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Energy Savings and Economics of Advanced Control Strategies for Packaged Air-Conditioning Units with Gas Heat

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December 2011

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Abstract

Packaged air-conditioners and heat pumps serve over 60% of the commercial building floor space in the U.S., contributing to about 230 trillion Btus of energy consumption annually. Therefore, even a small increase in operational efficiency of these units can lead to significant reductions in energy use and carbon emissions. Pacific Northwest National Laboratory, with funding from the U.S. Department of Energy's (DOE's) Building Technologies Program, evaluated a number of control strategies that can be implemented in a controller, which can be retrofit into an existing unit, to improve the operational efficiency of packaged heating, ventilation and air-conditioning (HVAC) equipment.

The results from detailed simulation analysis show significant energy (24% to 35%) and cost savings (38%) from fan, cooling and heating energy consumption when packaged units are retrofitted with advanced control packages. The major findings include:

- Retrofitting packaged HVAC units with the most energy-efficient package controls option considered (integrated differential enthalpy economizer, multi-speed supply fan, two-stage capacity control and demand-controlled ventilation [DCV]) relative to a base case with no economizer and a constant speed supply fan, results in average HVAC energy savings (electricity for cooling and fan and gas for heating) across 16 locations in 15 climate zones of about 35% for three building types (small office, stand-alone retail, strip mall) and 24% for supermarkets.
- For the most energy efficient controls package considered, average HVAC **cost** savings are 46%, 43%, 35%, and 24%, respectively, for the small office, retail, strip mall and supermarket buildings.
- Retrofitting packaged HVAC units with a modified (less aggressive) energy efficient controls package option (integrated differential dry-bulb economizer, multi-speed supply fan, single-stage capacity control and DCV) relative to *modified* base case with integrated differential dry-bulb economizer, constant speed supply fan and single-stage capacity control , results in average HVAC energy savings of about 28% for the small office building, 32% for the stand-alone retail and strip mall buildings, and 24% for the supermarket.
- For the modified packaged control option, average HVAC energy **cost** savings are 38% for all four building types.
- The maximum controller cost that will provide payback periods of no more than 3 years for all U.S. locations under current utility rates are $2103 per controller for stand-alone retail, strip mall and supermarket buildings and between $540 and $1350 for small office buildings. The precise value depends on the number of square feet of floor space per controller (1100 and 2750 ft^2, respectively, for the small office building costs given).
- Individual control strategies have different degrees of impact on energy and cost savings. The simulation results indicate that multi-speed fan control and DCV are the two control strategies contributing most of the savings. In many cases, multi-speed fan control dominates the impact in hot and mild climates (e.g., Miami and Los Angeles), while DCV dominates the impact in climates with significant heating and cooling loads (e.g., Baltimore) and cold climates (e.g., Seattle, Chicago and Duluth).

Even if one-half of the packaged HVAC units are retrofitted with the modified control package option, it will result in annual savings of approximately 55 trillion Btus (assuming the percent savings are 30%). The energy savings are equivalent to removing over 16 coal-powered (200 MW each) power plants.

Executive Summary

Packaged cooling equipment is used in 46% of all commercial buildings, serving over 60% of the commercial building floor space in the U.S. (EIA 2003). The site cooling energy consumption associated with packaged cooling equipment is about 160 trillion Btus annually (EIA 2003). Packaged heat pumps account for an additional 70 trillion Btus annually (EIA 2003). Therefore, even a small increase in the efficiency of part-load operation of these units can lead to significant reductions in energy use and carbon emissions. Pacific Northwest National Laboratory (PNNL), with funding from the U.S. Department of Energy's (DOE's) Building Technologies Program (BTP), evaluated a number of control strategies that can be implemented in a controller, which can be retrofit into existing units, to improve the operational efficiency of packaged air conditioning units.

The two primary objectives of this research project are to: 1) determine the magnitude of energy and cost savings achievable by retrofitting existing packaged air-conditioning units with advanced control strategies not ordinarily used for packaged units and 2) estimate the maximum installed cost of a replacement controller with the desired features in various regions of the U.S. to provide acceptable payback periods to owners.

Many local building codes require that the supply fan on packaged units operates continuously while a building is occupied to meet the ventilation needs, irrespective of whether the unit is providing cooling or heating. A significant portion of the packaged units in the field (over 90%) have constant speed supply fans. Because the fan is on continuously (and the compressor only intermittently under most conditions), in many locations in the U.S., the fan energy consumption can be greater than the compressor energy consumption). It is not uncommon to see packaged units in ventilation mode for 40% to 60% of the time in any climate.

Packaged equipment with a constant speed supply fan is designed to provide ventilation at the design ventilation rate at all times when the fan is operating. Although there are a number of hours during the day when a building may not be fully occupied or the need for ventilation is lower than designed, the ventilation rate cannot be adjusted easily with a constant speed fan. Studies have shown that demand-based ventilation control can save significant energy in climates that are not favorable for economizing. Traditional demand controlled ventilation (DCV) strategies modulate the outdoor-air damper to reduce the rate at which outdoor air enters the unit and the associated energy needed to condition that air (Brandemuel and Braun 1999; Roth et. al. 2003; Stanke 2006). This strategy reduces cooling or heating energy use, but the supply fan still runs at full speed even in the ventilation mode.

When the unit is in ventilation mode, the role of the supply fan is to provide fresh air to maintain proper indoor-air quality in the spaces that it serves. Therefore, modulating the supply-fan speed in conjunction with DCV not only reduces the cooling and heating energy requirements but also reduces the fan energy use.

Analytic Approach

As noted earlier, the two main objectives for this study are to estimate energy and cost savings from use of advanced controls on packaged units and to estimate the maximum installed cost of the controller that will yield generally acceptable payback periods based on the energy savings and prices of electricity and gas. Only packaged rooftop air conditioners with direct expansion cooling and gas furnace heating are considered in this study. The analysis approach used is as follows: specify advanced control options, create packages of advanced control options, select representative buildings that predominately use packaged units, simulate the energy performance of the selected buildings in U.S. climate zones, determine energy savings associated with changing from initial control packages to more advanced controls, and conduct the economic analysis. Although the control options selected apply equally to both air conditioners and heat pumps, the results presented in this report are limited to packaged air conditioners with gas heating.

The energy savings are estimated based on detailed EnergyPlus (DOE 2010) simulations. Twenty-two combinations of advanced control strategies are simulated in each of 4 building types in 16 climate zones.

Control Sequence of Operation for Packaged Air Conditioners with Gas Heating

There are a number of control options that can be added to packaged units including: air-side economizer, supply-fan speed control, cooling-capacity control, and demand-controlled ventilation. For this study, all four control options are evaluated in terms of their impact on energy and cost savings for packaged single-zone air-conditioning systems with gas heating as compared to a base case. These base case the control options are analyzed individually as well as in combinations of one or more options.

Building Prototypes

For this study, four prototype buildings that predominately use packaged heating and cooling units are chosen from the DOE's post-1980 commercial reference building models (Deru et al. 2011): small office, stand-alone retail, strip mall, and supermarket. The post-1980 reference building models are developed to represent existing buildings constructed in or after 1980. They are widely used for DOE commercial building research to assess new technologies. Significant changes were made to the reference models to simulate the various control strategies that were evaluated using the EnergyPlus energy management controls module.

Methodology

To estimate the energy consumption of a prototype building with the baseline rooftop control option and a modified prototype with advanced packaged unit control options, a detailed simulation model is needed. An EnergyPlus model with energy management feature was used to simulate the buildings and the various control options for the package units in four different prototype buildings resulting in 1,408 simulation runs.

For each simulation, EnergyPlus provides estimates of fan electricity energy consumption, cooling electricity energy consumption, heating gas energy consumption and total energy consumption. The total energy consumption is the sum of all three end-uses in consistent units. Energy cost is simply calculated as a product of the utility rates and the annual energy consumption. The total energy cost is the sum of the both gas and electricity costs.

Energy Savings Results for Various Control Combinations

Only heating, ventilation and air-conditioning (HVAC) energy uses are considered in estimating the energy and cost savings, because the investigated control strategies do not affect the energy use for lighting, plug loads and service hot water. The total annual HVAC energy consumption, which is simply the sum of the gas energy use for heating and the electrical energy use for cooling and fan operation, lies between 90 and 420 million Btus/y per building for the small office building, 640 and 5,610 million Btus/y for the stand-alone retail building, 700 and 5,590 million Btus/y for the strip mall, and 1,310 and 13,920 million Btus/y for the supermarket building. After normalization with the building area, the HVAC energy use intensity for the four building types is in the following ranges: 17 through 82 kBtu/ft^2/yr for the small office building, 26 through 227 kBtu/ft^2/yr for the stand-alone retail building, 31 through 248 kBtu/ft^2/yr for the strip mall, and 29 through 287 kBtu/ft^2/yr for the supermarket.

For the baseline case (no economizer, constant speed supply fan and single-stage compressor), when the air conditioning unit with gas furnace is on, it operates in one of the three operating modes: ventilation mode, cooling mode or heating mode. The simulation results indicate that packaged single-zone rooftop units operate in the ventilation mode for more than 50% of their run time. The units in the hot climates have the lowest percentage of time in the ventilation mode, while the mild climates such as Los Angeles and San Francisco have the highest percentage of time in the ventilation mode. The percentage of time the unit is in the cooling mode ranges between 4% and 40%. The percentage of time the unit is in the heating mode lies in the range from less than 1% to about 12% for the small office building. For other building types it is about 20%.

The most energy efficient combination of control strategies investigated includes a multi-speed supply fan control, demand-controlled ventilation, two-stage compressor control and integrated differential enthalpy economizer control. Figure ES 1 depicts the percentage reductions of HVAC energy use (gas for heating and electricity for cooling and fan) for the most energy efficient control option considered by climate zone and location, while Table ES 1 summarizes the energy savings including maximum, minimum and average savings. The key findings include:

1. The range of energy savings, by building type, is between 22% and 56% for the small office building, 25% and 47% for the stand-alone retail building, 24% and 46% for the strip mall, and 16% and 47% for the supermarket.
2. The average of the HVAC energy savings across the 16 locations is about 35% for the small office building, the stand-alone retail building, and the strip mall, and 24% for the supermarket.
3. The maximum HVAC energy savings as a percentage of the pre-retrofit HVAC energy use occurs in Los Angeles for the small office, retail and strip mall building types, while it occurs in Miami for the supermarket.
4. The minimum percentage savings occurs in Fairbanks for all four building types.

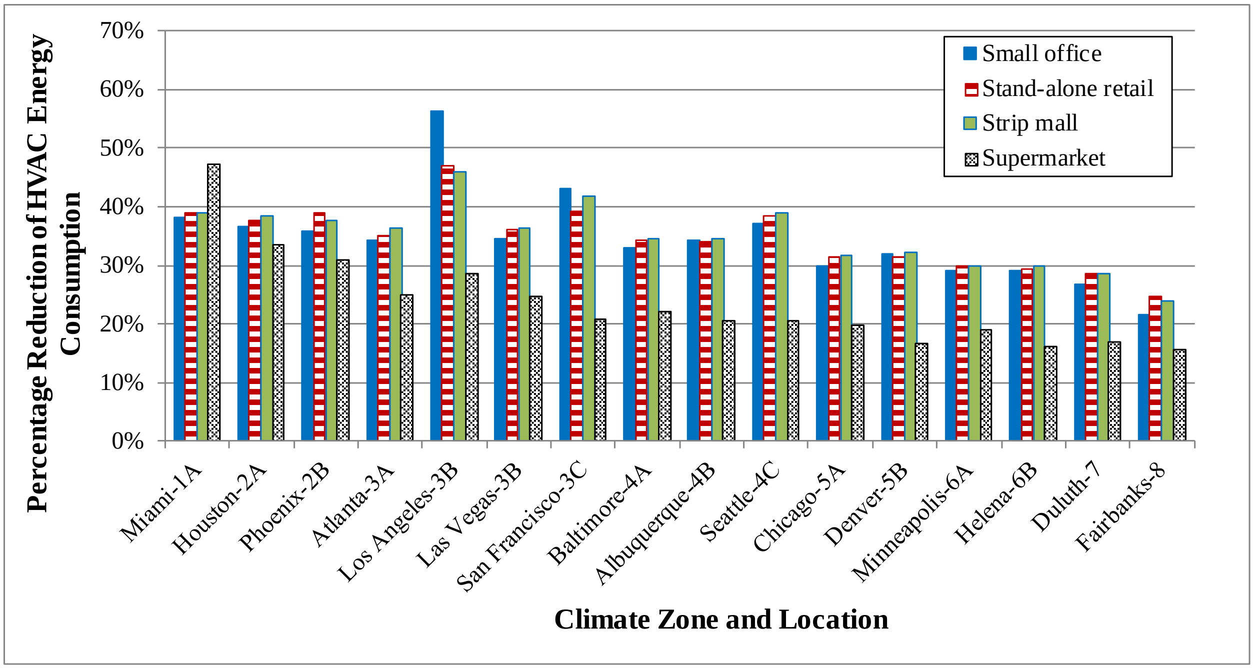

Figure ES 1: HVAC Energy Savings from Retrofit Installation of the Most Energy Efficient Control Package Considered (integrated differential enthalpy economizer, multi-speed supply fan, two-stage capacity control, and DCV) relative to and as a percentage of the HVAC Energy Use of the Base Case (no economizer and constant speed supply fan) for Four Building Types at all Locations Examined

Table ES 1: Summary of HVAC Energy Savings for from Replacing Controllers with No Economizers or Other Advanced Controls with the Most Energy Efficient Control Package Considered Having Integrated Dry-bulb Economizers, Multi-speed Supply-Fan Controls, Two-stage Capacity Controls and DCV

	Building Type			
	Small office	**Stand-alone retail**	**Strip mall**	**Supermarket**
Construction area (ft^2)	5500	25000	22500	45000
Maximum percentage savings	56%	47%	46%	47%
Location for maximum percentage savings	Los Angeles	Los Angeles	Los Angeles	Miami
Minimum percentage savings	22%	25%	24%	16%
Location for minimum percentage savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Average percentage savings	35%	35%	35%	24%
Maximum absolute savings (MMBtu/yr)	97	1388	1333	2029
Location for maximum absolute savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Minimum absolute savings (MMBtu/yr)	40	300	324	582
Location for minimum absolute savings	San Francisco	Los Angeles	Los Angeles	Los Angeles
Average absolute savings (MMBtu/yr)	59	609	608	1010

Another possible controls combination is use of a multi-speed supply fan, demand-controlled ventilation, single-stage compressor control and integrated differential dry-bulb economizer control. It is less expensive to convert a supply fan to multi-speed or variable-speed than to convert the compressor to a multi-speed or variable-speed compression. Because many of the existing units may have economizer controls, a more common advanced controls retrofit would likely be conversion of a unit with constant-speed supply fan, single-stage compressor and an integrated dry-bulb economizer to multi-speed supply-fan control and demand control ventilation, keeping single-stage compressor and integrated dry-bulb economizer controls.

Figure ES 2 depicts the percentage reductions of HVAC energy use (gas for heating and electricity for cooling and fan) for the modified control package option by climate zone and location, while Table ES 2 summarizes the energy savings including maximum, minimum and average savings.

1. The range of HVAC energy savings, by building type, is between 20% and 42% for the small office building, 23% and 40% for the stand-alone retail building, 21% and 40% for the strip mall, and 14% and 41% for the supermarket.
2. The average HVAC energy savings across 16 locations is about 28% for the small office building, 32% for the stand-alone retail and strip mall buildings, and 24% for the supermarket.
3. The maximum HVAC energy saving as a percentage of the pre-retrofit energy consumption occurs in Los Angeles for the small office building and the retail building, in San Francisco for the strip mall, and in Miami for the supermarket.
4. The minimum percentage savings occur in Fairbanks for all four building types.

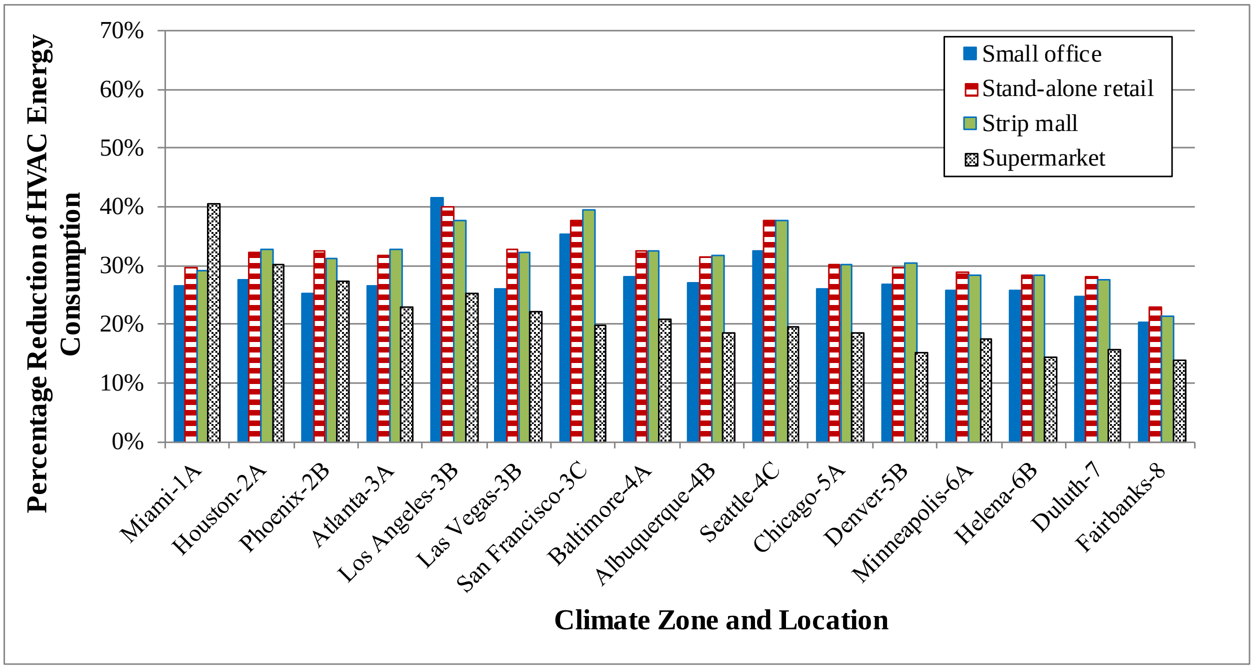

Figure ES 2: HVAC Energy Savings from Retrofit Installation of the Control Package using an Integrated Dry-bulb Economizer, Multi-Speed Supply Fan, Single-stage Capacity Control, and DCV relative to and as a percentage of the HVAC Energy Use of the Modified Base Case, which has an Integrated Dry-bulb Economizer, Constant-speed Supply Fan and Single-stage Capacity Control for Four Building Types at all Locations Examined

Table ES 2: Summary of HVAC Energy Savings from Replacing Modified Base Case Control Packages Having Integrated Dry-bulb Economizers, Constant-speed Supply-Fan Controls and Single-stage Capacity Controls with Controllers Having Integrated Dry-bulb Economizers, Multi-speed Supply-Fan Controls, Single-stage Capacity Controls and DCV

	Building Type			
	Small office	**Stand-alone retail**	**Strip mall**	**Supermarket**
Construction area (ft^2)	5500	25000	22500	45000
Maximum percentage savings	42%	40%	40%	41%
Location for maximum percentage savings	Los Angeles	Los Angeles	San Francisco	Miami
Minimum percentage savings	20%	23%	21%	14%
Location for minimum percentage savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Average percentage savings	28%	32%	32%	22%
Maximum absolute savings (MMBtu/yr)	91	1268	1165	1770
Location for maximum absolute savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Minimum absolute savings (MMBtu/yr)	29	232	237	500
Location for minimum absolute savings	San Francisco	Los Angeles	Los Angeles	Los Angeles
Average absolute savings (MMBtu/yr)	46	560	547	906

In addition to the most energy efficient control package considered, the impacts of the control strategies individually and in combinations were evaluated. Some of the result highlights include:

- Use of the air-side economizer potentially saves more energy in warm and dry climates than in other climates, and the savings vary with building types, with the small office building having the highest percent savings.
- The percentage HVAC energy savings from the use of an air-side economizer decreases if the fan speed control changes from constant speed to multiple speed.
- Switching from nonintegrated economizer controls to integrated economizer controls provide small incremental energy savings.
- Use of multi-speed fan control leads to about 15% reduction in HVAC energy in Miami and Los Angeles, which are representative of hot-humid and warm-dry climates.

