Team Brundtland

Executive Summary of Everything Store

The Everything Store, Inc has a corporate responsibility of pursuing energy efficient measures to ensure sustainable growth as well as increased energy savings for the company. The task was to explore the company's options for increasing energy efficiencies through the replacement of rooftop units (RTUs) while considering their cost effectiveness.

An optimization program was used to consider different RTU replacement options. Variables considered include building type, age, climate, usage and size of RTUs. The NPV of the annualized energy savings and capital costs (taking into account the initial down-payment), operational expenses and depreciation (for tax purposes) is used to evaluate its cost effectiveness. Every replacement possibility was fed through an optimizing algorithm to obtain the net annual profits and select the optimal combination of units to maximize profits under the constraint of ensuring a 5 year payback.

We found that a total of 719 units that result in positive NPV should be replaced, with 116 of these units having to be replaced anyways (as part of the base case where units older than 15 years are replaced immediately). Generally the decision to replace was for units between 10 and 15 years old (since older unit base cases were not considered) while the optimal solution for younger units was to stay as it is. For sizing of the units, the 40 ton cooling units offered the highest per unit savings and were a large factor in the overall NPVs but a large quantity of smaller units are replaced at older ages and hotter climate zones.

In addition, we recommend a lease sell-back financial scheme for the implementation of the new RTUs. The stakeholder would purchase the RTUs and immediately sell them to an investor such as GE Capital or Chase Manhattan who would in turn lease the units back to the Everything Store for the lifetime of the unit. The advantage of this scheme is that it provides the stakeholders with higher liquidity in capital without the large initial down payment and flexibility to purchase RTUs from multiple manufacturers and suppliers. When we repeated the financial model analysis, the leasing option provided a higher overall NPV even at a 12% lease rate, despite the fact that the Everything Store pays more money over the full period of time.

However, it was reported that cooling and heating energy only constitutes 24% of a grocery store's total building energy use. Hence, other energy design measures (EDMs) that address lighting (23%) and refrigeration (38%) should be considered so that 20% energy savings could be achieved more cost effectively. EDMs considered in our strategy are high efficient luminaires (T12, T8, T5 and LED), improving roof insulation (R20, R35 and R60), adding a dedicated outdoor air system (DOAS) with ventilation heat recovery and desiccant wheel, and improving refrigeration equipment.

A total of 161 parametric simulations with different combinations of EDMs were run for each of the 16 climate zones to obtain the different energy consumption levels for each strategy. The 5 year total life cycle cost of each strategy and its corresponding net energy saving were computed and compared to the baseline case, which is based on inputs from DOE's prototype model (for typical groceries stores and literature. The energy saving potential of the 4 EDMs varies considerably across different climate zones. From the simulation using EnergyPlus, a recommendation for each climate zone was selected by choosing the strategy that gives most significant benefits in energy savings given the constraint of a five year payback period.

The strategy is therefore to present EDMs in an integrated approach as opposed to the conventional approach of selecting the low handing fruit.

I. Introduction

The Everything Store, Inc has a corporate responsibility in pursuing energy efficient measures to ensure sustainable growth as well as increased energy savings for the company. In this case study the task was to explore the company's options for increasing energy efficiencies through the replacement of rooftop units (RTUs) while considering their cost effectiveness. However, it was reported that cooling and heating energy only constitutes 24% of a grocery store's total building energy use (Figure 1). Hence, in order to reduce the energy consumption of a grocery store substantially, other potential solutions that address lighting (23%) and refrigeration (38%) are also considered.

