Energy Saver program uses a third party to deliver components of the program, including application processing, direct mail and direct installation of the energy efficient measures, and customer service and reporting;
- The Fridge Retirement Program uses a third party to assist in delivery of the program including appointment booking, appliance pick up, appliance recycling, customer service and reporting.
- The Affordable Energy Program engages in-home auditors and pre-qualified furnace and insulation contractors to provide the energy assessment and technology installation components of the program. For outreach, funding is being provided to local non-profit organizations to complement Manitoba Hydro's marketing efforts to promote the program and encourage participation.

In addition, past programs such as the EcoENERGY Program and the Power Smart New Home Program utilized third party contractors to perform in-home energy assessments and home EnerGuide ratings. The former WISE Program (Wisdom in Saving Energy) delivered by the Manitoba Association of Seniors, through funding by Manitoba Hydro, provided in-home "energy walk throughs" and direct installations of low cost measures in qualifying seniors' residences.

SUBJECT: DSM

REFERENCE: CAC/MH I-029b

QUESTION:

Would Manitoba Hydro entertain a scenario in which a neighbouring utility with significant DSM experience would take full financial and operational responsibility for delivering 4x or greater DSM in Manitoba -- including responsibility for all risks related to DSM costs and savings --, in return for Manitoba Hydro physically exporting the saved power and being paid a reasonable markup? For example, if Xcel Energy were to fully pay for and deliver (or manage delivery of) DSM programs in Manitoba, and pay a markup to cover additional transmission costs and profit, in return for delivery by Manitoba Hydro of the saved power (subject to third-party evaluation, measurement and verification of savings quantities). Why or why not?

RESPONSE:

Manitoba Hydro does not agree that a neighbouring utility would be a more effective and efficient entity for pursuing demand side management opportunities in Manitoba. Manitoba Hydro's demand side management activities are fully integrated within the Corporation, including having access to billing information, integrated call taking functions, integrated customer relationship management with staff knowledgeable with Manitoba customer's energy use (e.g. approximately 50 key, major and energy advisor account representatives assisting customers with managing their energy bills), a dedicated Power Smart sales force, a technical engineering department familiar with the target market and overall demand side management strategies built on having a strong brand awareness in the Manitoba market.

In the proposed hypothetical situation, Manitoba Hydro would entertain assessing the economics of any additional DSM a third party could potentially achieve in Manitoba. The assessment would need to use consistent criteria to assess Manitoba Hydro's DSM efforts and to be assessed from an incremental perspective to what is planned to be achieved through the Corporation's planned efforts. Consideration would also need to include the fairness issue to all rate payers. As a general guideline, having overall lower aggregate energy bills for participating customers should not come at the expense of having higher aggregate energy bills for non-participating customers.

Consideration for capturing additional DSM must also be assessed in the context of Manitoba Hydro's overall integrated planning process. Both DSM and new resource options play an integral role in meeting the future energy needs of Manitoba. Manitoba Hydro is not building new generation or pursuring DSM opportunities for the specific purpose of exporting electricity to other regions. The objective of Manitoba Hydro's DSM initiative is to obtain the maximum benefit for Manitoba ratepayers and in the context of developing an integrated resource plan, timing of energy savings is an important consideration both seasonally and across the Corporation's planning horizon.

REFERENCE: CAC/MH I-003b

PREAMBLE: "Manitoba Hydro has monitored an air source heat pump system and the COP was 1.2. In addition to the low COP, the compressor ran for an additional 2000 hours, which significantly 17 reduces the life of the compressor."

QUESTION:

Please provide more information with regard to this ASHP monitoring (model(s) used, main technical characteristics, number of measurement sites, duration of the study, etc.).

RESPONSE:

The ASHP unit monitored was an ICP model C2H324GKA conventional two ton (24,000 Btu/h of cooling capacity) split system heat pump connected to an 18 kW electric furnace. There were 13 measurement points, and the study duration was for one heating season (eight months).

REFERENCE: CAC/MH I-003b

PREAMBLE: "Manitoba Hydro has monitored an air source heat pump system and the COP was 1.2. In addition to the low COP, the compressor ran for an additional 2000 hours, which significantly 17 reduces the life of the compressor."

QUESTION:

Why wasn't a setup used to shut-off the ASHP during very cold weather and reliance placed instead on the supplemental heating system, in order to raise the average COP and reduce the operating hours?

RESPONSE:

The system was installed and setup as per the manufacturer's installation instructions.

- The unit was monitored as operating per the manufacturer's installation instructions. The wiring was installed by the homeowner (electrical specialist qualified to do the work).
- Over 90% of the operating hours occurred at temperatures above -12^{0}C (10^{0}F) where the running hours would not be expected to be restrained.
- The unit did not operate below -21^{0}C (-6^{0}F) (i.e. no hours at low temperature) and operated only intermittently between -12^{0}C (10^{0}F) and -21^{0}C (-6^{0}F).

REFERENCE: CAC/MH I-003b

PREAMBLE: "ASHPs do not have sufficient capacity to heat a home at temperatures going below -30°C nor do they provide significant energy savings."

QUESTION:

Please provide any study or analysis to back-up the assertion that ASHP can't provide significant savings in Manitoba.

RESPONSE:

To clarify the intended meaning of the previous response and monitoring, ASHPs can save energy but at present do not necessarily yield sufficient benefits to off-set the incremental cost of installing the systems.

Longer term positive operating experience would also be required before ASHPs may be considered as a reliable long term investment in the Manitoba market. Long compressor run hours in a harsh operating environment such as Manitoba may impact reliability and long term savings persistence, creating additional marketing barriers and economic impacts that require further analysis.

REFERENCE: Question CAC/MH I-006

QUESTION:

Why is the real discount rate used for the potential study (5.95%) significantly higher than the discount rate used for the analysis of new production options (5.05%)?

RESPONSE:

The 5.95% discount rate used for the potential study was Manitoba Hydro's weighted average cost of capital at the time the data collection and analysis for the study began in 2011. The 5.05% discount rate was Manitoba Hydro's weighted average cost of capital in the fall of 2012 at the time of the analysis of the new production options.