However, the multi-speed fan control usually increases HVAC energy consumption in Chicago and Duluth, which are representative of cold climates. Although there is a reduction in fan energy consumption, which decreases the heat gains from the fan, the heating energy consumption increases in cold climates to compensate for the reduced fan heat gains. Despite this increase in heating energy consumption for cold climates, multi-speed fan control leads to a cost savings even in the cold climates because electricity prices are generally higher than gas prices.

- The impact of multi-speed fan control on energy consumption varies with building type. In Miami, the supermarket has the largest percentage (27%) energy savings while the other three building types show between 15% and 20% HVAC energy savings relative to the base case. In Los Angeles, the percentage HVAC energy savings from multi-speed fan control decreases in the sequence of small office building (35%), stand-alone retail building (17%), strip mall (16%), and supermarket (5%).
- DCV contributes to more than 10% of HVAC energy savings in all cases except for the small office building in Miami and Los Angeles. The largest percentage (35%) energy savings occurs in Seattle for the stand-alone retail building and the strip mall. DCV is more effective in heating-dominated climates.
- Changing the unit from single-stage to two-stage compressor controls can yield about 9% savings in hot climates, primarily from a reduction in cooling energy consumption.
- Multi-speed fan control and DCV are the two control strategies that dominate the impact on HVAC energy savings. Specifically, multi-speed fan control dominates the impact in hot climates (e.g., Miami) while DCV dominates the impact in cold climates (Seattle, Chicago, and Duluth).
- Adding an air-side economizer after adding multi-speed fan control does not have a large impact on HVAC energy savings except for a few cases, such as the small office building in Los Angeles.
- Both multi-speed supply fan control and air-side economizers have noticeable contributions to annual cooling energy savings. In particular, their combinations lead to more than 80% cooling energy savings in Los Angeles, Seattle, and Duluth.

Economic Analysis

In addition to the energy savings, PNNL estimated the energy cost savings from different combinations of control strategies. Furthermore, using the energy cost savings, the maximum installed cost for the add-on controller to achieve specific simple payback periods is determined for selected utility rates.

The energy cost savings for the most energy efficient control package option considered are shown in Figure ES 3 and Table ES 3. The key findings include:

1. The HVAC energy cost savings as a percentage of the base case energy consumption, which corresponds to a unit with no economizer or other advanced control features, from adding the most energy efficient control combination considered (having an integrated differential enthalpy economizer, multi-speed supply fan control, two-speed compressor control, and DCV) lies between 38% and 67% for the small office building, 36% and

60% for the stand-alone retail building, 36% and 59% for the strip mall, and 28% and 55% for the supermarket.

2. The average HVAC energy cost savings are 46%, 43%, 35%, and 24%, respectively, for the small office, retail, strip mall and supermarket buildings.
3. The maximum percentage HVAC energy cost savings occur in San Francisco for the small office building and in Los Angeles for the other three building types.

The minimum percentage of savings occurs in Miami for the small office building, in Fairbanks for the two retail buildings, and in Seattle for the supermarket.

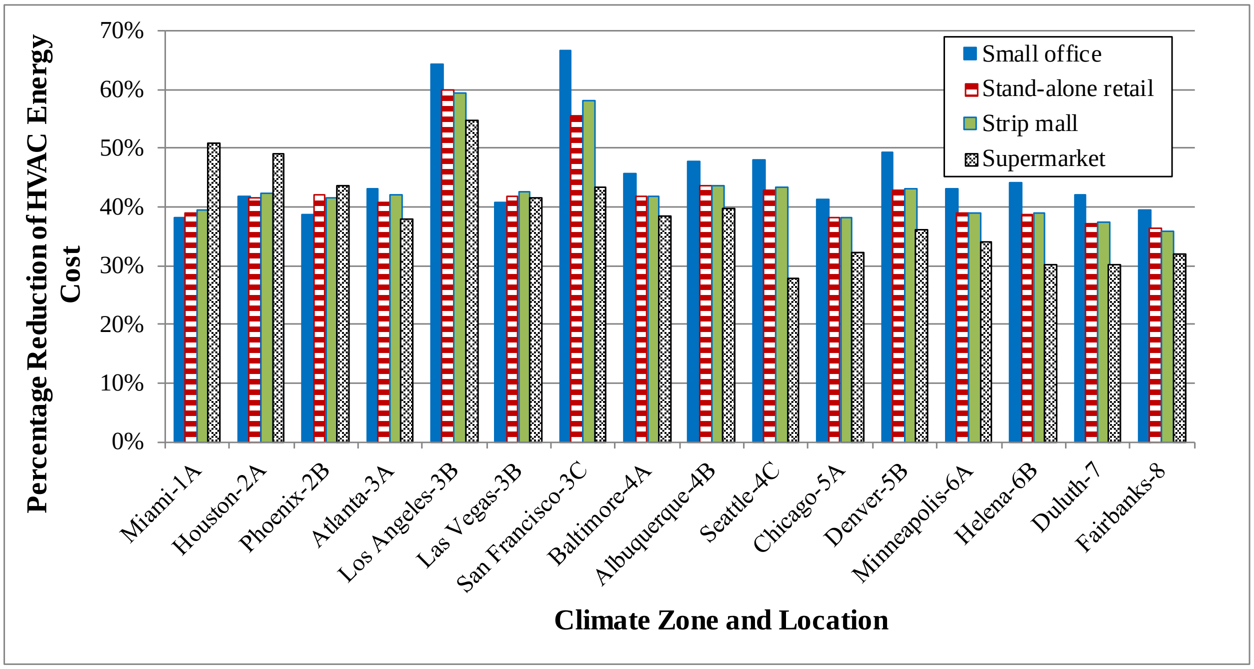

Figure ES 3: HVAC Energy Cost Savings from use of the Most Energy Efficient Control Package Considered (integrated differential enthalpy economizer, multi-speed supply-fan control, two-stage capacity [compressor-motor speed] control and DCV) relative to and as a percentage of the Base Case (no economizer and constant speed supply fan) HVAC energy use for Four Building Types at All Locations Examined

Table ES 3: Summary of Energy Cost Savings from Replacing Controllers with No Economizers or Other Advanced Controls with the Most Energy Efficient Control Package Considered Having Integrated Dry-bulb Economizers, Multi-speed Supply-Fan Controls, Two-stage Capacity Controls and DCV

	Building Type			
	Small Office	**Stand-alone Retail**	**Strip Mall**	**Supermarket**
Construction area (ft^2)	5500	25000	22500	45000
Maximum savings	67%	60%	59%	55%
Location for maximum savings	San Francisco	Los Angeles	Los Angeles	Los Angeles
Minimum savings	38%	36%	36%	28%
Location for minimum savings	Miami	Fairbanks	Fairbanks	Seattle
Average savings	46%	43%	43%	39%
Maximum absolute savings ($/yr)	2393	23779	23414	52217
Location for maximum absolute savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Minimum absolute savings ($/yr)	923	7,864	7,633	16,087
Location for minimum absolute savings	Seattle	Albuquerque	Albuquerque	Seattle
Average absolute savings ($/yr)	1,496	10,820	11,000	24,200

The energy cost savings for the modified base case control package option, which has an integrated dry-bulb economizer, constant-speed supply fan and single-stage capacity control (i.e., a constant single-speed compressor motor), with an advanced controller having an integrated dry-bulb economizer, multi-speed supply-fan control, single-stage capacity control, and DCV are shown in Figure ES 4 and Table ES 4. The key findings include:

1. The HVAC energy cost savings as a percentage of the modified base case energy cost lies between 27% and 59% for the small office building, 30% and 53% for the stand-alone retail building, 29% and 54% for the strip mall, and 27% and 50% for the supermarket.
2. The average HVAC energy cost savings across all 16 locations is about 38% for all four building types.
3. The maximum HVAC energy cost savings as a percentage of the modified base case energy cost occurs in Los Angeles for the supermarket building and in San Francisco for the other three building types.

The minimum percentage savings occurs in Seattle for the supermarket building and in Miami for the other three building types.

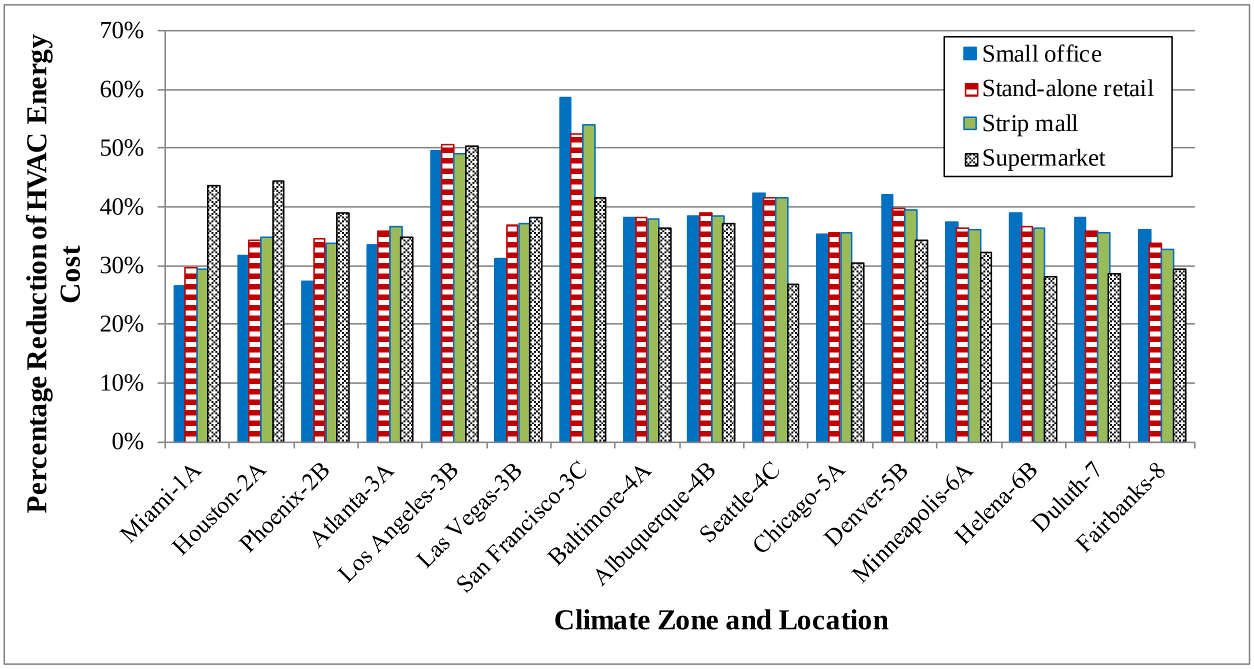

Figure ES 4: HVAC Energy Cost Savings from use of a Control Option with an integrated dry-bulb economizer, multi-speed supply fan control, single-stage capacity control and DCV) relative to and as a percentage of the Modified Base Case (with an integrated dry-bulb economizer, constant speed supply-fan control and single-stage capacity control) HVAC energy use for Four Building Types at all Locations Examined

The advanced control features affect electricity and gas cost savings differently. The percentage of the total cost savings attributable to electricity is usually more than 50% in the warmer climates (1A through 4B), while the gas cost savings dominate in the other climates (4C through 8). Both most energy efficient control package and modified control package have smaller percentages of the total energy cost associated with electricity than base case and a modified base case. This is primarily because the DCV and multi-speed fan controls, which are added in both the most energy efficient control package and modified control package, decrease electricity use considerably, and the price of electricity is greater than the price of natural gas, thus decreasing the fraction of the total cost attributable to electricity use.

Other highlights of the economic analysis results include:

- The percentage cost savings relative to the baseline are largest for Los Angeles. Using advanced controls in packaged roof top units can reduce HVAC energy consumption cost by more than 60% in Los Angeles.
- Relative to the baseline, energy cost savings are positive for all cases except for one (no economizer, constant speed supply fan, single-stage cooling and DCV) in Los Angeles for the small office building.

- Just like for the energy savings, multi-speed fan control and DCV are the two control strategies that dominate the impact on energy cost savings. Multi-speed fan control dominates the impact in hot and mild climates (Miami and Seattle), while DCV dominates the impact in mixed and cold climates (Seattle, Chicago, and Duluth).

Table ES 4: Summary of Energy Cost Savings from Replacing Modified Base Case Control Packages Having Integrated Dry-bulb Economizers, Constant-speed Supply-Fan Controls and Single-stage Capacity Controls with Controllers Having Integrated Dry-bulb Economizers, Multi-speed Supply-Fan Controls, Single-stage Capacity Controls and DCV

	Building Type			
	Small Office	**Stand-alone Retail**	**Strip Mall**	**Supermarket**
Construction area (ft^2)	5500	25000	22500	45000
Maximum savings	59%	53%	54%	50%
Location for maximum savings	San Francisco	San Francisco	San Francisco	Los Angeles
Minimum savings	27%	30%	29%	27%
Location for minimum savings	Miami	Miami	Miami	Seattle
Average savings	38%	38%	38%	36%
Maximum absolute savings ($/yr)	2,108	21,383	20,370	46,605
Location for maximum absolute savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Minimum absolute savings ($/yr)	752	6,868	6,556	15,046
Location for minimum absolute savings	Seattle	Albuquerque	Albuquerque	Miami
Average absolute savings ($/yr)	1,134	9,481	9,390	21,960

In contrast with the incremental impact on energy savings, cost savings are affected more by multi-speed fan control. This is because the price of electricity per unit of energy is greater than the price of natural gas, and the use of multi-speed fan control significantly reduces electricity consumption for all locations.

Controller Cost

The maximum installed cost of advanced controllers that will yield a specific simple payback period is important for potential users to evaluate the financial merits of installing advanced controllers but also for vendors and developers in pricing their advanced control products.

Because an add-on controller is usually associated with each rooftop unit, the total energy cost savings for a whole building needs to be normalized before calculating the maximum acceptable controller installed cost.

Controllers with different combinations of advanced control capabilities are likely to have different manufacturing and installation costs. Controllers with greater functionality will likely cost more. On the other hand, the examined control strategies have different degrees of impact on energy cost savings. Controllers with greater functionality (actually, the best combination of functionality) provide greater energy and cost savings. Therefore, analysis of the savings provided by a controller relative to its cost is important. We examine this by determining the maximum total installed cost per controller that yields a **3-year** simple payback for controllers with different combinations of control functionality. A total of four scenarios are considered:

- **Scenario 1**: the advanced controller with only multi-speed supply-fan control is retrofit to an existing packaged unit having a base case controller with no advanced control capabilities (including no economizer).
- **Scenario 2**: the advanced controller with only DCV is retrofit to an existing packaged unit having a base case controller with no advanced control capabilities (including no economizer)
- **Scenario 3**: the advanced controller with integrated differential dry-bulb economizer, multi-speed fan control and DCV is retrofit to an existing packaged unit with a controller having an integrated differential dry-bulb economizer, single-speed fan control, one-stage cooling, and no DCV.
- **Scenario 4**: the advanced controller with an integrated dry-blub differential economizer control, multi-speed supply fan control, two-stage compressor control and DCV is retrofit to existing packaged units having a base case controller with no advanced control capabilities (including no economizer).

The results show that the maximum total installed controller cost per packaged unit providing a 3-year payback period varies with the four scenarios. For all four building types, controllers discussed in Scenarios 3 and 4 can bear the largest maximum cost per controller for all 16 locations because the control options in those two scenarios produce the maximum cost savings. Also, because the initial packaged unit controllers before retrofit in Scenarios 3 and 4 differ only in that the one in Scenario 3 has an air-side dry-bulb temperature based economizer control, the differences between their maximum controller costs largely depends on the impacts of the air-side economizer control and the electricity prices.

The maximum acceptable total installed controller cost is larger in locations where the air-side economizer control contributes significant cooling energy savings and the electricity price is high (such as Los Angeles, San Francisco, and Fairbanks). The relationship between the maximum controller costs for Scenarios 1 and 2 depends on both location and building type. For the small office building, Scenario 1 with multi-speed fan control achieves a higher maximum controller cost than Scenario 2 with DCV for all 16 locations. For the two retail buildings, Scenario 1 usually has a higher maximum controller cost than Scenario 2 in hot (e.g., Miami, Houston, Phoenix) and warm climates (e.g., Los Angeles, Las Vegas, and San Francisco), while the reverse is true in cold climates (e.g., Chicago, Helena, and Duluth). For the supermarket building, Scenario 2 has a higher maximum controller cost than Scenario 1 only in four locations, Seattle, Chicago, Helena, and Duluth.

For a specific scenario and location, the maximum acceptable installed cost is highest for the supermarket, then progressively lower for stand-alone retail building, strip mall, and small office building. For example, for Scenario 4, the calculated maximum acceptable controller cost lies in the approximate range between:

1. $8,000 and $26,000 for the supermarket building,
2. $5,900 and $17,800 for the stand-alone retail building,
3. $2,300 and $7,000 for the strip mall building, and
4. $550 and $1,400 for the small office building.

The reasons for the differences are explained in more detailed in the main body of the report.

For purposes of vendors setting prices for advanced controllers the smallest value of the maximum total installed cost that provides sufficient return to building owners in the geographic regions targeted for sales is an important input. This cost is determined for two scenarios considered common opportunities for packaged unit controller retrofits in the commercial sector: 1) retrofit of a unit having differential dry-bulb temperature-based integrated economizer, single-speed fan, and single-stage compressor control (and no DCV) with an advanced controller that adds multi-speed fan and DCV control (Scenario A) and 2) retrofit of a unit having no advanced controls with an advanced controller having integrated enthalpy-based economizer, multi-speed fan, two-stage (speed) compressor control, and DCV (Scenario B). When the entire U.S. represents the targeted market, the minimum of the maximum total installed cost for stand-alone retail, strip mall and supermarket buildings is $2,103 per controller, which is found for Albuquerque to achieve a 3-year payback period and $3,505 for a 5-year payback period (see Table ES 5). For small office buildings, the maximum cost is smaller at $451 per controller for a building with 1 packaged unit per 1,100 sf of conditioned floor space and $1,128 per controller for 1 packaged unit per 2,750 sf of floor space.

Vendors may choose to target selected building types or geographic regions for sales of advanced controllers. In this case, the minimum value of maximum total installed cost for the selected building types and geographic regions is used. For example, the most favorable building-type market for advanced controller sales across the U.S. is supermarkets for which the maximum total cost per advanced controller is $7,523 for a 3-year payback period and $12,539 for a 5-year payback period. The report provides data that enables determination of the appropriate maximum cost per controller for many different selections of target building types and geographic region.

Table ES 5: Maximum values of the installed cost for advanced controllers that provide simple payback periods of 3 and 5 years across the U.S. and the specific locations and climate zones to which these values correspond

	Scenario*	Small Office	Standalone Retail	Strip mall	Supermarket
3-year payback	*Scenario A*	451 [Seattle-4C]	5,151 [Albuquerque-4B]	1,967 [Albuquerque-4B]	7,523 [Miami-1A]
	Scenario B	554 [Seattle-4C]	5,898 [Albuquerque-4B]	2,290 [Albuquerque-4B]	8044 [Seattle-4C]
5-year payback	*Scenario A*	752 [Seattle-4C]	8,585 [Albuquerque-4B]	3,278 [Albuquerque-4B]	12,539 [Miami-1A]
	Scenario B	923 [Seattle-4C]	9,830 [Albuquerque-4B]	3,817 [Albuquerque-4B]	13,406 [Seattle-4C]

* Scenario A: retrofit of a unit having differential dry-bulb temperature-based integrated economizer, single-speed fan, and single-stage compressor control (and no DCV) with an advanced controller that adds multi-speed fan and DCV control; Scenario B: retrofit of a unit having no advanced controls with an advanced controller having integrated enthalpy-based economizer, multi-speed fan, two-stage (speed) compressor control, and DCV

Conclusion

Individual control strategies have different degrees of impact on energy and cost savings. The simulation results indicate that multi-speed fan control and DCV are the two control strategies contributing the most to energy and cost savings for packaged units. In many cases, multi-speed fan control dominates the impact in hot and mild climates (e.g., Miami and Los Angeles), while DCV dominates the impact in climate that have significant cooling and heating load and cold climates (e.g., Seattle, Chicago and Duluth). Applying multi-speed fan control only may lead to increased overall HVAC energy consumption in cold climates but still show energy cost reductions. The air-side economizing is a powerful strategy to reduce cooling, but it usually has a very small contribution to the overall HVAC energy and energy cost savings, except for locations with mild climates, such as Los Angeles.

With the fullest set of advanced control strategies (most energy efficient package considered), the annual absolute energy cost savings relative to the base case lies the approximate ranges between:

1. $900 and $2,400 for the small office building,
2. $8,000 and $24,000 for the stand-alone retail building,
3. $7,600 and $23,000 for the strip mall, and
4. $16,000 and $52,000 for the supermarket.