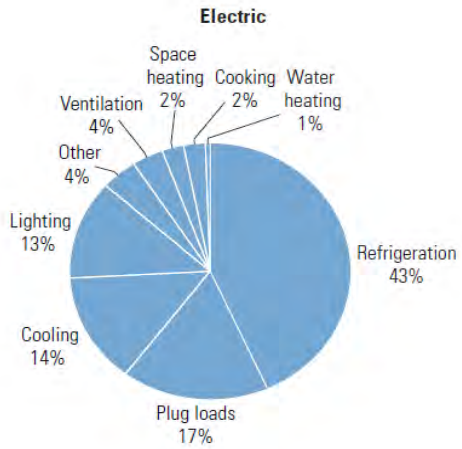

Figure 1: Energy usage breakdown of grocery store in U.S (EnergyStar, 2008)

The first section of the report evaluates the cost effectiveness of the different RTUs and optimizes the options based on capital cost and energy savings. We considered a sell back financing scheme that would allow for capital equity for the stakeholder while preserving annual savings benefits. Lastly, we also considered other viable energy design measures (EDMs) to implement based on different climate zones.

II. Roof Top Unit

i. Choice Optimization Overview

To optimize different RTU options, a dynamic programming framework could have been used to consider the RTU replacement at every time period, for every store and with minimal cost. However, after some initial analysis on individual RTU replacements, it was determined that the incremental benefit from replacement at a later time would not outweigh the positive benefits from replacing as soon as possible since the 5 year payback period guarantees a spike in savings after 5 years (hence, replacing as soon as possible is the best option). Given this result, emphasis was placed on other aspects of integrating RTUs rather than from timing replacements optimally.

ii. Assumptions and Methods

The capital costs of the RTUs can be calculated as a function of the size and unit type (minimum standard, Tier I, Tier II, and IEER 18) as the product of tons of cooling capacity and

corresponding price and unit type (from Appendix E: Pricing Considerations). The primary source of data for the analysis was gathered from the Appendices from the attached source materials (cooling capacity of the units (tons), equipment efficiencies, prices, and general usage rate) for "The Everything Store". Different climate zones were assumed to increase energy requirements for cooling linearly (NOAA 2005). Units less than 15 years of age were compared against the scenario of doing nothing while units older than 15 years had a baseline where a switch to the minimum allowable standard was required.

80% of the capital cost (we assumed a 20% down-payment) was annualized over 5 years at an interest rate of 5% to ensure that the calculated energy savings could result in a desired payback over the chosen period. The following formula calculates the annualized cost facing the purchaser:

$$PMT_{size,type} = \frac{PV_{size,type} \times i}{\left[1 - \frac{1}{(1+i)^N}\right]}$$

Where:

- i = 5% discount rate
- N = 5 year payback period
- $PV_{size,type}$ = Capital cost of RTU as a function of size and unit type

We then took the NPV of both the annualized energy savings and the annualized capital costs (taking into account the initial down-payment) while considering operational expenses and depreciation (for tax purposes), and a 9% discount rate.

The primary model was constructed in MATLAB where every possible replacement possibility was fed through the equations in the previous sections to obtain the net annual profits over a five year time interval and select the optimal unit to maximize profit. These results were then filtered to provide only the existing replacement outcomes among the 100 stores and possible unit replacement options. Variables considered include building type, age, climate, usage and size of RTUs.

iii. Results

We found that a total of 719 units should be replaced, with 116 of these units having to be replaced anyways (as part of the base case where units older than 15 years are replaced immediately).

As can be seen in Figure 2, the overall replacement scenario of 700 units results in a positive NPV over 5 years. Figure 2 also breaks down the NPV costs and benefits by the unit type being replaced – in this case over half the total costs and savings are being generated by the IEER RTUs. There are no Tier II unit replacements (it is strictly dominated by other strategies) and the "no change"