The maximum absolute cost savings relative to the base case all occur for Fairbanks. The average absolute cost savings (not normalized for differences in building floor area) across the 16 locations are about $1,500 for the small office building, $11,000 for the two retail buildings, and $24,200 for the supermarket building.

Future Work

Bringing retrofitable advanced control packages rapidly to the mass market to realize the large energy and cost savings potential found in this study will likely require additional information and further development of the technology. Some key needs identified by the project team include the following.

- The energy savings estimated with simulations in this study should be validated with field tests of retrofitable controllers for packaged units that are beginning to enter the marketplace. Testing can be used to validate overall energy savings as well as savings from individual control strategies and specific combinations of control strategies.
- As this study considered packaged rooftop air conditioners with direct expansion cooling and gas furnace heating, similar analyses of packaged air source heat pumps and air conditioners with electric resistive heating would prove valuable.
- The small office building model is a single-story building with just less than 5000 ft^2 floor area. The small size, together with its somewhat atypical attic roof construction, makes it not representative of most office buildings served by packaged rooftop units. Therefore, results may be improved by using an office building model that corresponds closer to the size and construction of the median office building that uses packaged rooftop units, such as the DOE reference building model for a medium office building, which has a conditioned floor area of about 50,000 ft^2.
- If the cost of advanced controllers on the market exceeds the maximum cost for a payback period commonly found acceptable by building owners, additional technological innovation may be required to lower the cost of advanced controllers to acceptable levels. This technology development may be best performed in government-industry collaborations (e.g., national laboratories with building controller manufacturers).
- Development of a guide or software tool for building owners and managers to assist them in making decisions to install advanced controllers may be important to accelerate the market penetration of advanced controllers, which based on this study can save considerable energy (approximately 25% to 60% of the energy consumption of rooftop units over a broad range of U.S. climates).
- In addition to the measures considered (air-side economizer, multiple supply-fan speed control, DCV and staged direct expansion cooling using multi-speed control of compressor motors), other advanced control technologies applicable to packaged rooftop units should be evaluated. Such technologies include optimal start times, closing outdoor-air dampers during morning warm up or cool down periods, and fully variable-speed control of the supply fan, condenser fan and compressor.
- The analysis in this report assumes that all sensors are accurate. However, sensors are rarely perfectly accurate and control precise in practice. For this reason, it is important to consider the uncertainty of sensor measurements. The impacts of uncertainty on energy savings, cost savings, and the maximum economical total cost of the control retrofits should be investigated.
- The impact assessment was made for a single set of predefined values for the key control parameters. Because these values are likely to vary in field applications, it is worthwhile

to investigate the impact on energy and cost savings of using different parameter values. The control parameters could even be optimized.

- The EnergyPlus program and DOE reference building models were used in the current work to evaluate the energy saving potential of advanced rooftop unit control strategies. The impact of compressor cycling on cooling efficiency was not considered in this analysis. Because ignoring cycling losses underestimates the savings potential from staged cooling, the simulation of control needs to be improved to incorporate compressor cycling.

Acknowledgement

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1. Introduction

Efforts to increase the energy efficiency in commercial buildings have focused mainly on improving the efficiency of heating, ventilation and air conditioning (HVAC) equipment along with improvements to lighting, windows and other envelope measures. Because the efforts directed at improving the efficiency of HVAC equipment primarily focus on the rated (or design) efficiency, they are usually not applicable to building retrofits without equipment replacement. In addition, focusing on improving the rated efficiency may not yield significant energy savings because systems tend to operate at off-design or part-load conditions for most of their lives. In contrast, approaches that address the improvement in the part-load performance can lead to significant increases in the operating efficiency of equipment and buildings. More importantly, measures that address the operational efficiency apply to both existing and new buildings.

The objective of this research and development project is to determine the magnitude of energy savings achievable by retrofitting existing packaged rooftop air conditioners with advanced control strategies not ordinarily used for packaged units.

Packaged cooling equipment is used in 46% (2.1 million) of all commercial buildings, serving over 60% (39 billion square feet) of the commercial building floor space in the U.S. (EIA 2003). The site cooling energy consumption associated with packaged cooling equipment is about 160 trillion Btus annually. Packaged heat pumps account for an additional 70 trillion Btus annually. Therefore, even a small improvement in part-load operation of these units can lead to significant reductions of energy use and carbon emissions.

Building codes require that when a building is occupied, the supply fan on packaged units operates continuously to meet the ventilation needs, irrespective of whether the unit is providing cooling or heating. A significant portion of the packaged units in the field (over 90%) have constant speed supply fans. Because the fan is on continuously, the fan energy consumption can be greater than the compressor energy consumption in many locations in the U.S. This implies that there exists a big potential to achieve energy savings from fan speed control.

Packaged equipment with constant speed supply fans is designed to provide ventilation at the design rate at all times when the fan is operating. Although there are a number of hours during the day when a building may not be fully occupied or the need for ventilation is lower than designed, the ventilation rate cannot be adjusted easily with a constant speed fan. Studies have shown that demand-based ventilation control can save significant energy in climates that are not favorable for economizing (Brandemuehl and Braun 1999; Roth et al. 2003). Traditional demand controlled ventilation (DCV) strategies modulate the outdoor-air damper to reduce the rate at which outdoor air enters and the associated energy needed to condition that air. This strategy reduces cooling energy, but the supply fan still runs at full speed.

Supply-fan energy savings can be achieved by modulating the supply-fan speed during the ventilation mode. When the unit is in ventilation mode, the role of the supply fan is to provide fresh air to maintain proper indoor air quality in the spaces that it is serving. Therefore, modulating the supply fan in conjunction with DCV will not only reduce the coil energy but also reduce the fan energy. The total savings (fan and coil) will depend on a number of factors including control strategy, thermostat set point and characteristics (throttling range and deadband), oversizing of the packaged unit, the efficiency of the packaged unit, and the thermal load profiles.

To estimate the potential energy and the associated cost savings from widespread use of advanced control strategies with packaged rooftop units, the U.S. Department of Energy's (US DOE's) Building Technologies Program (BTP) has sponsored this study. In this study, the savings are estimated based on detailed EnergyPlus (DOE 2010) simulation. Although it is possible to simulate buildings with various combinations of the influencing parameters, the size of simulation runs will become large and unmanageable. Therefore, for this study, only a selected combination of influencing parameters is used to estimate the savings from use of advanced control strategies. The parameters that will be varied include building type (4), building location (16), and various control strategies (22).

The various control strategies and how they differ from conventional controls is summarized in Section 2. Four buildings types that predominantly use packaged units are considered: small office, stand-alone retail, strip mall, and supermarket. Detailed descriptions of the building types, the climate zones and representative locations used for the analysis are described in Section 3. The methodologies used in estimating the energy consumption, energy cost and maximum total cost of the control technology are described in Section 4. Sections 5 and 6 provide results for the energy and cost savings for the various combinations of control strategies by building type and location. Conclusions and discussion of potential future work are provided in Section 7.

2. Control Sequence of Operation for Packaged Rooftop Units with Gas Heating

Packaged rooftop air conditioners are factory-made, self-contained units comprising a number of off-the-shelf components available in standard design and cooling capacities. Typically, a packaged rooftop unit consists of a fan and filter section, a mechanical cooling section, and a heating section. In the fan and filter section, outdoor air enters the rooftop unit through a damper and is mixed with the air returned from the space. The mixed air then passes through filters to protect downstream components from dirt accumulation. A relief fan may also be used to exhaust some return air to the outdoors through a damper. The mechanical cooling section provides cooling through a vapor compression cycle, which usually consists of a reciprocating or scroll compressor, an air-cooled condenser, a direct expansion (DX) evaporator and a thermal expansion valve. The supply air is cooled by heat exchange with the cooler refrigerant passing through the evaporator coil, and an air condenser fan passes air through the condenser coil to dissipate refrigerant heat to the outdoors. The heating section provides heating to the supply air stream by a gas furnace, electrical resistance heating element, or a reverse vapor compression cycle (in heat pumps).

According to its cooling capacity, packaged equipment is divided into three categories: residential with cooling capacities less than 65,000 Btu/h, light commercial with capacities up to 135,000 Btu/h, and commercial with capacities of 135,000 Btu/h or greater (ASHRAE 2008). The cooling efficiency is normally measured in terms of energy efficiency ratio (EER) and integrated energy efficiency ratio (IEER) at standard rated conditions for commercial units. Although high efficiency equipment contributes to saving energy, it is not always possible to improve the efficiency of packaged rooftop units because of technical and economic constraints. This is especially true for existing building retrofits when the replacement of rooftop units is not a viable consideration. On the other hand, a number of technologies are commercially available to improve the operational efficiency of packaged rooftop units. Representative technologies include economizer controls, supply-fan speed controls, optimal start and stop controls, and demand-controlled ventilation. Many of these advanced control options could be added if they are not used in existing rooftop units. This study investigates the energy and cost savings associated with some of these advanced control options for packaged rooftop units individually and in various combinations. The savings are estimated by comparing annual estimated energy consumption of the unit when using an advanced control option with the energy use for the base case controls. The base case control options and the advanced control options are discussed in this section, together with the sequences of operations considered for this work.

2.1 Conventional Control Options for Packaged Rooftop Units

In most packaged units, a thermostat controls the operation of the compressor or the gas furnace, depending on whether the zone is calling for cooling or heating. In conventional control (base case), the compressor or the furnace is turned on or off to maintain the required zone set point. Although the compressor and furnace are cycled, the supply fan runs continuously when the building is occupied. Even though some packaged units might have air-side economizer controls and staged cooling and heating, the base case scenario used for this study assumes that the package unit has single-stage cooling and heating with no economizer controls. Therefore, the base case controls use the zone thermostat to cycle the compressor and the furnace, with the supply fan operating continuously when the building is occupied to provide ventilation.

2.2 Advanced Control Options for Packaged Rooftop Units

There are a number of additional control options that can be added to rooftop units including: air-side economizers, supply-fan speed controls, cooling capacity controls, and demand-controlled ventilation. For this study, the energy savings impacts of all four control options were evaluated for packaged single-zone systems compared to the base case.[1] The control options were analyzed individually as well as in combinations of multiple control options. These four control options are discussed next.

<u>Air-side economizer controls</u>

Air-side economizers use cool outdoor air (OA) to reduce energy use for mechanical cooling. When the space served requires cooling and the outdoor conditions are favorable for economizing (as determined by the economizer controls), an air-side economizer brings in outdoor air at a rate greater than the minimum required for ventilation through damper modulation. This displaces the need for some or all mechanical cooling and reduces energy consumption of the unit. Several commonly used economizer control strategies include fixed (high-limit) dry-bulb temperature, fixed (high-limit) enthalpy, differential dry-bulb temperature, and differential enthalpy.

With a fixed dry-bulb or enthalpy high limit controller, the outdoor air property used for control (i.e., dry-bulb temperature or enthalpy) is measured and compared to a fixed set point. If the value of the outdoor air property is less than the set point, outdoor air is used to meet all or part of the cooling demand; otherwise, the air-side economizer is not used (outdoor air dampers are positioned at the minimum position to meet ventilation needs). Depending on the climate and whether the economizer is integrated with mechanical cooling, the fixed dry-bulb set point is usually set between 55^{o}F and 75^{o}F, whereas the fixed enthalpy set point is set around 28 Btu/lb (Brandemuel and Braun 1999; Taylor and Cheng 2010).

With a differential dry-bulb temperature or differential enthalpy economizer control, the outdoor-air condition is measured and compared with the return-air condition. If the value of the outdoor-air condition (dry-bulb temperature or enthalpy) is less than the condition for the return air, outdoor air is used to meet all or part of the cooling demand; otherwise, the air-side economizer is not used.

In addition to these strategies, air-side economizers can either work in concert with the mechanical cooling or not. These modes of economizer operation are respectively referred to as integrated and nonintegrated. An integrated economizer, as its name implies, is fully integrated with the mechanical cooling system such that it can use 100% outdoor air to provide as much cooling as possible and mechanical cooling is engaged to make up the cooling load not met by use of outdoor air alone. On the other hand, a nonintegrated economizer does not operate simultaneously with the mechanical cooling system. When the outdoor-air condition is favorable, the economizer provides all necessary cooling. However, when the outdoor-air conditions are not sufficiently favorable to meet all the cooling demand, the outdoor-air damper returns to its

[1] Savings achieved by changing between any two control options can be determined by taking the difference between the tabulated energy savings relative to the base case for the two operations considered.

minimum position without the use of economizing, and the mechanical system provides all necessary cooling.

Fan-Speed Control

Generally, a packaged rooftop unit serving a single zone has three fan control options: constant- speed control, multi-speed control, and variable -speed control.

- With a constant fan -speed control, the supply fan runs at its design speed as long as the packaged rooftop unit is on or as long as the building is occupied. This is the base case option.
- With a multi-speed fan control, the supply fan runs at different speeds depending on the space load and the rooftop unit operation mode. For example, the fan may run at a reduced speed when neither cooling nor heating is requested (ventilation mode), or with a multi -stage unit, the fan speed can also be discretely changed at different stages of cooling or heating. Modulating the fan to a lower speed can reduce fan energy consumption and improve humidification control in the space. Many advanced control scenarios simulated for this study use the multiple supply-fan speed option.
- With a variable-speed fan control, the supply fan speed is modulated in proportion to the difference between the actual space temperature and the temperature set point. Meanwhile, the heating or cooling output is adjusted through staging or capacity modulation to satisfy the discharge air temperature set point. This option is not evaluated in this study.

Cooling Capacity Control

Packaged rooftop units are usually sized to handle the system load at peak design conditions, which are expressed in terms of the weather and the internal loads of the space served. However, because the majority of actual operating hours occur at off-peak conditions, the packaged unit must have some capacity reduction mechanisms to deal with part-load conditions. Three cooling capacity control methods commonly used in packaged rooftop units are:

- Simple on-off control (base case option). For this case, the compressor is switched on and off as necessary to meet the load requirements. Once the compressor is on, it operates at full capacity, and the packaged unit provides cool air to the space. When the space temperature drops below the zone set point temperature, the compressor is turned off. This simple on-off control is normally used in package units with capacities less than 90,000 Btu/h.
- Staged cooling. Staged cooling is often accomplished by using two or more separate refrigeration circuits, which allows independent operation of the individual circuits. The magnitude of the cooling load (indicated by the deviation of the zone temperature from zone set point temperature) determines whether the unit operates at its full capacity or a lower capacity. At part-load conditions, using part of the unit’s cooling capacity can reduce the compressor’s excessive on-off cycling and contribute to better indoor temperature and humidity control.
- Capacity modulation. Cooling capacity can be modulated through compressor cylinder unloading, multi- or variable-speed compressors, and hot-gas bypass control (ASHRAE

2008). Cooling capacity modulation is usually used in packaged rooftop units serving variable-air-volume systems, but not single-zone constant-air-volume systems. This control option was not evaluated in this study.

Ventilation Control

Depending on whether the outdoor-air intake flow rate is dynamically reset based on the ventilation needs, the following two ventilation control strategies can be considered in a packaged rooftop unit:

- The first strategy maintains a fixed minimum outdoor-air intake rate during system operation. The fixed rate at which outdoor air is brought in is based on the design occupancy of the space served, which is usually larger than the actual occupancy during many operating hours. Therefore, excess outdoor air is supplied to the space whenever the space is partially occupied. This is the base case option.
- The second strategy, referred to as demand-controlled ventilation (DCV), adjusts the amount of outdoor air based on the number of occupants and the corresponding ventilation demand. Although a number of options such as direct people counting, time-of-day schedule tracking, and measuring CO_2 concentration are available to estimate the actual occupancy of spaces, CO_2-based DCV is by far the most commonly implemented measure when outdoor-air ventilation is dynamically reset (Stanke 2006). CO_2-based DCV relies on sensed CO_2 concentrations in the space (usually measured in the return air) to regulate the ventilation rate. Assuming that the CO_2 generation rate is proportional to the number of occupants, the minimum required outdoor-air flow rate for single-zone systems can be calculated from the space CO_2 concentration set point and the difference between indoor and outdoor CO_2 concentrations (ASHRAE 2010a). By reducing outdoor-air intake, DCV has the potential to reduce the energy associated with conditioning the outdoor air.

Table 1 summarizes the control options for each control technology applied to rooftop units for this study.

Table 1: Advanced Control Options Considered for this Study

Technology	**Considered control options**
Air economizer	No economizer (base control option) Differential dry-bulb, nonintegrated Differential dry-bulb, integrated Differential enthalpy, nonintegrated Differential enthalpy, integrated
Fan-speed control	Constant speed (base control option) Multiple speed
Cooling capacity control	Single stage (base control option) Two stages
Ventilation control	Constant outdoor-air supply (base control option) Demand-controlled ventilation

2.3 Sequences of Operation

The sequence of operation for packaged rooftop units varies with the control options selected. Figure 1 illustrates the typical control sequence for rooftop units in single-zone HVAC systems. Some details such as the control limits for safe equipment operations are not shown. Based on the sensed space temperature T, the rooftop unit has four basic operation modes: idle, ventilation, heating, and cooling.

Idle mode. The rooftop unit is in the idle mode if 1) the sensed space temperature lies between the heating and cooling set points, that is, $T_{HeatSP} \le T \le T_{CoolSP}$ and 2) the space is unoccupied. In the idle mode, the fan, the heating and the cooling are all off. Note that the heating and cooling set points during occupied and unoccupied modes may be different.

Ventilation mode. The rooftop unit operates in the ventilation mode if 1) the sensed space temperature lies between the heating and cooling set points, that is, $T_{HeatSP} \le T \le T_{CoolSP}$ and 2) the space is occupied. In the ventilation mode, the fan runs at the speed of Fan_{Ven} but both the heating and the cooling are off. In this study, the supply fan runs at 100% of the design speed ($Fan_{Ven} = 100\%$) in the ventilation mode for the control option with a constant fan speed, while it runs at 40% of the design speed ($Fan_{Ven} = 40\%$) for the control option with multiple fan speeds.

Heating mode. The rooftop unit operates in the heating mode if the sensed space temperature is less than the heating set point ($T < T_{HeatSP}$). Once heating is initiated, it continues until the space temperature rises above the heating set point plus a differential, $T > T_{HeatSP} + \delta$, where δ is the differential. In the heating mode, the fan runs at the speed Fan_{Heat}, which takes the value of 100% for the two considered options of fan-speed control.

Cooling mode. The rooftop unit operates in the cooling mode if the sensed space temperature is greater than the cooling set point ($T > T_{CoolSP}$). Depending on the economizer and mechanical cooling stage control status, the rooftop unit may work in two different sub modes: economizing or mechanical cooling.