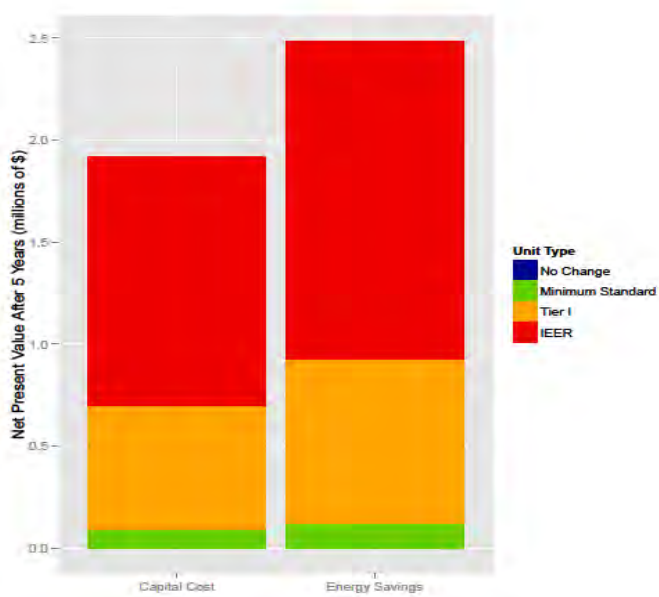

Figure 2: NPV Capital Cost versus Energy Savings over 5 Years

scenario does not affect the NPVs since they are the baseline of comparison for our analysis. In terms of distribution of units, and number of units being installed to different buildings, see Figure 3 below. Most buildings are replacing either 5 units, or greater than 17 units.