- Economizing (OA cooling) mode. Right after the cooling mode is initiated, the system controller determines whether the outdoor air is suitable for free cooling. If the outdoor air is favorable for cooling, the OA damper is modulated to maintain the supply-air temperature at the economizer supply-air set point, i.e., $T_{Supply} = T_{EcoSP}$. The economizing mode is used as long as the space temperature lies between the cooling set point and the cooling set point minus the differential, i.e., $T_{CoolSP} - \delta \le T \le T_{CoolSP}$. Otherwise, if $T < T_{CoolSP} - \delta$, the economizer is off and the outdoor-air damper returns to the ventilation-only position. The controller initiates mechanical cooling if the time in economizing mode, Δt_{Eco}, exceeds the interstage delay time limit, Δt_{Limit} (i.e., $\Delta t_{Eco} > \Delta t_{Limit}$) and the supply-air temperature is greater than the threshold of changeover from OA cooling to mechanical cooling ($T_{Supply} > T_{Eco-DX}$). In the economizing mode, the mechanical cooling is off and the supply fan operates at the speed Fan_{Eco}, which takes the value of 100% for the constant fan-speed control and 75% for the control option with

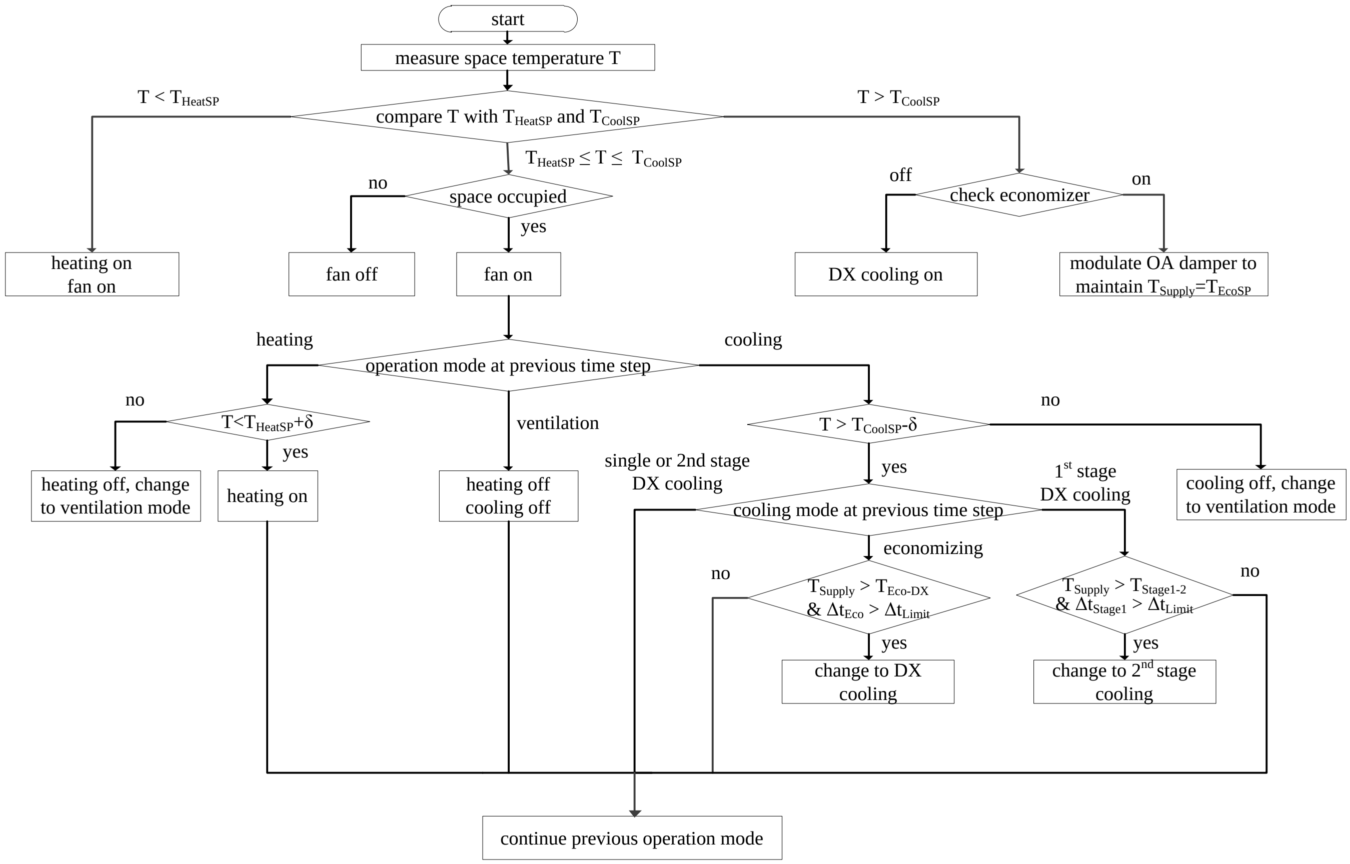

Figure 1: Illustration of the Typical Control Sequence for Rooftop Units in Single-Zone HVAC System

multiple fan speeds. The economizing mode occurs only if an air-side economizer is available.

- Mechanical cooling mode. For single-stage cooling, the rooftop unit runs at its full cooling capacity until the space is cooled down to a temperature below the difference of the cooling set point and the differential (i.e., $T < T_{CoolSP} - \delta$). For two-stage cooling, the unit runs stage-one cooling first. Cooling continues with only the first stage operating as long as the space temperature lies between the cooling set point and the cooling set point minus the differential, i.e., $T_{CoolSP} - \delta \le T \le T_{CoolSP}$. Otherwise, the mechanical cooling is discontinued when $T < T_{CoolSP} - \delta$. The rooftop unit triggers the second stage mechanical cooling if the time in stage-one cooling mode exceeds the interstage delay time limit (i.e., $\Delta t_{Stage1} > \Delta t_{Limit}$) and the supply-air temperature is greater than the threshold of changeover between cooling stages ($T_{Supply} > T_{Stage1-2}$). After the rooftop unit initiates the second stage of cooling, both stages are on until the space is cooled to a temperature below $T_{CoolSP} - \delta$. In the mechanical cooling mode, if an integrated economizer is used and the OA condition is favorable for cooling, the control system fully opens the OA damper; otherwise, the controls keep the OA damper at the minimum position required by ventilation. The supply fan runs at the speed of Fan_{Stage1} and Fan_{Stage2}, respectively for first stage and second stage cooling (Fan_{Stage2} applies if there is a single-stage cooling). Fan_{Stage1} and Fan_{Stage2} are set to 75% and 100% of the design speed in this study for the control option with multiple fan speeds.

If DCV control is available, the OA damper can be modulated depending on the sensed CO_2 concentration ($C_{CO2,S}$) in the return air. The OA damper is modulated further toward fully closed if $C_{CO2,S}$ is less than the space CO_2 set point ($C_{CO2,SP}$), while it is opened further if $C_{CO2,S}$ is greater than $C_{CO2,SP}$. An absolute lower limit for OA ventilation is usually applied to ensure adequate ventilation to dilute air contaminants from non-occupant-related sources, such as building materials, furnishings, and finishes. This lower limit is reflected by the OA rate per area as indicated in ASHRAE Standard 62.1-2010 (ASHRAE 2010a). For example, in office spaces, the OA rate per space area is required to be 0.06 cfm/ft^2. It needs to be noted that when both air-side economizer and DCV controls are active, the economizer control takes precedence over DCV control.

3. Representative Buildings, Climates and Locations

To estimate the energy savings potential of advanced control packages across the U.S., the energy use for a number of prototypical buildings, which predominantly use packaged units for heating and cooling, needs to be simulated in different climates. The representative building types, locations, and climates are discussed in this section.

3.1 Representative Buildings

The U.S. DOE has developed 16 reference building prototypes to represent most of the commercial buildings in the U.S. (Deru et al. 2011). These reference building prototypes cover about 70% of the commercial building stock, including office buildings, restaurants, retail buildings, schools, healthcare buildings, supermarkets, lodging, and warehouses. For each reference building prototype, the associated model has three versions with different vintages: new construction, post-1980 construction, and pre-1980 construction. The models with different vintages differ with respect to envelope insulation levels, lighting power densities, and HVAC equipment types and efficiencies. Because significant efforts were taken to have the reference building models represent realistic building characteristics and construction practices, the reference models are usually used as the starting point for energy efficiency research (Field et al. 2010; Fumo et al. 2010).

Four building prototypes including small office, stand-alone retail, strip mall, and supermarket are chosen for analysis in this study. The post-1980 construction reference models corresponding to the four building types were used because they predominantly use packaged equipment for which the advanced controls being evaluated apply. The four building prototypes are discussed briefly below.

<u>Small Office Building</u>

The small office building model shown in Figure 2 has a single above-ground floor with a total floor area of 5,500 ft^2. The building has a rectangular shape with aspect ratio of 1.5. The total window-to-wall ratio is about 20%. Five packaged units with gas heating and DX-coil cooling serve four perimeter zones and one core zone. Key building characteristics of the small office building are listed in Table A1 in Appendix A.

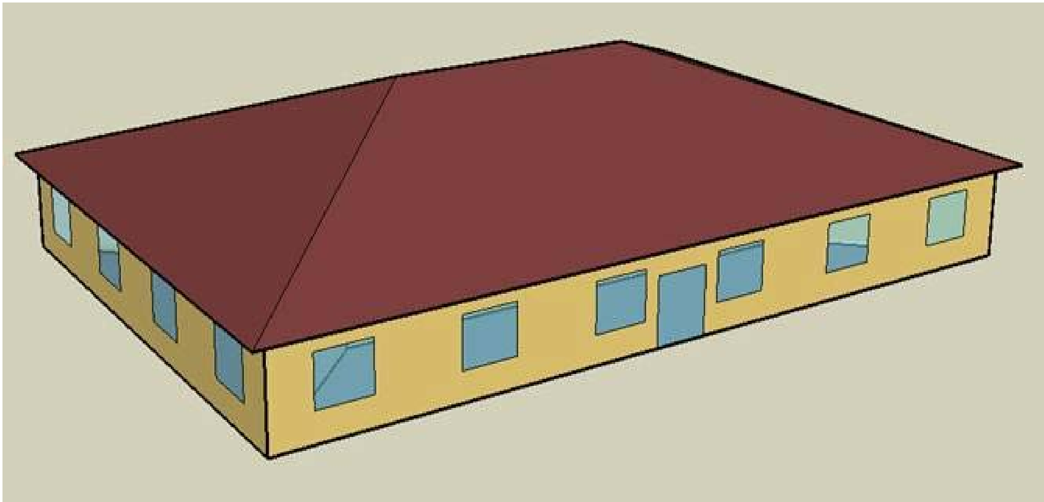

Figure 2: Axonometric View of Small Office Building

Stand-alone Retail Building

The stand-alone retail prototype shown in Figure 3 represents a retail box store with a total floor area of about 25,000 ft^2. Based on the space usage and the location, the store is divided into five areas: front entry (0.5%), storage space (16.5%), core retail (70%), front retail (6.5%), and cashier area (6.5%), where the number in parenthesis indicates the percentage of that space area. Each space area is regarded as one thermal zone. Except for the front entry served by a unit heater, the other thermal zones are equipped with a packaged unit with DX cooling and gas furnace heating. Key building characteristics of the stand-alone building are shown in Table A2 in Appendix A.

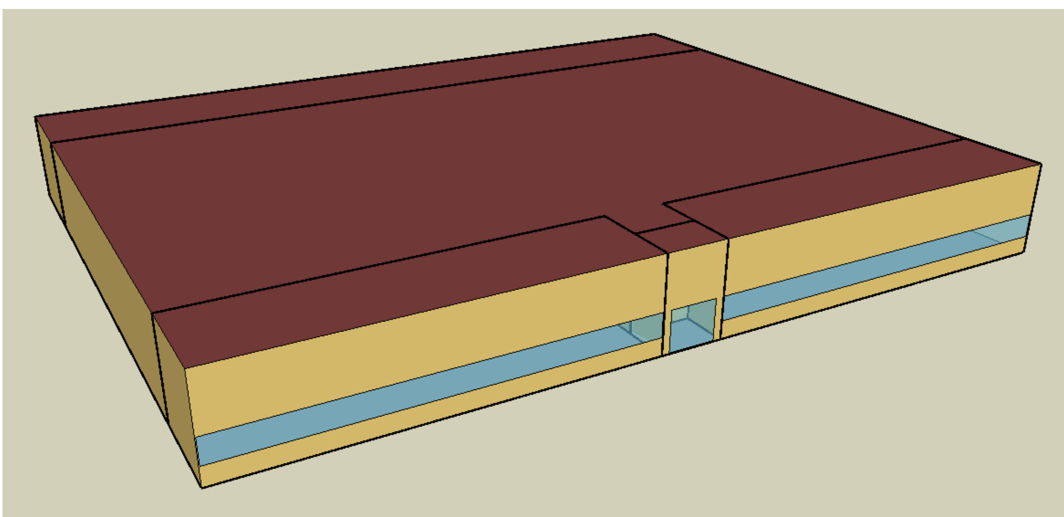

Figure 3: Axonometric View of Stand-alone Retail Building

Strip Mall

The strip mall retail prototype building (Figure 4) has a total floor area of 22,500 ft^2. It consists of two large stores and eight small stores. The large store has an area of 3,750 ft^2 and the small store has an area of 1,875 ft^2. All glazing is on the south façade, and the overall window-to-wall ratio is 10.5% for the whole building. Each store is served by a packaged single-zone unit with gas furnace heating and DX cooling. Major building characteristics of the strip mall are given in Table A3 in Appendix A.

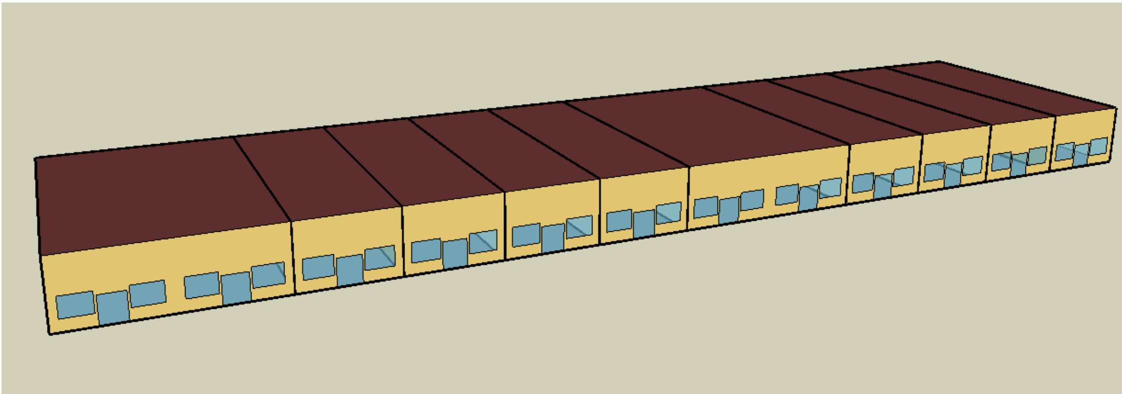

Figure 4: Axonometric View of Strip Mall

<u>Supermarket</u>

The supermarket prototype building (Figure 5) has a total floor area of 45,000 ft^2. There is glazing only on the south façade. The overall window-to-wall ratio for the whole building is 10.5%. This single-floor store is divided into six different functional spaces: main sales (56%), produce (17%), bakery (5%), deli (5%), office (2%) and dry storage (15%), where the number in parenthesis indicated the percentage of area for each space. Each functional space is dealt as a thermal zone served by a packaged air conditioner with gas furnace heating and DX cooling. The basic characteristics of the supermarket building are listed in Table A4 in Appendix A.

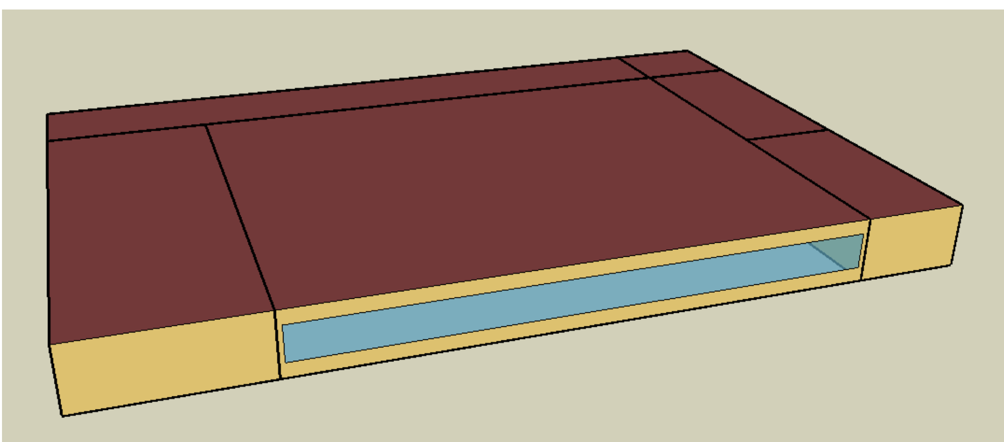

Figure 5: Axonometric View of Supermarket

Table 2 summarizes the floor area, number of packaged systems, system operation hours and ventilation requirement for all four building types. Because these building are modeled as post-1980 construction, the ventilation requirements for different spaces are set according to ASHRAE Standard 62.1-1999 (ASHRAE 1999).

Table 2: Building Types Studied

Building Type	Floor Area (ft^2)	Number of Packaged Systems	System Operation Hours per Week (Hours)	Ventilation
Small Office	5,500	5	92	20 cfm/person
Stand-alone Retail	25,000	4	91	0.15 cfm/sf (storage) 0.3 cfm/sf (sales)
Strip Mall	22,500	10	91	0.3 cfm/sf
Supermarket	45,000	6	168	20 cfm/person (office) 0.15 cfm/sf (storage) 0.3 cfm/sf (sales)

3.2 Climates and Locations

The energy saving potential from adding advanced controls to packaged rooftop units usually varies with climate conditions. Hence, it is desirable to simulate the same building model in different climate conditions. ASHRAE Standard 90.1 (ASHRAE 2010b) provides a classification of climate zones according to the heating- and cooling-degree-days and the atmospheric moisture. This classification covers eight major climate zones from 1 to 8 with increasing heating-degree-days and decreasing cooling-degree-days. A major climate zone may be further divided into humid, dry, and marine climate types, which are labeled as A, B and C, respectively. For example, climate zone 3 is characterized as warm climate, and it has three subcategories: 3A for humid climate; 3B for dry climate and 3C for marine climate. Following the DOE reference building models (Deru et al. 2011), a total of 16 populous cities were selected to represent all climate zones in the U.S. (Table 3). Two locations were selected for climate zone 3B because of the large variations of the regional weather conditions within that zone (Deru et al. 2011).

Table 3: Selected Climates and Corresponding Representative Locations for Saving Analysis

Climate Zone	Climate Type	Representative City	Thermal Criteria
1A	Very hot, humid	Miami, FL	5000 < CDD50 °F
2A	Hot, humid	Houston, TX	3500 < CDD50 °F ≤ 5000
2B	Hot, dry	Phoenix, AZ	3500 < CDD50 °F ≤ 5000
3A	Warm, humid	Atlanta, GA	2500 < CDD50 °F ≤ 3500
3B	Warm, coastal	Los Angeles, CA	2500 < CDD50 °F ≤ 3500
3B	Warm, dry	Las Vegas, NV	2500 < CDD50 °F ≤ 3500
3C	Warm, marine	San Francisco, CA	HDD 65 °F ≤ 2000
4A	Mixed, humid	Baltimore, MD	CDD50 °F ≤ 2500 HDD 65 °F ≤ 3000
4B	Mixed, dry	Albuquerque, NM	CDD50 °F ≤ 2500 HDD 65 °F ≤ 3000
4C	Mixed, marine	Seattle, WA	2000 < HDD 65 °F ≤ 3000
5A	Cool, humid	Chicago, IL	3000 < HDD 65 °F ≤ 4000
5B	Cool, dry	Denver, CO	3000 < HDD 65 °F ≤ 4000
6A	Cold, humid	Minneapolis, MN	4000 < HDD 65 °F ≤ 5000
6B	Cold, dry	Helena, MT	4000 < HDD 65 °F ≤ 5000
7	Very cold	Duluth, MN	5000 < HDD 65 °F ≤ 7000
8	Subarctic	Fairbanks, AK	7000 < HDD 65 °F

CDD: cooling-degree-days; HDD: heating-degree-days

4. Analytic Methodology

The energy usage impacts (savings or potential penalties) associated with changing from the baseline control for packaged units to one of the advanced control packages is determined using simulation of the representative prototype buildings with the EnergyPlus software. By taking the difference in energy use of the packaged units between the base case control and the advanced control package, the impact of using the advanced control package can be determined. Electricity and gas consumption are separated to obtain the impacts by energy source. Savings on energy costs are estimated by multiplying the change in use of each of the energy sources by the corresponding energy price. Blended rates that essentially combine demand charges with usage charges are used for electricity. The energy cost impacts are then used to calculate the breakeven non-energy costs (capital plus installation) that would yield selected values of the simple payback period. The analyses are performed for the four building types identified in Section 3, at least one location in each primary U.S. climate zone, and many selected combinations of advanced control options (i.e., control packages). The results provide insight into how impacts vary with location (and climate), building type and energy prices, and perspective on the total of the capital and installations costs that yield a range of payback periods likely to be acceptable to building owners. Greater detail on the methodology is provided in the sections that follow.

4.1 Energy Use Estimation Methodology

To estimate the energy consumption of a prototype building using packaged rooftop units with various control options, detailed EnergyPlus simulation models are used. Specifically, the EnergyPlus software with the energy management system feature (DOE 2010) is used to simulate energy usage over a typical climatological year for each location. Simulations were performed for:

- 4 building types,
- 16 locations (in 15 climate zones), and
- 22 control options (base case + 21 different combinations of advanced control options).

Combinations of these characteristics resulted in 1,408 cases (and corresponding EnergyPlus runs). In this section, the various packages of advanced control strategies are described. All combinations of control strategies are listed in Table 4. The strategies include economizer control, supply-fan-speed control, single- and two-stage cooling, and demand-control ventilation (DCV) control. In Table 4:

- The case name and number are used as identifiers and are used while discussing the results. The case name consists of four to five dot-separated parts identifying the control strategies associated with each case. The following abbreviations are used to designate the control features in each case: nonintegrated economizer (NIEcon), integrated economizer (IEcon), no economizer (NoEcon), differential dry-bulb economizer control (DB), differential enthalpy economizer control (EH), single-speed fan (SSFan), multi-speed fan (MSFan), single-cooling stage (CS1), two-cooling stages (CS2), DCV control (DCV1), and no DCV control (DCV0).