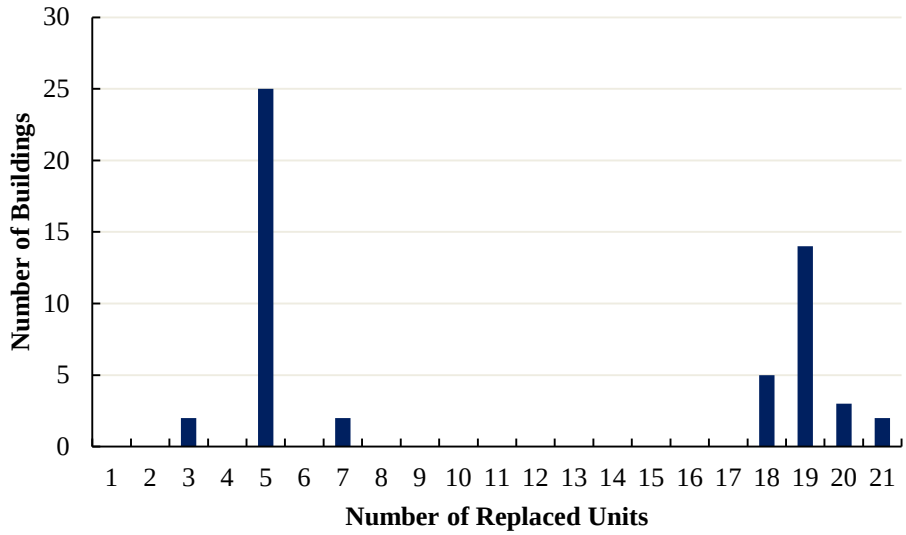

Figure 3: Number of buildings replacing variable numbers of RTUs

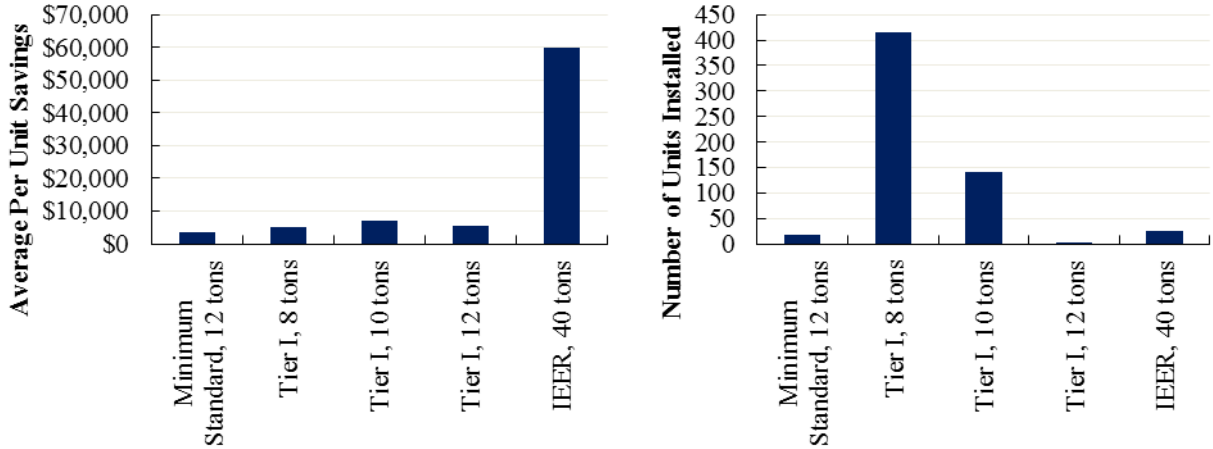

Figure 4: Average total NPV savings by unit (left) and
Total number of units installed by type (right)

As can be seen in Figure 4 above, the highest average savings are for the IEER 40 ton units but this is countered by the large volume of Tier I 8 and 10 cooling ton units that are optimal to replace through the various Everything Stores.

iv. Financing

Realizing that the financing method impacts the feasibility and ultimate effectiveness of retrofitting RTUs, we sought to design a strategy that would allow for the greatest flexibility of technical options while returning the most favorable financial results. We understood the advantages of emerging funding resources such as Property Assessed Clean Energy (PACE) Bonds and Energy Savings Performance Contracts (ESPCs) through Energy Service Companies (ESCOs), as well state and locally funded incentive programs and subsidies. We quickly recognized however that although these programs offer substantial benefits, the effort and resources necessary to pursue the many different localized options made it difficult for the company to pursue at a nation-wide level.

We needed a financing solution that combined the positive attributes of PACE Bonds and ESPCs (low up-front costs, and low annual payments), but with the streamlined approvals process and payment structure of a single loan provider. We therefore propose a sell-leaseback financing solution. Sell-leaseback agreements are currently in wide use in the aviation industry for the financing of jet engines (airlines buy engines separately from the rest of the plane). They are also used to finance heavy construction equipment, farm machinery, and commercial real estate.

With a sell-leaseback agreement, the Everything Store would buy all the replacement RTUs as-needed per the cost benefit analysis. The RTU's would not need to be purchased from a single supplier or manufacturer. This gives the Everything Store flexibility to pursue the most advantageous purchasing scheme irrespective of RTU manufacturer or supplier (factoring in switching costs and discounts). Once all the units are purchased, they are then sold as a single lot to an investor such as GE Capital or Chase Manhattan. The investor then leases the RTU's back to the Everything Store for a term equal to the life of the unit (in our case, 20 years).

The Everything Store will benefit from the following advantages of a sell-leaseback agreement:

- Capital is not tied up in a large down payment
- The sale of the equipment improves the company's balance sheet and provides immediate cash for re-investment
- Annual lease payments will be lower than the annual loan payments, freeing up cash
- The lease expenses can be claimed as operating expenses for tax purposes (As long as the lease term is shorter than the 39 year depreciation period, tax benefits will be greater)
- The leaser has a greater degree of flexibility to negotiate the lease terms
- There will be one payment per period to the lease holder instead of multiple payments to a variety of financiers
- Flexibility to purchase RTUs from multiple manufacturers and suppliers
- Due to the time value of money, a sell-leaseback agreement will generate a higher NPV as compared with a loan (assuming a 20% down payment and 5 year loan term)

Disadvantages:

- Larger cost over the lifetime of the lease agreement
- Initial purchase of equipment requires a large (but temporary) cash outlay

Sell-leaseback agreements are highly attractive to potential investors because of the long-term guaranteed cash flows that they receive at reasonable rates of return. Furthermore, because they are now the equipment owners, they can depreciate the assets to harvest the tax benefits, passing the tax savings on to the leaser in the form of lower lease payments.

During the lease term, the Everything Store will have continued use of the equipment. Maintenance will continue to be the responsibility of the Everything Store. At the end of the lease period the Everything Store will have the option to continue the lease at renegotiated rates, buy out, or replace the equipment.