- The baseline case has a constant speed supply fan, single-stage cooling, no air-side economizer and no DCV. This baseline is assumed to be typical for many existing light commercial rooftop units. Although in many locations some form of economizer control is required, for this study the base case building has no economizer controls. This definition of the base case is not critical because any case (e.g., Case 2 or 3, which include economizer control), can be considered as the base case for determining the incremental impacts of adding more control options. Thus, by comparing energy consumption of the base case with other cases, the energy and cost savings from retrofitting existing packaged units with advanced control packages can be estimated. For other initial control capabilities, the energy use with the appropriate initial control package can be compared to the energy use with other control packages to investigate the benefits from adding other advanced control features to those initially present.

- Not all possible combinations of different control strategies are investigated for the purpose of simplification. For example, the nonintegrated economizer is considered in only four cases (Cases 2, 3, 7 and 8) in the context of single-stage cooling and no DCV, although many more cases could be created by combining it with two-stage cooling and DCV.

Simulations were performed for all 22 control cases for the four building types in each of the 15 climates and 16 locations, leading to 1408 simulations.

Following the original DOE commercial building reference models (Deru et al. 2011), both gas furnace and DX cooling are sized automatically by EnergyPlus. The weather conditions for HVAC equipment sizing are selected as: the dry-bulb temperature corresponding to the 99.6% annual cumulative frequency of occurrence for the heating-design-day condition and the dry-bulb temperature corresponding to the 1% annual cumulative frequency of occurrence and the corresponding wet-bulb temperature for the cooling-design-day condition. The internal loads including occupancy, lights, and plug loads are specified as zero on the heating design day and as the peak values (Table A1 thru A4 in Appendix A) on the cooling design day.

For packaged rooftop units serving single-zone systems, EnergyPlus sizes the supply-fan air flow and the capacities of DX cooling and gas furnace in a number of steps. The space heating and cooling loads are calculated for each predefined time step (e.g., 15 minutes) for each design day. Based on the system-design supply-air temperature, the zone supply-air flow rates needed to meet the zone design loads are calculated using the heat balance method (ASHRAE 2009). The sub-hourly zone loads are summed and averaged across a wide time window (e.g., 1 hour) to prevent unrealistically large flow rates caused by space warm up or cool down when an abrupt change of thermostat set points occurs. The maximum heating and cooling air flow rate is then regarded as the supply-fan design flow rate. This design flow rate is used together with the design minimum outdoor-air flow rate to obtain the mixed-air conditions, based on which heating and cooling coil loads can be calculated. The maximum heating coil load is then assigned as the gas furnace capacity. Because the coil inlet-air and outdoor-air conditions at the peak cooling coil load may differ from the rating conditions for packaged DX cooling, the maximum cooling load needs to be processed further by accounting for the capacity change with operating conditions to obtain the rated DX cooling capacity (DOE 2010). An oversize factor of 1.2 is applied to the resulting capacities to size the equipment consistently with general design practice.

As shown in Table 5, the packaged cooling equipment at different capacities and the gas furnace efficiencies were selected as those used in the DOE reference buildings (Deru et al. 2011). Post-1980 vintage buildings were selected to represent control strategies commonly used for packaged units on existing buildings.

Table 4: Combinations of Control Options (or Control Packages) Considered for Each Building Type in all 16 Locations

Case No	Case Name	Economizer Control	Integrated Economizer	Fan Speed Control	DX Cooling Stages	DCV
1	Baseline	No economizer	—	Constant	One	No
2	NIEcon.DB.SSFan.CS1.DCV0	Differential dry bulb	No	Constant	One	No
3	NIEcon.EH.SSFan.CS1.DCV0	Differential enthalpy	No	Constant	One	No
4	IEcon.DB.SSFan.CS1.DCV0	Differential dry bulb	Yes	Constant	One	No
5	IEcon.EH.SSFan.CS1.DCV0	Differential enthalpy	Yes	Constant	One	No
6	NoEcon.MSFan.CS1.DCV0	No economizer	—	Multiple	One	No
7	NIEcon.DB.MSFan.CS1.DCV0	Differential dry bulb	No	Multiple	One	No
8	NIEcon.EH.MSFan.CS1.DCV0	Differential enthalpy	No	Multiple	One	No
9	IEcon.DB.MSFan.CS1.DCV0	Differential dry bulb	Yes	Multiple	One	No
10	IEcon.EH.MSFan.CS1.DCV0	Differential enthalpy	Yes	Multiple	One	No
11	NoEcon.MSFan.CS2.DCV0	No economizer	—	Multiple	Two	No
12	IEcon.DB.MSFan.CS2.DCV0	Differential dry bulb	Yes	Multiple	Two	No
13	IEcon.EH.MSFan.CS2.DCV0	Differential enthalpy	Yes	Multiple	Two	No
14	NoEcon.SSFan.CS1.DCV1	No economizer	—	Constant	One	Yes
15	IEcon.DB.SSFan.CS1.DCV1	Differential dry bulb	Yes	Constant	One	Yes
16	IEcon.EH.SSFan.CS1.DCV1	Differential enthalpy	Yes	Constant	One	Yes
17	NoEcon.MSFan.CS1.DCV1	No economizer	—	Multiple	One	Yes
18	IEcon.DB.MSFan.CS1.DCV1	Differential dry bulb	Yes	Multiple	One	Yes
19	IEcon.EH.MSFan.CS1.DCV1	Differential enthalpy	Yes	Multiple	One	Yes
20	NoEcon.MSFan.CS2.DCV1	No economizer	—	Multiple	Two	Yes
21	IEcon.DB.MSFan.CS2.DCV1	Differential dry bulb	Yes	Multiple	Two	Yes
22	IEcon.EH.MSFan.CS2.DCV1	Differential enthalpy	Yes	Multiple	Two	Yes

Table 5: Efficiency of Cooling, Heating and Fan Systems

Equipment	Capacity	Performance Metric	Value
Packaged DX cooling	<65 kBtu/h	SEER	11.06
	≥65 kBtu/h and <135 kBtu/h	EER	9.63
	≥135 kBtu/h and <240 kBtu/h	EER	9.28
	≥240 kBtu/h and <760 kBtu/h	EER	8.92
	>760 kBtu/h	EER	8.63
Gas furnace	all	Combustion efficiency	0.8
Fan	<7,487 cfm	Pressure rise	2.5 in. w.c.
		Mechanical efficiency	65%
	≥7,487 cfm and <20,000 cfm	Pressure rise	4.46 in. w.c.
		Mechanical efficiency	65%
	> 20,000 cfm	Pressure rise	4.09 in. w.c.
		Mechanical efficiency	65%

The sequence of rooftop unit operation considered in this work requires specialized control of packaged single-zone systems. The traditional controls built into EnergyPlus are not capable of modeling many control options, for example, the temperature set point differential and variation of fan speed with operation modes. To address the challenge, the energy management system (EMS) feature in EnergyPlus (DOE 2010) is used to provide the ability to customize controls. The EMS provides a variety of sensors and actuators much like actual building automation systems. The sequences of operations embedded in the EnergyPlus input files are used to override the traditional control and to add the desired control functionality into the simulation.

Several significant considerations in use of the EMS feature of EnergyPlus are discussed below.

- A number of control parameters need to be defined for the EMS control. Table 6 lists the parameters that are independent of climate, location, and building type. The table shows that the constant speed fan runs at its design speed, and the multi-speed fan runs at different speeds in different operation modes: 40% of the design speed in ventilation mode, 75% of the design speed in economizing mode, 75% and 100% of the design speed in first and second stage cooling modes, respectively, when two-stage cooling applies. The fan runs at 100% of the design speed when single-stage DX cooling is used.

Table 6: Default Values of the Key Control Parameters

Parameter	**Value**
Heating and cooling set point differential (δ)	1.8°F
Economizer supply-air temperature set point (T_{EcoSP})	55°F
Interstage delay time limit (Δt_{Limit})	9 min
Temperature threshold for changeover from OA economizer cooling to DX cooling ($T_{Eco\text{-}DX}$)	58°F
Temperature threshold for changeover from first to second stage DX cooling (T_{DX_Stage})	58°F
Fan speed in ventilation mode (Fan_{Ven})	100% (constant speed) 40% (multi-speed)
Fan speed in heating mode (Fan_{Heat})	100%
Fan speed in economizing mode (Fan_{Eco})	100% (constant speed) 75% (multi-speed)
Fan speed in first stage cooling (Fan_{Stage1})	100% (constant speed) 75% (multi-speed)
Fan speed in single-stage cooling or second stage of two stage cooling (Fan_{stage2})	100%
Ambient CO_2 concentration	400 ppm (ASHRAE 2010a)
Space CO_2 concentration set point ($C_{CO2,SP}$)	1000 ppm (ASHRAE 2010a)
CO_2 generation rate from people	0.0084 cfm/met (ASHRAE 2010a)

- The fan power consumption is calculated based on the design pressure rise, the air flow rate, and the fan efficiency. For the ideal situation of no power loss on fan drive and motor, the power is proportional to the cube of the fan speed. Chan (2004) and Ford (2011) have shown that to approximately account for these losses, the fan power can be expressed as proportional to fan speed, to a power of between 2.0 and 3.0. Therefore, we express the fan power at any fraction of full speed by the relation:

$$P_{Fan,x} = P_{Fan,100} * \left(\frac{x}{100}\right)^{2.5} = \frac{Q_{design}\Delta P}{6350\eta_{total}} * \left(\frac{x}{100}\right)^{2.5} \quad (1)$$

  where P_{Fan} is the fan power in hp; Q_{design} is the design air flow rate of the fan in cfm; ΔP is the design pressure rise in in. w.c. across the fan; η_{total} is the fan total efficiency including fan mechanical efficiency, drive efficiency and motor efficiency; and the subscripts x and 100 designate the fraction fan speed to which the variable corresponds.

- For cases with two-stage cooling, it is assumed that the two stages have the same cooling capacity under the same operating conditions. The decrease in efficiency caused by compressor cycling is not considered in this work.

- For the ventilation control, the EMS works directly on the outdoor air flow rate instead of through OA-damper modulation as usually found in practice. Thus, for the cases with no DCV control, the OA flow rate is maintained at the design ventilation level unless an air economizer is activated. For the cases with DCV control, the minimum OA flow rate is set at 25% of the design ventilation level to dilute contaminates from non-occupants (i.e., even if the space CO_2 concentration is less than 1000 ppm, 25% of the design ventilation air is provided).

4.2 Economic Analysis Methodology

For each simulation, EnergyPlus provides estimates of fan electricity consumption, cooling electricity consumption, gas consumption for heating, and total (electricity plus gas) energy consumption. The total energy consumption is the sum of all four end-uses in consistent units. Annual energy cost is simply calculated from the utility rates and the annual energy consumption using the equation:

$$\begin{aligned} AEC &= GC + EC \\ &= r_{gas} * Q_{gas} + r_{elec} * Q_{elec} \end{aligned} \tag{2}$$

where *AEC*, *GC* and *EC*, respectively, represent annual energy cost, annual gas cost, and annual electricity cost; r_{gas} and r_{elec} are the utility rates (i.e., prices) for natural gas and electricity, respectively; Q_{gas} is the annual natural gas consumption in Therms; and Q_{elec} is the annual electricity consumption in kWh.

Average blended gas and electricity prices from EIA (2011) are used for the analysis. EIA provides the historical data on monthly utility rates in all states back to the 1970s. For each location, the corresponding state average price in the year of 2010 is used as the applicable price for a whole year.

Table 7 lists the electricity and gas prices for all 16 locations, each located in a different climate zone (except for Las Vegas and Los Angeles).

The maximum total initial (non-energy) cost of retrofitting an advanced control package on an existing rooftop unit equals the breakeven initial total cost that can be supported by the energy savings from adding the advanced control package. This initial cost, which is the sum of the initial capital cost of the advanced controller equipment and the cost of installation, is a function of the simple payback period desired by the purchaser (ordinarily the building owner). Having the annual energy cost for a given advanced control package in case i, the maximum acceptable initial cost can be calculated as:

$$\begin{aligned} IC_{i,max} &= (IC_{i,capital} + IC_{i,installation})_{max} \\ &= (AEC_i - AEC_{base}) * N_{spp} \end{aligned} \tag{3}$$

where, $IC_{i,max}$ is the maximum acceptable initial total installed cost of the advanced controller with case i for a building in \$; $IC_{i,capital}$ is the corresponding capital cost of the controller; $IC_{i,installation}$ is the installation cost; N_{spp} is the simple payback period in years; and the subscripts i and $base$ refer to the i-th case and the baseline case, respectively. Note that IC is the total installed cost for a building. Therefore, if the building has a number of units, then per unit cost can be estimated by dividing IC by the number of units to obtain the maximum acceptable total initial cost for a single advanced controller.

The conventional approach of assuming a total initial cost (IC_i) of the advanced controller for a building could, of course, be assumed. In this situation, the payback period for the controller could be estimated as:

$$N_{spp} = \frac{IC_i}{AEC_i - AEC_{base}} \tag{4}$$

Table 7: Electricity and Gas Prices by Location in the Year of 2010 (EIA 2011)

Climate Zone	City	State	Electricity (\$/kWh)	Natual Gas (\$/Therm)
1A	Miami	FL	0.098	1.052
2A	Houston	TX	0.092	0.806
2B	Phoenix	AZ	0.094	1.073
3A	Atlanta	GA	0.091	1.137
3B	Los Angeles	CA	0.138	0.830
3B	Las Vegas	NV	0.099	0.977
3C	San Francisco	CA	0.138	0.830
4A	Baltimore	MD	0.116	1.006
4B	Albuquerque	NM	0.086	0.755
4C	Seattle	WA	0.073	1.072
5A	Chicago	IL	0.088	0.983
5B	Denver	CO	0.090	0.775
6A	Minneapolis	MN	0.083	0.736
6B	Helena	MT	0.085	0.895
7	Duluth	MN	0.083	0.736
8	Fairbanks	AK	0.141	0.863

5. Energy Savings

The energy savings from different packaged rooftop unit control strategies are presented and discussed in this section. The baseline HVAC energy use and the distribution of time in different operating modes are presented first. Then, in Section 5.2, the impact of each individual control strategy on HVAC energy savings is investigated. Section 5.3 shows the incremental impact of several advanced control strategies. Two pairs of control combinations are selected, and they are compared in Sections 5.4 and 5.5 to understand the potential of energy savings from different control combinations.

5.1 Baseline HVAC Energy Use and Distribution of Operation Modes

It is important to have a clear picture of the baseline energy use before investigating the potential of energy savings with various control combinations. Because the investigated control strategies do not affect the energy use for lighting, plug loads and service hot water, only HVAC energy uses (i.e., ventilation, cooling, and heating) are considered. Figure 6 through Figure 9 show the annual HVAC energy use and its split between heating, cooling and fan consumption across all 16 locations for the four building types. For the horizontal axis, the number and letter after the location name indicates the climate zone that the location belongs to. In these figures, the gas energy for heating and the electrical energy for cooling and fan operation are simply summed without distinction of the fuel types to obtain the total energy use. These figures lead to the following observations:

- The annual HVAC energy consumption lies in between 90 and 420 MMBtu for the small office building, 640 and 5,610 MMBtu for the stand-alone retail building, 700 and 5,590 MMBtu for the strip mall, and 1310 and 13,920 MMBtu for the supermarket building. After normalization with the building area (Table 2), the HVAC energy use intensities for the four building types are in the following ranges: 17 through 82 kBtu/ft^2/yr for the small office building, 26 through 227 kBtu/ft^2/yr for the stand-alone retail building, 31 through 248 kBtu/ft^2/yr for the strip mall, and 29 through 287 kBtu/ft^2/yr for the supermarket.
- Except for the supermarket, all building types have the lowest energy consumption in mild climates, such as Los Angeles and San Francisco. Because of the additional energy required to compensate for the heating load from refrigeration cases, the supermarket building has the lowest energy consumption in Miami. As expected, all four building types have the largest energy consumption in the extremely cold climates, i.e., Fairbanks.
- Of the three HVAC end uses, fans consume about 10% to 40% of the total HVAC energy, the precise fraction depending on the climate. Fan energy use accounts for larger fractions in mild climates and smaller fractions in cold climates. Cooling and heating, in contrast, account for 1% to 70% and 1% to 90% of the total HVAC energy use, respectively.

For ease of reference, the annual HVAC energy uses for the base case and all other 21 advanced control cases are also tabulated in Appendix B for the four building types.

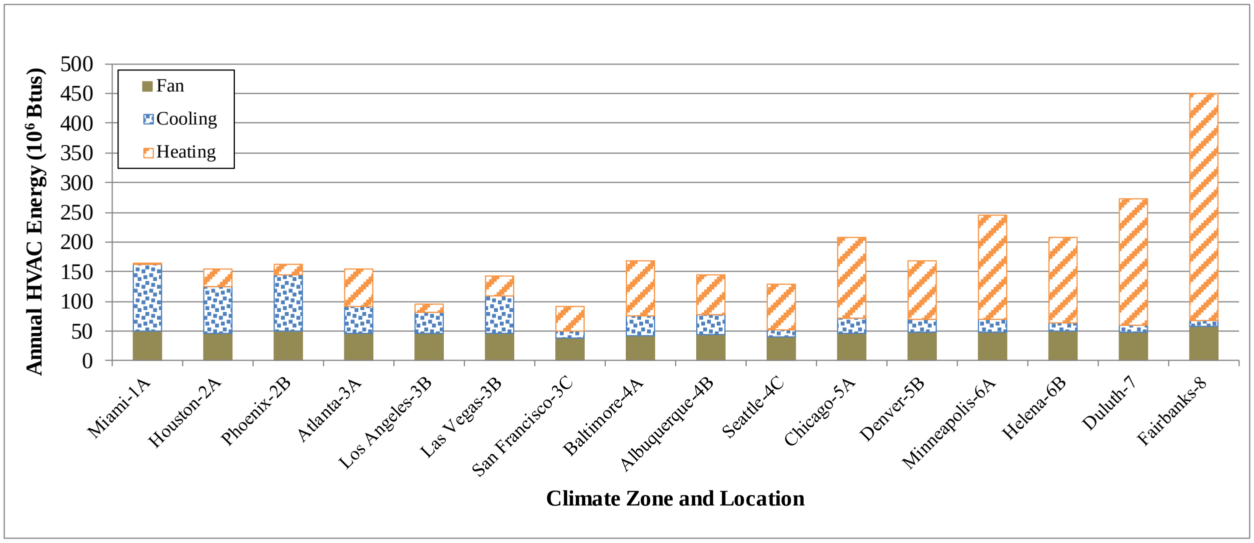

Figure 6: Annual HVAC Energy Use for Base Case Control (Case 1) of the Small Office Building

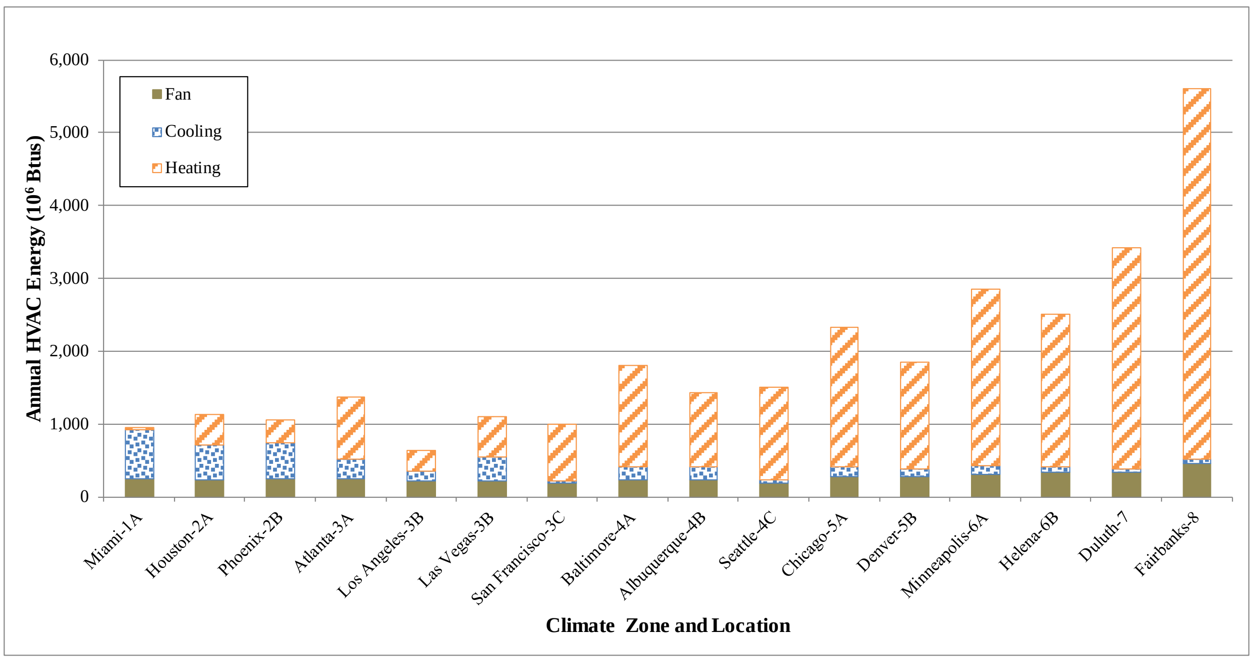

Figure 7: Annual HVAC Energy Use for Base Case Control (Case 1) of the Stand-alone Retail Building