III. Alternative Energy Saving Strategies

Although the replacement of RTUs has a significant impact on a building's energy consumption, other energy design measures (EDMs) should be considered so that 20% energy savings could be achieved more cost effectively. Since superstores are significantly more energy intensive than standard stores, we have decided to focus on the effect of implementing these EDMs on the building energy consumption of superstores. Since the Everything Store Inc. has superstores across different climate zones, no single EDM can be generalized to be applicable at every store given that climate has a huge impact on the potential savings of a particular EDM. Therefore, to account for interactions between different systems, the climate and different EDMs, EnergyPlus, a building energy simulation tool, is used to model the energy savings that could be achieved from different EDMs and their combinations.

Energy savings are determined with respect to a baseline building that was modelled based on inputs from DOE's prototype model (DOE, 2010b) for typical groceries stores and literature (Leach, Hale, Hirsch, & Torcellini, 2009). The baseline model used is a one storey building with 45,000 ft² total conditioned floor area. Lighting fixtures are assumed to contain T12 lamps and the space cooled by packaged units with direct-expansion coils and air cooled condensers. Heating is provided by natural gas furnaces. The EDMs considered in our study can be categorized into four categories, namely: using high efficient luminaires (T8, T5 and LED), improving roof insulation (R20, R35 and R60), adding a dedicated outdoor air system (DOAS) with ventilation heat recovery and desiccant wheel, and improving refrigeration equipment (Using LED lights, adding sliding doors or cover at night, anti-sweat controls and more efficient fans). Using an illumination level of 500 lux on a 0.85m work plan and assuming luminaires are suspended 3.5m above floor level, lighting power densities for each light source (T12, T8, T5 and LED) was obtained through simulation using lighting software DIAlux 4.10. A total of 2,576 parametric simulation with different combinations of EDMs were run for all 16 climate zones defined by ASHRAE (2009). For validation, we compare our baseline energy usage intensity (EUI) for each of the 16 climate zones to the benchmarks established by DOE for existing supermarkets (post 1980) (DOE, 2010a) (Figure 5). There is reasonable agreement between the trends observed in the baseline model and the benchmark used.

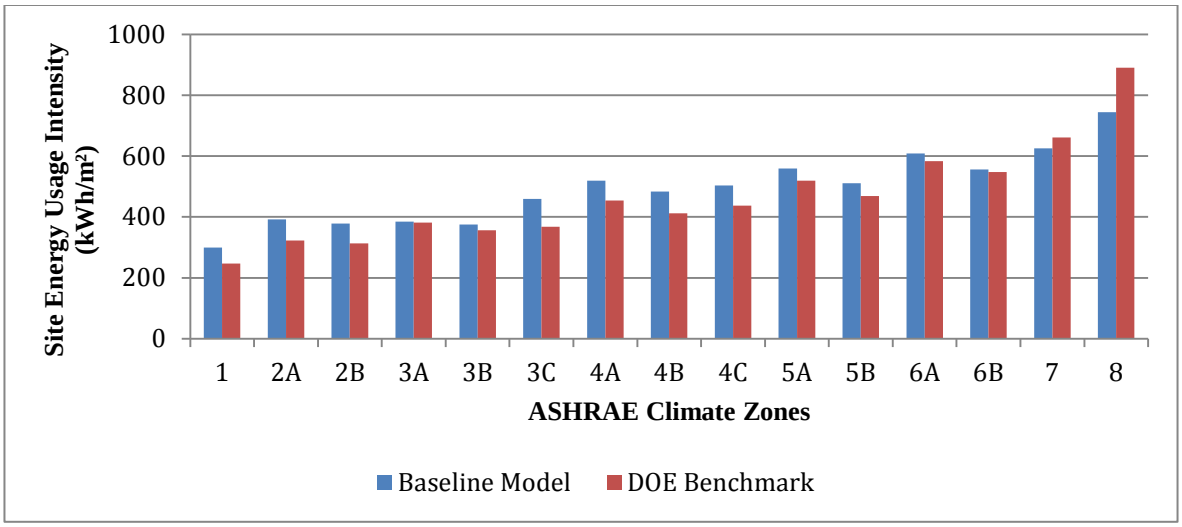

Figure 5: Comparison of baseline EUI with DOE and EnergyStar benchmarks

In order to evaluate the cost effectiveness of each energy-saving strategy in every climate zone, the total life cycle cost, including capital costs and energy cost, over a period of 5 years, is computed and compared to the baseline case. A 9% discount rate is used for computing the net present value of the annual cash flow for each strategy as well as the baseline case. The annual cost and consumption of energy are assumed to be constant over the period of 5 years. The cost of electricity per climate zone for commercial sector is retrieved from the national average cost of electricity of 10.23 cents (Adminstration, 2013). The capital costs of the different refrigeration, luminaires with specific efficiency, insulation and DOAS are retrieved from literature (Leach, Hale Hirsh & Torcellini, 2009).

IV. Simulation Results

After the 5 year total life cycle cost of a strategy is computed, it is plotted against its corresponding net energy saving with respect to the baseline case. The net energy saving is defined as energy consumption reduced per year as a percentage of the baseline case. Due to space constraints, only 3 of the 16 simulation results which were deemed to be most representative are illustrated in Figures 6 below. Each point represents one of the 161 parametric run that was simulated for each climate zone. The red line indicates the 5 year life cycle cost intensity (operation and maintenance of equipment and higher cost due to higher energy usage) of the baseline building without retrofit. Hence, any energy saving strategy located below the red line indicates a payback period below 5 years, deeming it a cost effective strategy for existing buildings in that climate zone to pursue.