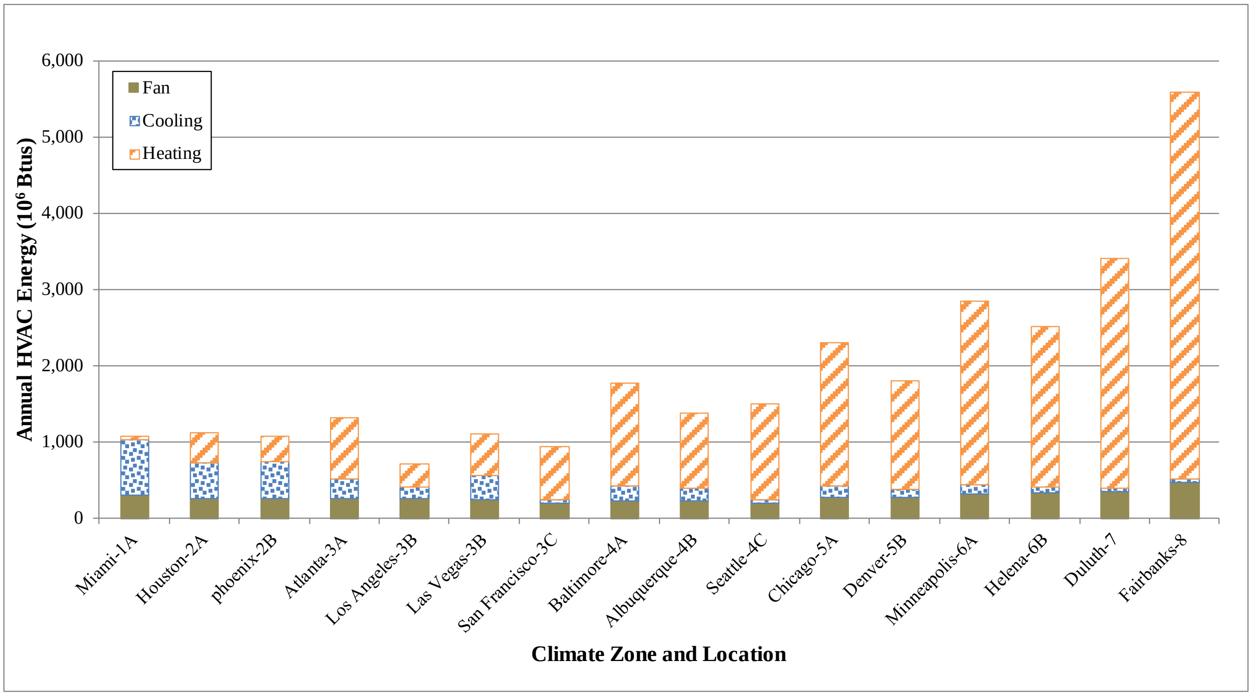

Figure 8: Annual HVAC Energy Use for Base Case Control (Case 1) of the Strip Mall Building

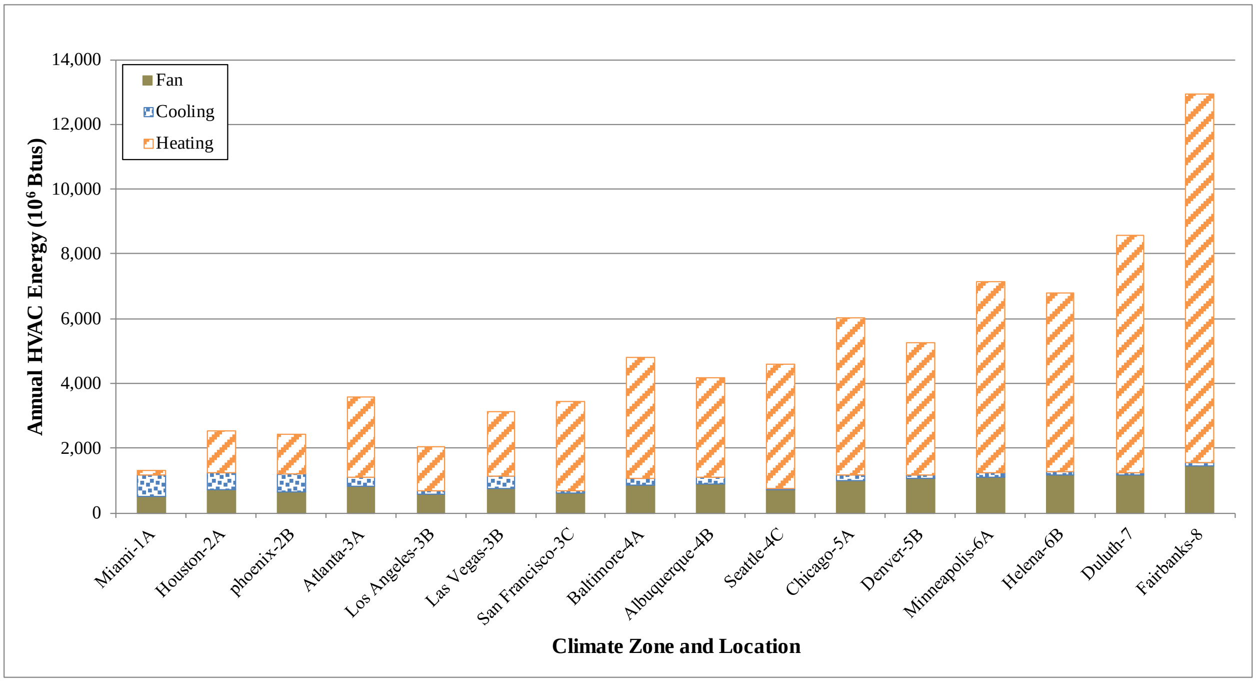

Figure 9: Annual HVAC Energy Use for Base Case Control (Case 1) of the Supermarket Building

For the base case, when the packaged rooftop unit is on, it operates in one of the three operating modes: ventilation mode, cooling mode or heating mode. Figure 10 through Figure 13 show the distribution of the operation modes as a percentage of the total operating time in each location for the four building types. These results indicate that:

- Packaged single-zone rooftop units operate in the ventilation mode for more than 50% of their run time. This is observed for all examined building types and locations. The units in the hot climates have the lowest percentage of their operating time in the ventilation mode, while the units in the mild climates (such as Los Angeles and San Francisco) have the highest percentage of time in the ventilation mode.
- The percentage of time in the cooling mode ranges from about 4% to 40%. As expected, the percentage of time in the cooling mode is generally greater for hot than for cold climates.
- The percentage of time in the heating mode lies in the range from less than 1% to about 12% for the small office building and to about 20% for the other three building types. In comparison with the other three building types, the small office building has a relatively small percentage of time in the heating mode. This is likely caused by the small office building having an attic roof, which acts as a buffer between the outdoors and the indoors, reducing the heat loss through the ceiling and thus the total heating load. As expected, the percentage of time in the heating mode increases as the climate becomes colder.

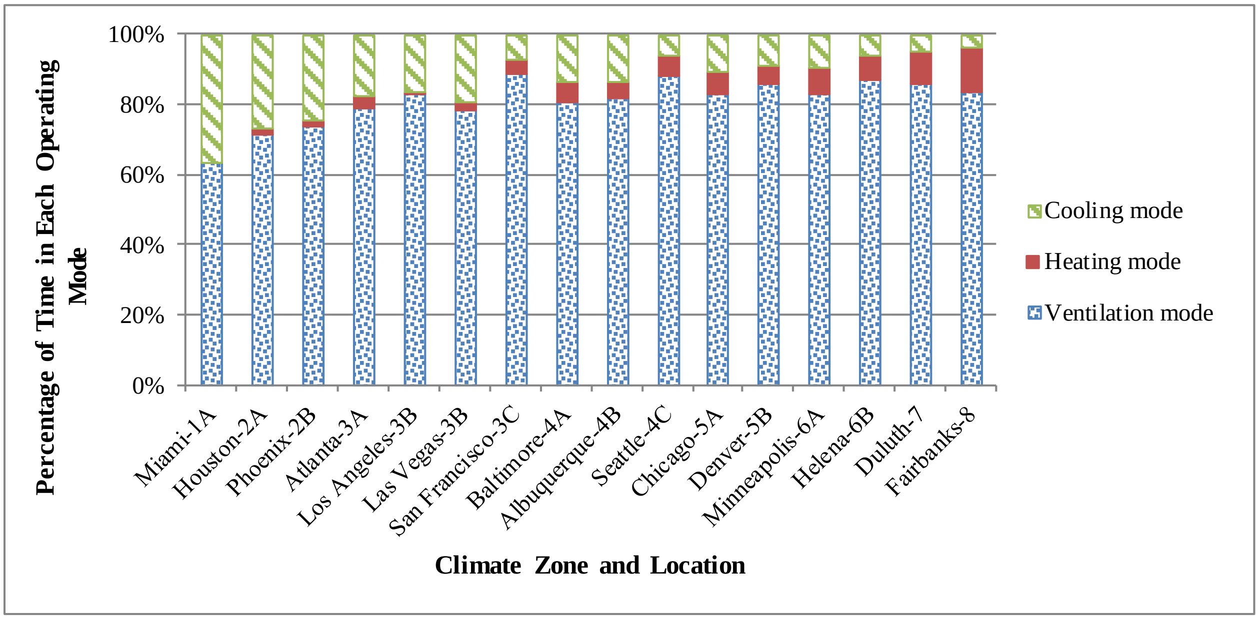

Figure 10: Percentage of Time in Each of the Operational Modes for the Small Office Building for all 16 Locations

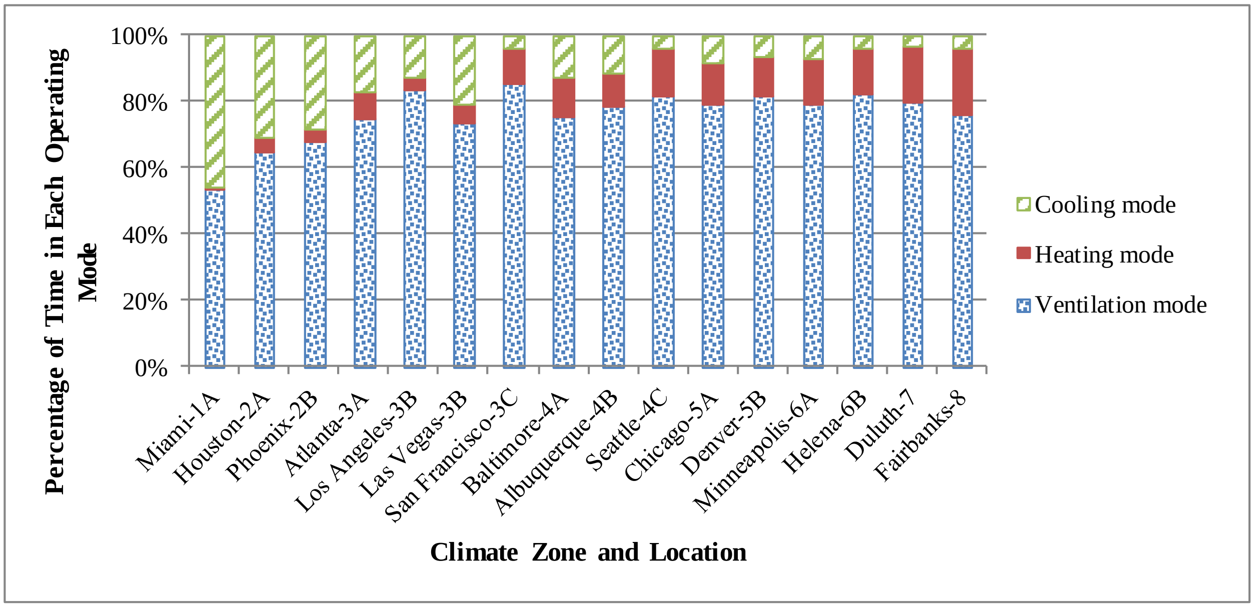

Figure 11: Percentage of Time in Each of the Operational Modes for the Stand-alone Retail Building for all 16 Locations

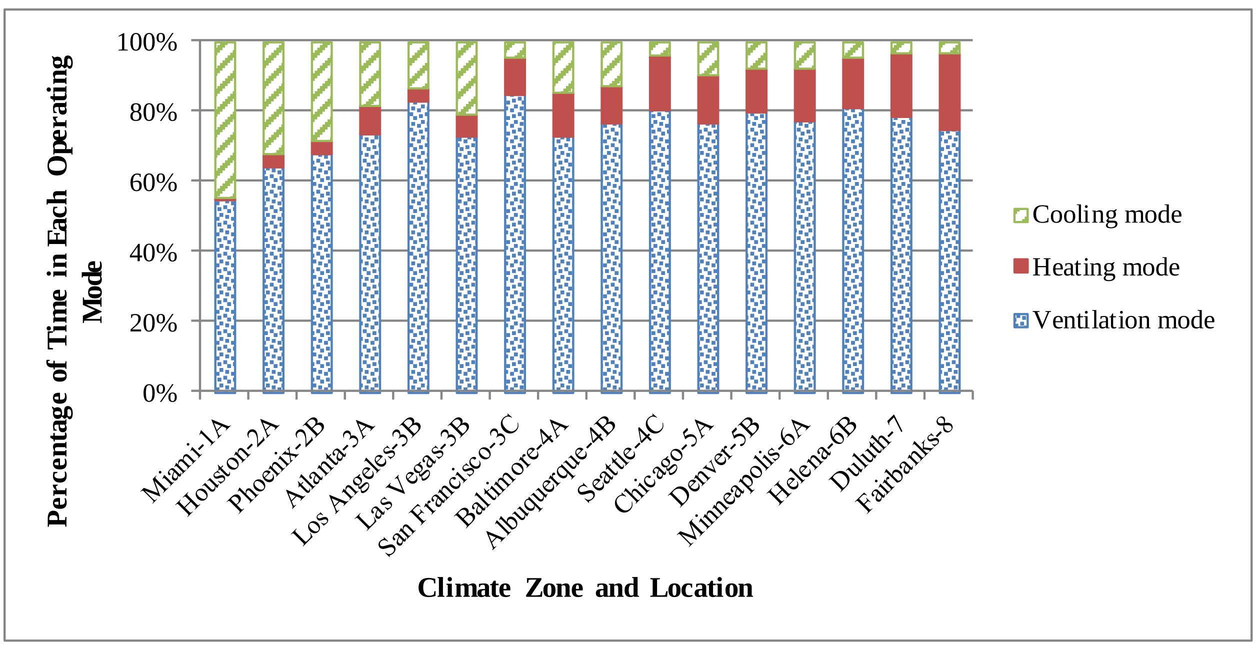

Figure 12: Percentage of Time in Each of the Operational Modes for the Strip Mall Building for all 16 Locations

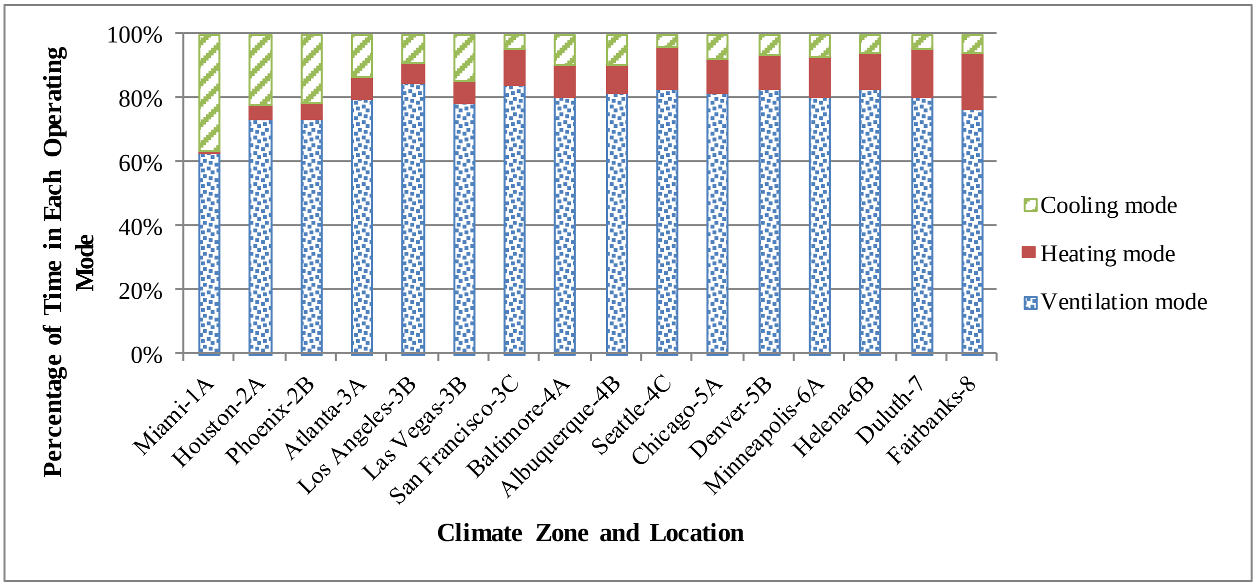

Figure 13: Percentage of Time in Each of the Operational Modes for the Supermarket Building for all 16 Locations

5.2 Impact Assessment of Individual Control Strategies on HVAC Energy Uses

With the HVAC energy uses for all 22 cases, the annual HVAC energy savings for each of the 21 advanced control combinations (cases) can be easily calculated as the difference between energy consumption for the base case and an advanced case for a given building type. The results are provided in Appendix C. To provide insights into the impact of advanced control combinations on the savings of different fuel sources, the results are presented for the total energy savings (Table C1 through C16), the electricity savings (Table C17 through C32), and the gas savings (Table C33 through C48). In all tables, the energy savings are shown as both absolute values and the percentages of the base case (Case 1) annual energy consumption. The difference between the tabulated energy savings for any two cases for a specific building type and location provides the average annual HVAC energy savings (i.e., consumption change) when changing from one combination of packaged-unit control strategies to another. Based on these results, the impact of air-side economizer, multi-speed fan control, DCV, and staged cooling is evaluated individually below.

The impact of an air-side economizer based on differential dry-bulb temperature is investigated in two steps: 1) the nonintegrated economizer control compared to the base case control is studied first, and 2) the results for the integrated economizer are then compared with the energy savings for the nonintegrated economizer control to obtain the additional benefits from integrating the air-side economizer with the mechanical cooling system. The integrated economizer option allows use of mechanical cooling to meet any cooling load that is not met by the economizer when outdoor conditions are suitable for economizing (compared to a packaged unit with a nonintegrated economizer that does not operate the economizer and mechanical cooling simultaneously), thus providing additional savings.

Comparing the energy consumption of Case 2 with the baseline (Case 1) provides the energy savings attributable to the nonintegrated air-side economizer using differential dry-bulb temperature as the control variable. In terms of the percentage savings (the upper part in Figure

14), the nonintegrated air-side economizer has much greater energy savings potential in warm climates (Los Angeles and San Francisco) than it has in other climates. In Los Angeles, for example, energy savings of more than 20% of the Case 1 energy consumption are achieved for the small office building. In contrast, much smaller (less than 5% of the Case 1 HVAC energy consumption) HVAC energy savings are observed for the locations with hot (e.g., Miami and Houston) or cold climates (e.g., Minneapolis and Duluth).

The percentage savings also vary with the building type. The small office building mostly has a higher percentage of energy savings than the other three building types. However, in terms of the absolute energy savings, the supermarket mostly has higher energy savings than other building types, which is simply because it has the largest floor area among the four building types.