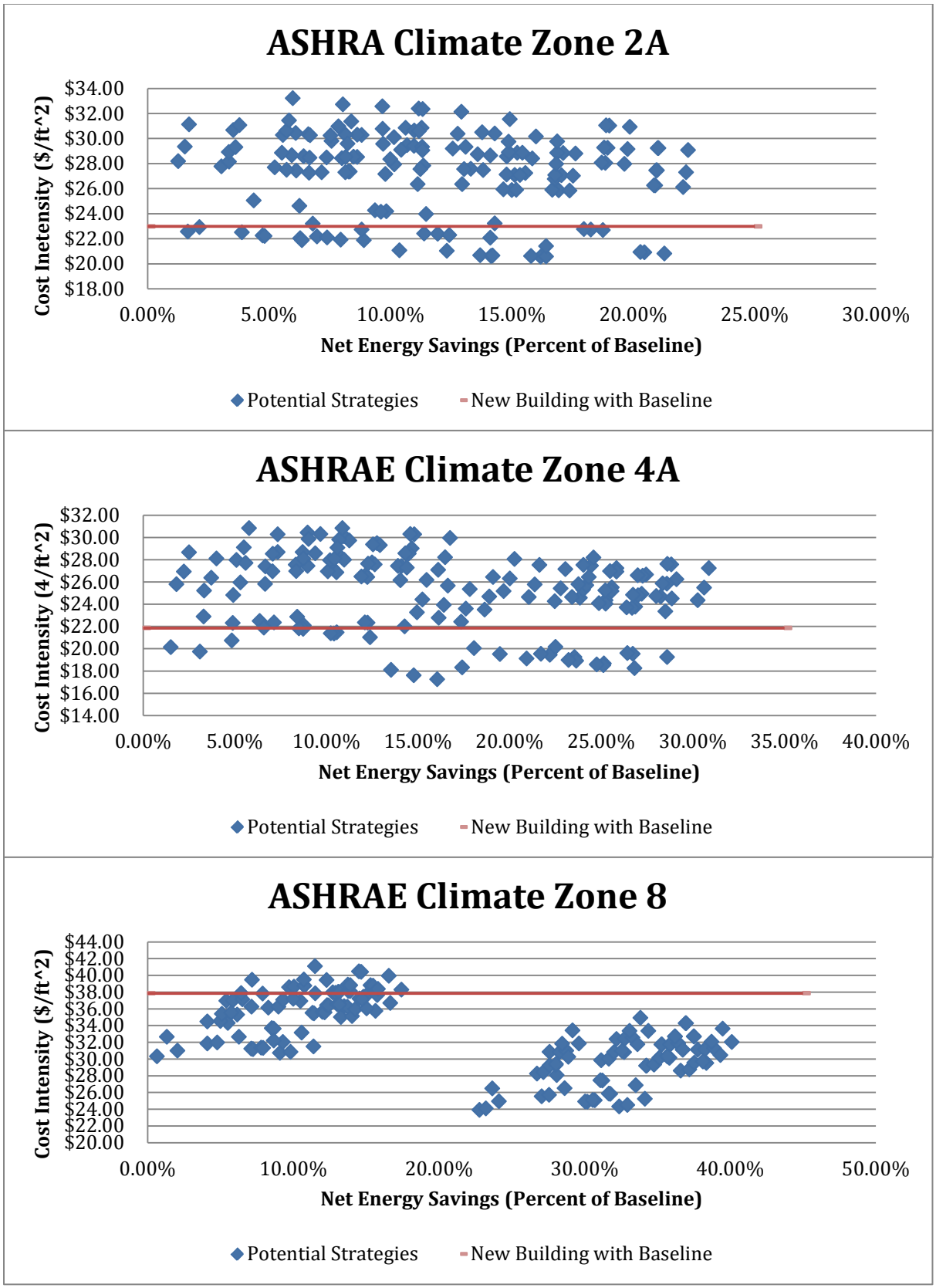

Figure 6 Total Life Cycle Cost Intensity vs Net Energy Savings for Zones 2A (top), 4A (middle) and 8 (bottom)

From Figure 6, it can be observed that the energy saving potential of the 4 EDMs considered varies considerably across different climate zones with saving potential increasing from climate zone 2A (hot, humid) to zone 4A (mild, humid) to zone 8 (extremely cold). This is because of the four EDMs considered, 2 (roof insulation and DOAS with desiccant wheel and heat recovery) are strategies which result in greater energy savings in cold climates as compared to hot climates. The addition of better roof insulation is more cost effective in cold climate because the temperature difference (delta-T) between outdoor and indoor temperatures is much higher during winter in a cold climate as compared to a hot summer day. Similarly, for a heat recovery system the larger delta-T also results in greater energy saving potential in a cold climate. A desiccant wheel is also less efficient in a hot and humid climate because desiccants regenerate at a slower rate due to higher humidity levels. Regardless of climate, it is found that it is cost effective over all climate zones to retrofit their T-12 bulb to more energy efficient bulbs (T-8, T-5 or LED).

V. Recommendations for each climate zone

From the simulation using EnergyPlus, a recommendation for each climate zone was selected by choosing the strategy that produced the greatest energy saving given the constraint of a five year payback period. Table 1 below is a summary of all the recommendations for each of the 16 climate zones. It is also important to note that store owners are not limited to the recommended strategies as can be seen in Figure 2. There are many energy saving options (indicated as points below the red line) available that are within a payback period of 5 years and could be chosen given the preference of each owner. From the table, the general recommendation is to install a DOAS with heat recovery and desiccant wheel, have LED lighting and improve refrigeration equipment by using cases that have sliding doors, anti-sweat controls and LED lighting. Only in climate zone 8 is insulation cost effective. This is because the energy savings from addition insulation to the base roof (U-value: 0.351 W/m²K) does not justify the high cost of adding insulation given the large roof area of superstores. It is important to note that these recommendations represent an integrated approach towards energy saving options instead of the typical approach of identifying the low handing fruit. For instance, for climate zone 8, the inclusion of a DOAS has a payback period of 3 years while the use of LED lighting has a payback period of 6 years. By combining these strategies together, a payback period of less than 5 years can be achieved, thus achieving greater energy savings than either alone.