The percentage savings from use of a nonintegrated economizer are greatest for the office building because the energy use for cooling, as a fraction of the total HVAC energy use, is greatest for the small office building compared to the other types of buildings. Furthermore, because economizing displaces mechanical cooling with "free" cooling with outdoor air, when cooling represents a greater fraction of the HVAC energy use (as with the small office building), the energy savings as a percentage of total HVAC energy use are also greater. It needs to be noted that the energy savings impacts of air-side economizer shown in Figure 14 correspond to a packaged unit having a single-speed fan, single-stage cooling, and no DCV. The results vary slightly with changes in the other advanced controls present on the packaged unit. For example, the percentage HVAC energy saving from the use of an air-side economizer decreases if the unit has multi-speed fan control rather than a constant fan speed, as can be found by comparing Cases 7 and 6.

For packaged single-zone rooftop units, switching from a nonintegrated economizer to an integrated economizer yields little energy savings. In hot-humid climates such as Miami, the use of integrated dry-bulb economizers may even increase the cooling energy consumption, as can be found by comparing Case 2 and Case 4 in Appendix B. This energy increase can occur because 1) the control logic based on differential dry-bulb temperature may causes the OA damper to fully open when the outdoor-air condition is cool but sufficiently humid to make the enthalpy of the outdoor air greater than the enthalpy of the return air (Taylor and Cheng 2010), and 2) the use of an integrated economizer increases the frequency at which this incorrect control decision occurs.

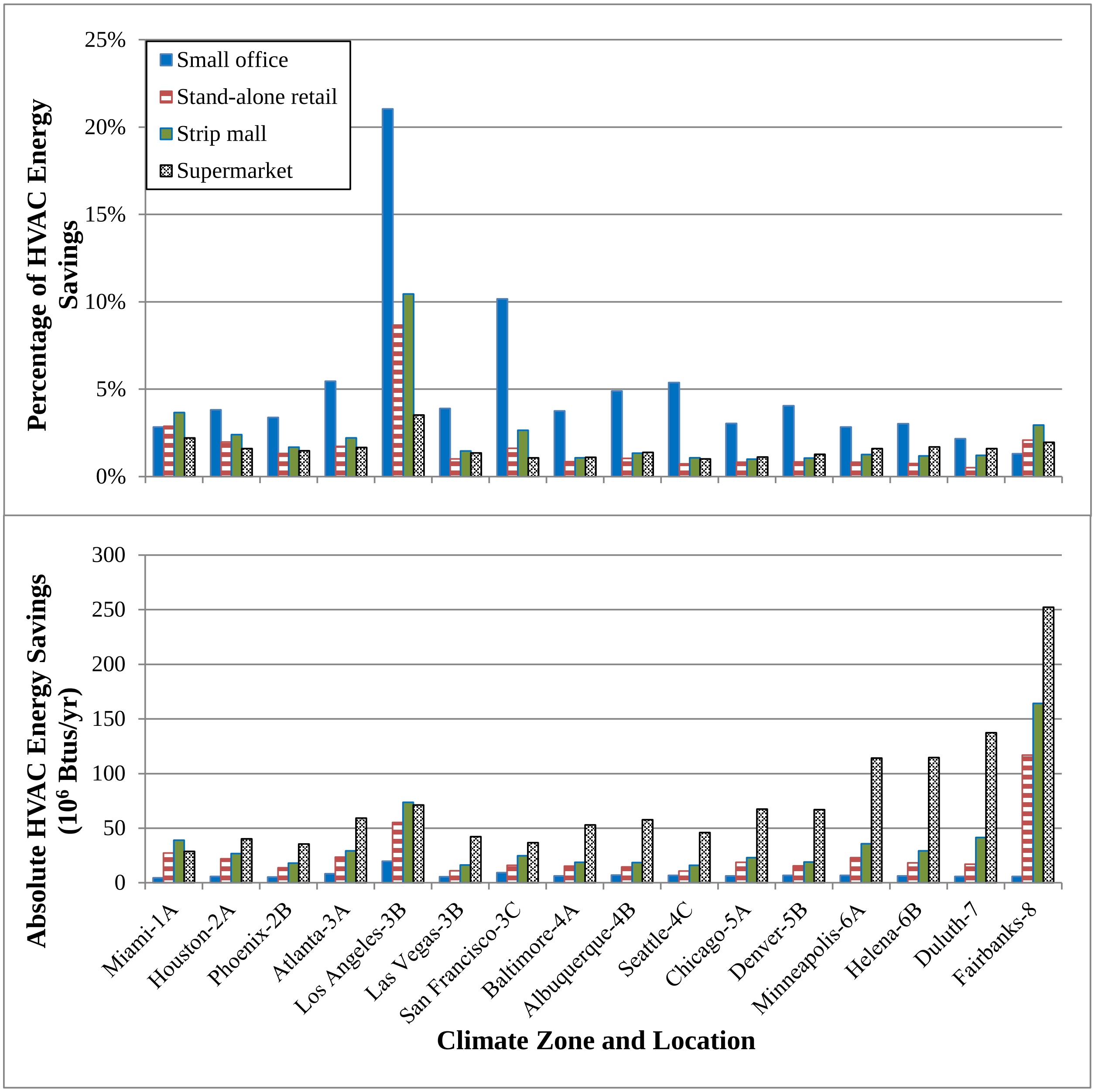

Figure 14: HVAC Energy Savings from the Use of Nonintegrated Air-Side Differential Dry-Bulb Economizer Controls (Case 2) Compared to the Base Case without Air-Side Economizer

Figure 15 shows the change of HVAC energy consumption from replacing nonintegrated differential dry-bulb economizing (Case 2) with nonintegrated differential enthalpy economizer control (Case 3). The upper part of the figure shows the energy savings as percentages of Case 2 HVAC energy consumption, whereas the lower part shows the energy savings as absolute values. Because a constant-speed fan is used for both cases, the fan energy consumption is identical. Therefore, the difference in HVAC energy consumption shown in Figure 15 results from changes in the energy required for cooling only. The negative values show that the differential enthalpy-based economizer control saves no cooling energy. In fact, it increases the energy consumption. This result is expected for dry climates such as Los Angeles and Duluth. However, it is somewhat unexpected in humid climates such as Miami and Chicago, where differential enthalpy-based economizer control would intuitively be expected to perform more effectively than differential dry-bulb temperature-based economizer control. This phenomenon needs to be further investigated for possible explanations.

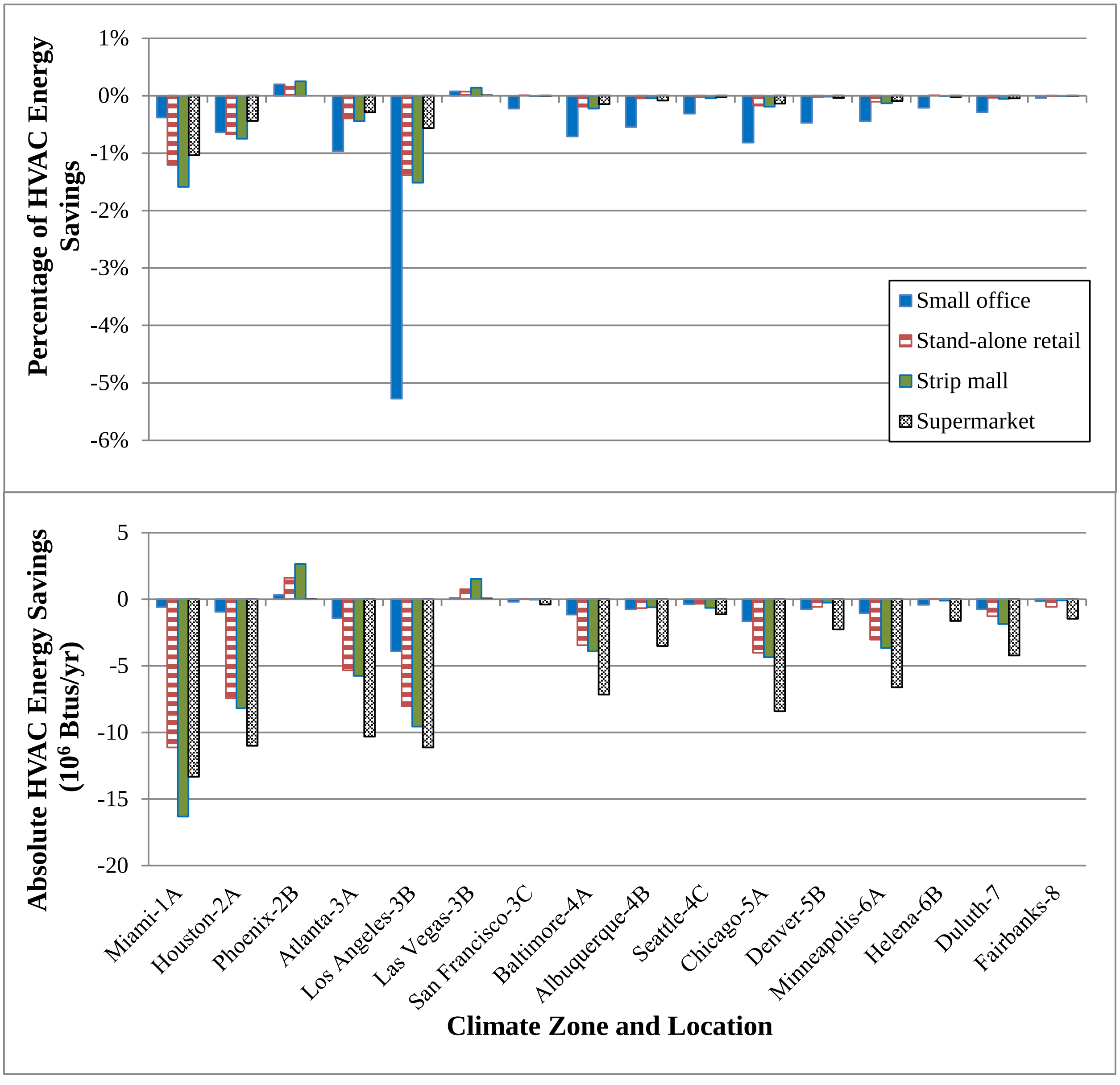

Figure 15: HVAC Energy Savings from use of a Nonintegrated Air-Side Differential Enthalpy Economizer in place of a Nonintegrated Differential Dry-Bulb Economizer for Four Building Types

The impact of supply-fan control on HVAC energy consumption can be investigated by comparing two cases, one using single-speed fan control and the other using multi-speed fan control. Figure 16 shows the change of HVAC energy consumption between the base case and Case 6, which uses multi-speed supply fan control. The upper part of the figure shows the energy savings as percentages of the base case HVAC energy consumption whereas the lower part shows the energy savings as absolute values. From Figure 16, the following observations are made:

- For all 4 building types, replacement of constant-speed fan control with multi-speed fan control yields energy savings of about 10% or more of the baseline HVAC energy consumption in hot climates (climate zones 1 and 2). However, the multi-speed fan option increases the HVAC energy consumption in cold climates (climate zones 6, 7 and 8). This observation can be explained by the impact of supply-fan control on energy end uses. The use of multi-speed fan control can significantly reduce fan energy use as a result of the fan speed reduction in a large fraction of the total fan operation time. Because fan power use is proportional to approximately the cubic power of the air flow rate, the significant decrease in fan speed provides substantial energy savings for fan operation. The fan energy reduction also contributes to reduction in cooling energy use because heat gains from the supply-fan motor also decrease. Therefore, multi-speed fan control can achieve significant energy savings in hot climates, where fans and mechanical cooling often account for more than 60% of the total HVAC energy use. In contrast, in cold climates with large heating loads, heating dominates the total HVAC energy consumption, and the increased heating energy required to compensate for the substantial decrease in heat loss from the supply-fan motor usually exceeds the decrease in cooling and fan energy use while the unit operates in cooling mode, resulting from the change from constant-speed to multi-speed fan control. As a result, the overall annual HVAC energy consumption increases in cold climates. Although not shown in Figure 16, savings on energy costs result even in heating-dominated climates because the decrease in the cost for highly priced electricity is greater than the cost increase for lower-priced gas used for heating.
- The impact of multi-speed fan control on energy consumption varies with building type. In terms of the percentage energy saving relative to the base case (Case 1) energy consumption, the office building and the supermarket building have higher savings than the two retail buildings in three locations, including Miami (climate zone 1A), Houston (climate zone 2A), and Phoenix (climate zone 2B). The small office building maintains its highest percentage savings (or lowest percentage of energy increases) for all examined locations in climate zones 3 through 8. The supermarket building shows an energy increase in many locations belonging to climate zones 4 through 8. In terms of the absolute values of energy consumption changes, the use of multi-speed fan control has the largest impact on the supermarket building, while it has the smallest impact on the small office building. This difference in absolute energy savings among the building types is mainly caused by the difference in building size.

Certainly, the energy saving potential from multi-speed supply-fan control depends on the advanced control strategies already present on a packaged unit when multi-speed fan control is added. In addition to the comparison between Case 6 and the baseline, the impact of supply-fan control on energy savings can be investigated also by comparing a pair of other cases with multi-speed supply-fan control as the only difference. Several examples of such case pairs are Case 7 vs. Case 2, Case 9 vs. Case 4, Case 18 vs. Case 15 and Case 19 vs. Case 16.

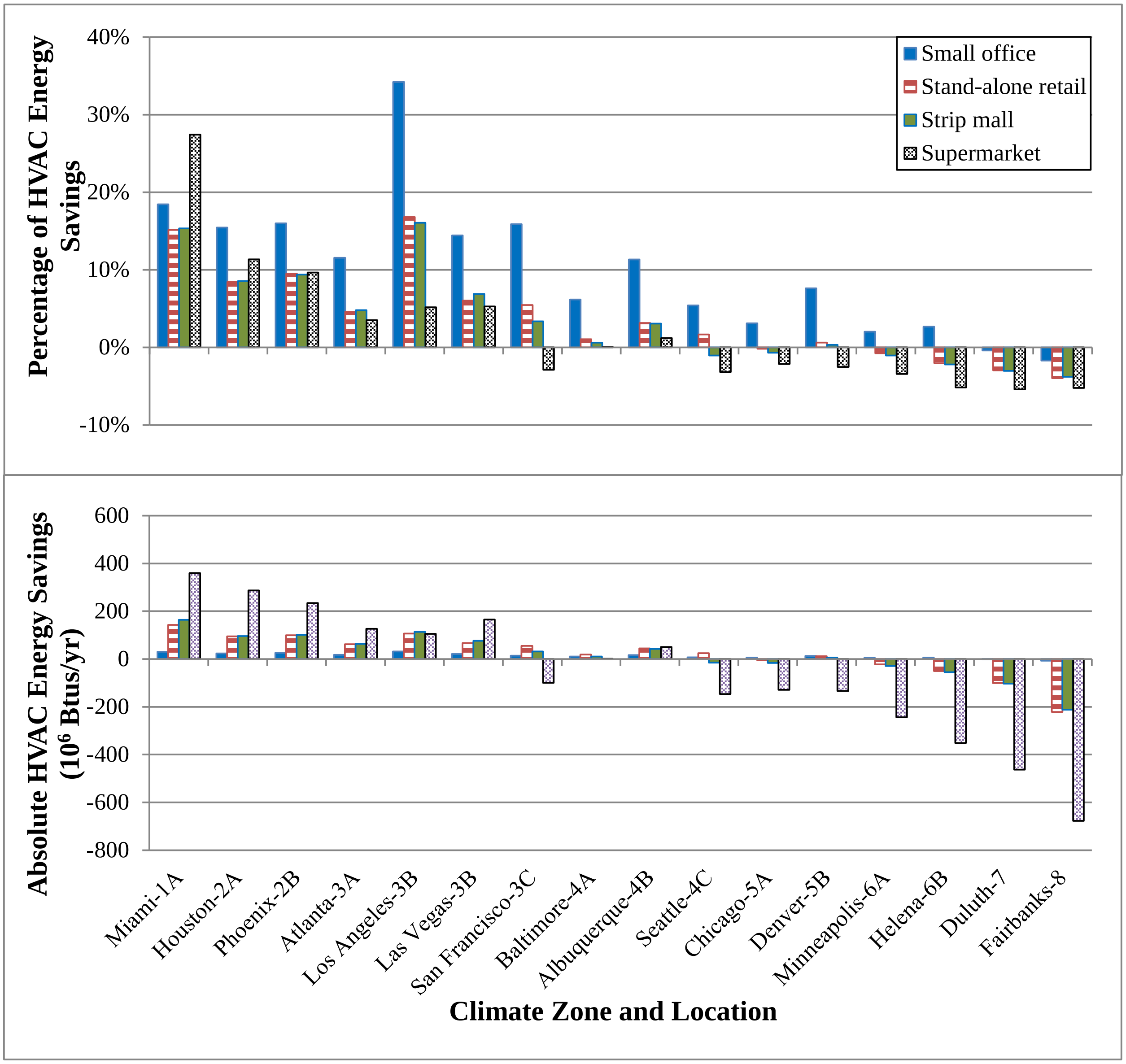

Figure 16: HVAC Energy Savings from the Use of Multi-speed Supply-Fan Control (Case 6) Compared to the Base Case with Constant-Speed Fan Control

The impact of demand controlled ventilation (DCV) on HVAC energy consumption can be investigated by comparing two cases, one using DCV and the other not using it. Figure 17 shows the change of HVAC energy consumption between the base case and Case 14, which differs from the base case only by the presence of DCV. The upper part of the figure shows the energy savings as percentages of the base case HVAC energy consumption whereas the lower part shows the energy savings as absolute values.

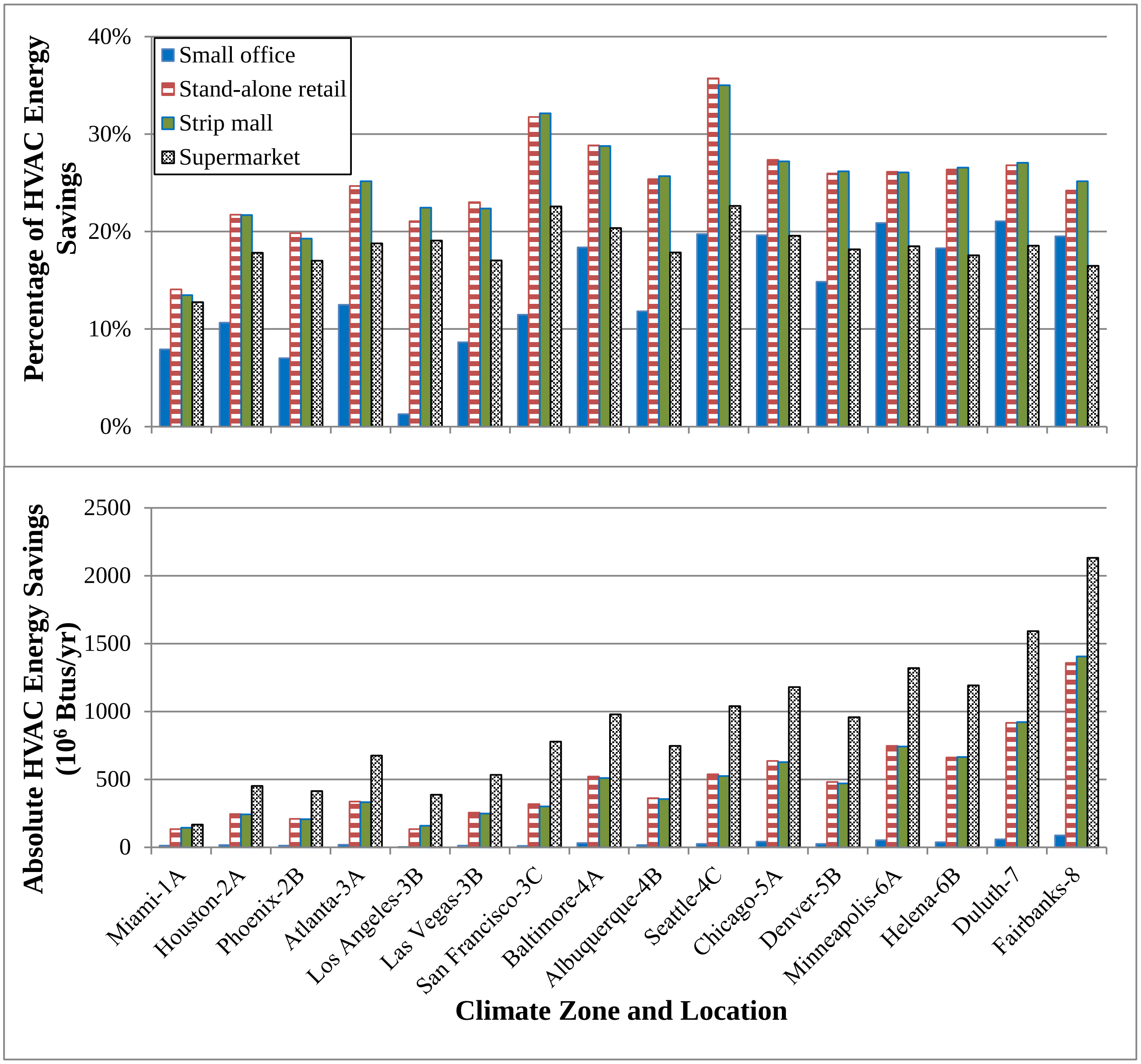

Figure 17: HVAC Energy Savings from the Use of Demand Controlled Ventilation (Case 14) Compared to the Base Case with Constant Outdoor-Air Supply

From Figure 17, the following can be observed:

- DCV provides HVAC energy savings of more than 10% of the base case energy consumption in all cases except for the small office building in Miami, Phoenix, Los Angeles, and Las Vegas. The largest percentage (approximately 35%) energy savings occurs in Seattle for the stand-alone retail and the strip mall buildings.
- DCV achieves a smaller percentage HVAC energy savings for the small office building than it does for the other building types (except in the very cold climate of Duluth and Fairbanks). The difference in savings between building types can be attributed to some extent to their different occupancy profiles. Figure 18 shows the weekday occupancy profiles where the stand-alone retail building and the strip mall have the same occupancy

schedule. For most occupied hours, the small office building has a more constant and higher occupancy ratio than the other three building types. A stable ventilation requirement close to the peak design limits the potential of energy savings from DCV.