Table 1: Recommended strategies for each climate zone

Climate Zone	Strategies				Net Energy Savings (%)	LEED (Energy and Atmosphere: Credit 1) possible pt: 19	Cost Intensity ($/ft^2)
	DOAS	Lighting	Insulation	Refrigeration Equipment			
1A	-	T8	-	-	2.60	0	19.05
2A	Yes	LED	-	Yes	21.29	7	20.81
2B	Yes	LED	-	-	14.55	4	18.82

3A	Yes	T8	-	Yes	21.16	7	20.15
3B	Yes	LED	-	Yes	25.39	9	20.50
3C	Yes	LED	-	Yes	27.36	10	19.44
4A	Yes	LED	-	Yes	28.61	11	20.83
4B	Yes	LED	-	Yes	27.47	10	20.09
4C	Yes	LED	-	Yes	30.45	12	20.06
5A	Yes	LED	-	Yes	30.70	12	21.43
5B	Yes	LED	-	Yes	29.19	11	20.48
6A	Yes	LED	-	Yes	32.28	13	22.34
6B	Yes	LED	-	Yes	31.61	12	21.16
7	Yes	LED	-	Yes	33.48	13	20.90
8	Yes	LED	R3.5 (R-20) c.i	Yes	38.38	16	27.91

VI. Additional sustainable strategies

Besides the energy saving strategies evaluated using simulation, we would also like to recommend the following sustainable tactics based on benefits quantified from case studies in the U.S.

VII. Harvest Daylighting using skylights or solar tubes

Suggestion: Since stores are usually one-storey buildings with large roof areas, they provide a great opportunity to introduce daylight into interior spaces through the use of skylights or solar tubes. Daylight sensors and dimmable ballasts should be used to decrease the use of artificial lighting when daylight meets the illumination level. Daylight also has high colour temperature (12,000 – 18,000K) leading to pleasing visual quality and thus improving shopping experience. (LEED Indoor Environmental Quality Credit 8.1)

Case Study: Giant Eagle grocery store in Pennsylvania, 2010 (Streed, 2010)

Benefits:

- Energy saving: 40% reduction in lighting energy or $10,000/month reduction in electricity bills
- Revenue Sales: 31-49% increase compared with non-skylight store in 18 months with greater consumer satisfaction
- Annual monetary saving per store: $120,000
- Annual Reduction of CO2 emissions per store: 410 tons
- Total Cost: $385,000 (include installation fee)

VIII. Green roof

Suggestions: Implement extensive green roof (more cost effective than intensive green roofs) to reduce storm water run-off, increase energy efficiency and lower roof temperature to decrease the heat island effect. (LEED-Sustainable Site Credit 6.1, 6.2, 7.2 – roof heat island effect)

Case Study: Green Circle Shopping Center, located in the Ward Branch Watershed (Green Circle, 2009)

Floor Area: 42,000 square feet (comparable to size of superstore)

Benefits:

- 5200 gallons of rainwater held by the vegetated roof.
- Along with a 10,000 gallon cistern buried underground, 70% of domestic water (3.5 million gallons) is saved.

IX. Conclusion

We recommend that a Sell-leaseback scheme for the retrofitting of RTUs for the Everything Store Inc. However, the replacement of RTUs as the only energy efficient strategy for superstores is not sufficient given that cooling and heating energy consumption constitutes 16% of total electric energy consumption. Alternative energy saving strategies were therefore explored (through building energy simulation) to determine their viability in terms of cost effectiveness and net energy saving. Based on simulation results, a recommendation for each climate zone was selected by choosing the strategy that produced the greatest energy saving given the constraint of a five year payback period. These recommendations represent an integrated approach towards energy saving options instead of the usual selection of the low handing fruit. For instance, for climate zone 8, the inclusion of a DOAS has a payback period of 3 years while the use of LED lighting has a payback period of 6 years. By combining these strategies together, a payback period of less than 5 years can be achieved, thus achieving greater energy savings than either alone. More in depth study should also be conducted to quantify the applicability of different daylighting strategies and green roof for different climate zones.

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