- DCV seems to be more effective in the climates that have cold winters (climate zones 4 through 8). DCV is less effective in mild climates for two reasons. First, in mild climates, the outdoor-air temperature is close to the return-air temperature during much of the occupied period. Therefore, the amount of outdoor air exceeding ventilation requirements brought in by the packaged unit has less impact on energy consumption in mild climates than it has in harsher climates. Second, Case 14 and the base case have no air-side economizers. If DCV is used without an air-side economizer, reducing the OA flow rate may increase energy consumption when the system is in cooling mode and the outdoor-air condition is favorable for economizing. This situation is expected to occur more often in mild climates.

Again, the energy savings potential from DCV depends on the other control strategies already used by the packaged unit. In addition to the comparison between Case 14 and the baseline, the impact of DCV on energy savings can also be investigated by comparing other case pairs such as Case 15 vs. Case 4 and Case 17 vs. Case 6. For example, comparing Case 17 and Case 6 leads to the impact of DCV when the packaged units have already used the multi-speed supply-fan control.

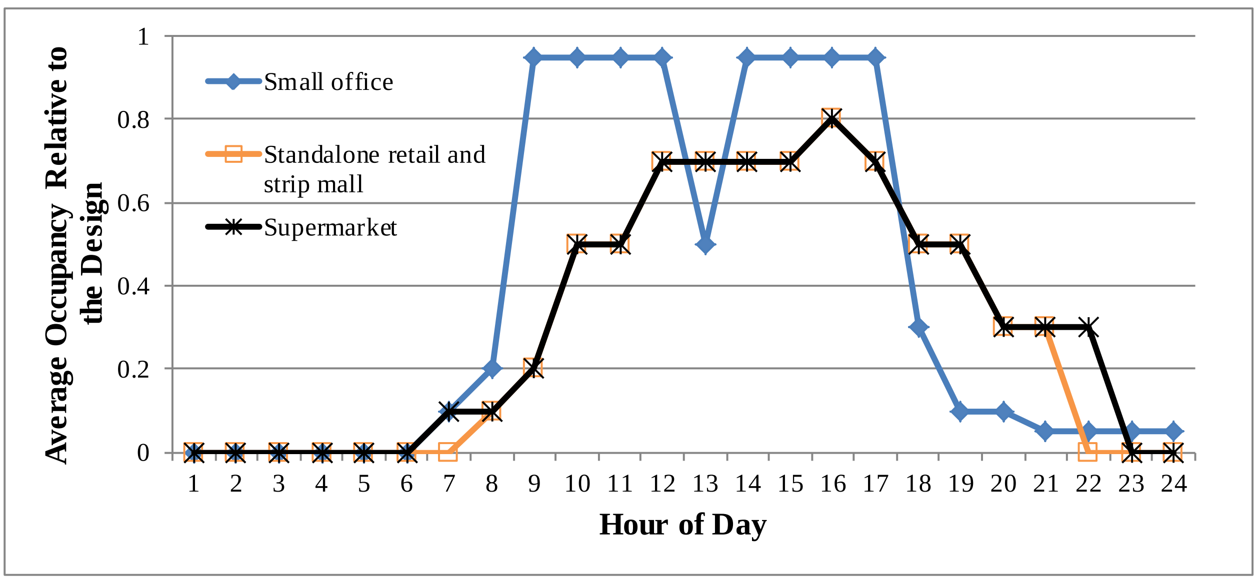

Figure 18: Weekday Occupancy Schedules for the Four Building Types

Retrofit devices are available on the market to vary the speed of compressor in existing rooftop units (Criscione 2011). Therefore, it is technically feasible to upgrade from one-stage cooling to multi-stage cooling without changing the whole compressor. The impact of two-stage cooling on HVAC energy consumption can be investigated by comparing two cases, one using two-stage cooling and the other using single-stage cooling. Figure 19 shows the change in total HVAC energy consumption in changing from single-stage cooling (Case 6) to two-stage cooling (Case 11). As shown, two-stage cooling is more effective in hot climates. It can save as much as 12% of the total HVAC energy use. Recall that for two-stage cooling, the supply fan runs at 75% and 100% of its full design speed, respectively, in the first and second stage, while it runs at the full speed in the cooling mode when there is only single-stage cooling. Because the cooling efficiency does not vary with cooling stages, the energy savings associated with staged cooling result mostly from the reduced supply-fan energy. The decrease in fan energy use also leads to a decrease in energy use for mechanical cooling because less heat is rejected by the supply fan to the supply air stream. Since staged cooling reduces energy consumption for fan operation and cooling, it is more effective in hot climates where cooling requirements are greater. Similarly, because the energy used for fan operation and mechanical cooling in the small office building represents a larger fraction of the total HVAC energy use than it does in the other building types, staged cooling achieves a higher percentage of energy savings for the small office building.

Similar results for the impact of staged cooling can be obtained by comparing other pairs of cases such as Case 13 vs. Case 10 and Case 21 vs. Case 18. In addition, it needs to be noted that one major advantage of staged cooling is to reduce the frequency of compressor on-off cycles. Because the simulation model does not consider the efficiency reduction caused by compressor cycling, the energy saving results shown in Figure 19 are likely somewhat underestimated.

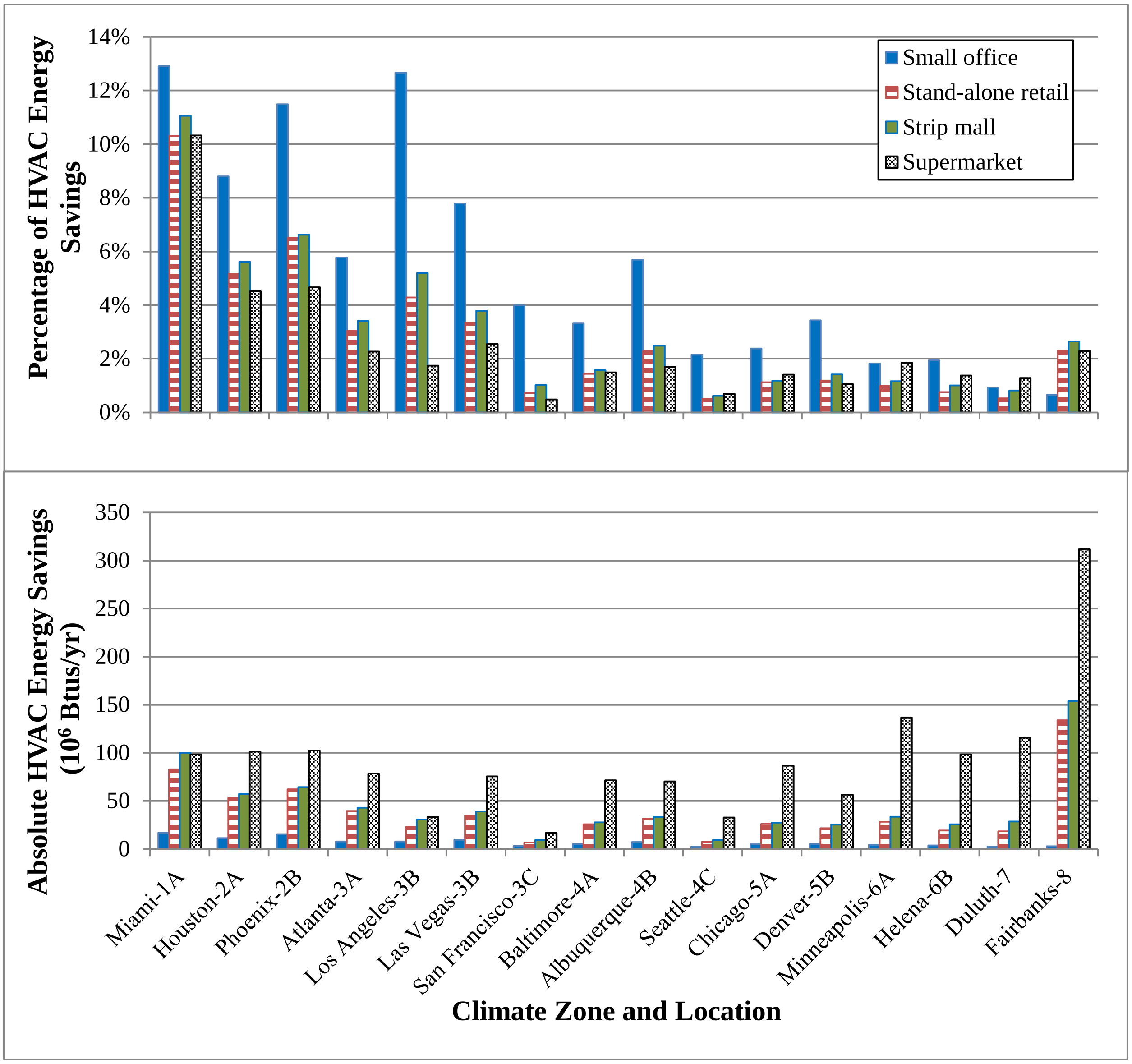

Figure 19: HVAC Energy Savings from the Use of Two-Stage Cooling (Case 11) Compared to Single-Stage Cooling (Case 6)

5.3 Incremental Impact of Selected Advanced Control Strategies on HVAC Energy Uses

The results presented in Section 5.2 have focused on the impact of individual control strategies with Case 1 mostly selected as the common base case. It is worthwhile to investigate the incremental impact on HVAC energy savings of adding control strategies gradually (one at a time). In addition, in this section, the HVAC energy savings are broken down into the fan energy savings, the cooling energy savings, and the heating energy savings to better characterize how each control strategy affects the primary components of HVAC energy use.

Five cases (Cases 1, 6, 7, 9 and 18) from Table 4 are selected to illustrate the impact on energy savings of incrementally adding control strategies. The sequence of incrementally adding control strategies is:

- Starting with a packaged unit with none of the advanced control features, add supply-fan multispeed control (Case 1 to Case 6)
- Add a nonintegrated air-side economizer based on differential dry-bulb temperature control to the unit having multiple-speed supply-fan control as the only advanced control feature (Case 6 to Case 7)
- Change the economizer control from nonintegrated to integrated (Case 7 to Case 9)
- Add DCV to Case 9 (Case 9 to Case 18).

Figure 20 through Figure 23 show the incremental total HVAC energy savings for all 16 locations. The incremental energy savings may be negative if adding a control strategy leads to an increase in HVAC energy consumption. The sum of these incremental energy savings (both positive and negative) equals the total savings for Case 18 (compared to the base case, Case 1). It can be seen from these figures that:

- Multi-speed fan control and DCV are the two control strategies that contribute most to the HVAC energy savings. Specifically, multi-speed fan control dominates the impact in a small number of cases, including all four building types in Miami and the small office building in Houston, Phoenix and Los Angeles. DCV dominates the impact for all other cases. The multi-speed fan contribution to savings can be negative in cold climates (e.g, Duluth and Fairbanks for all building types).
- Adding an air-side economizer after multi-speed fan control does not have a large impact on HVAC energy savings except for a few cases, such as the small office building in Los Angeles. In comparison with a nonintegrated economizer, the integrating economizer has negligible impact on HVAC energy savings.

All of these findings are consistent with those for the individual control strategies.

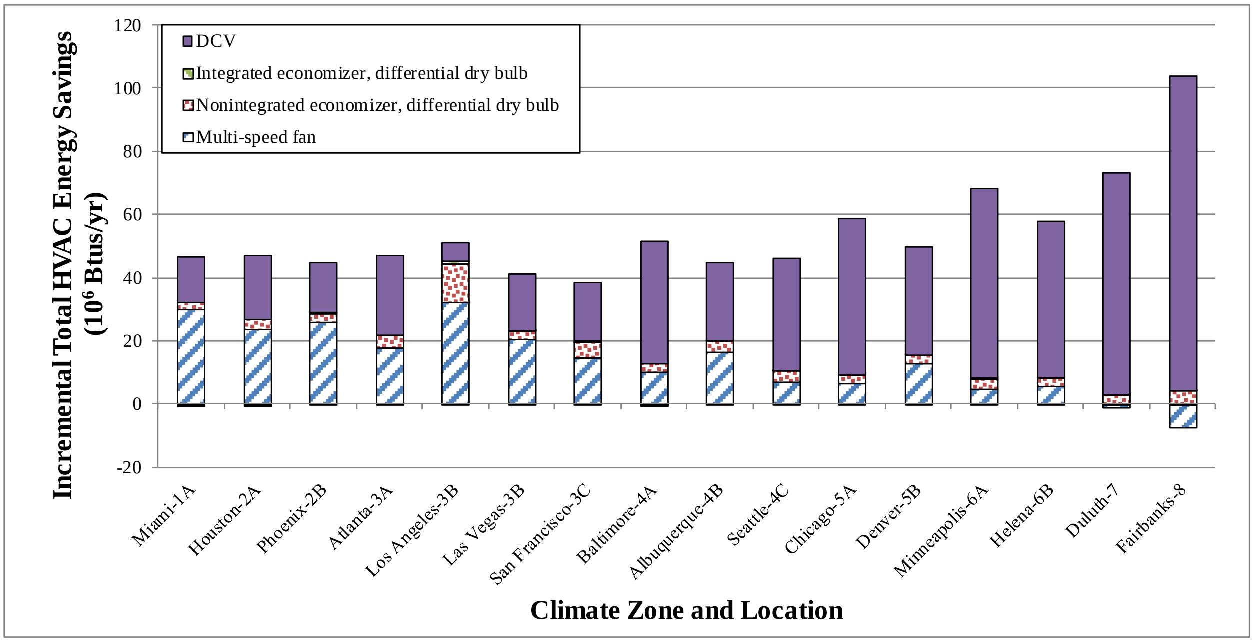

Figure 20: HVAC Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Small Office Building

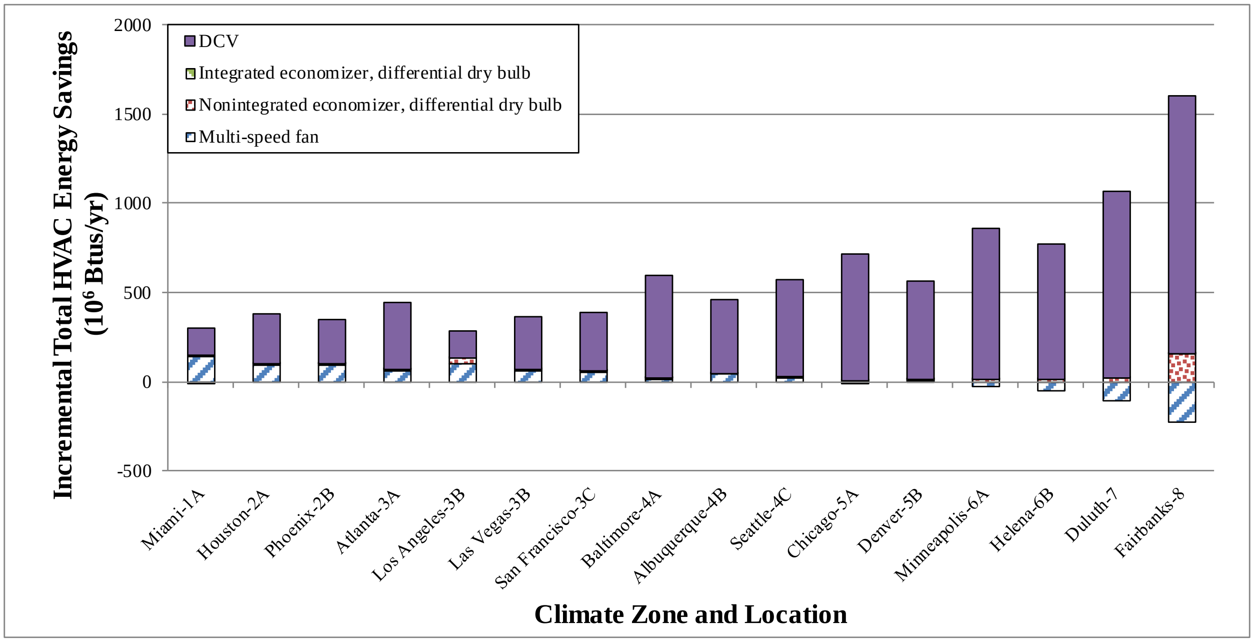

Figure 21: HVAC Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Stand-alone Retail Building

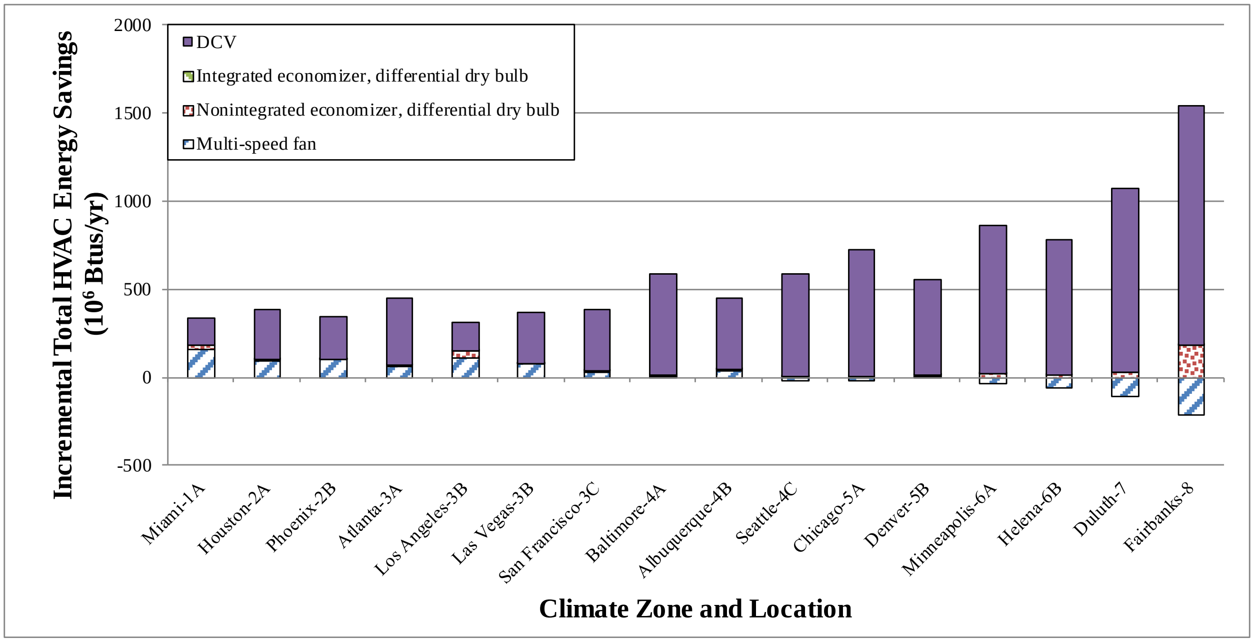

Figure 22: HVAC Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Strip Mall Building

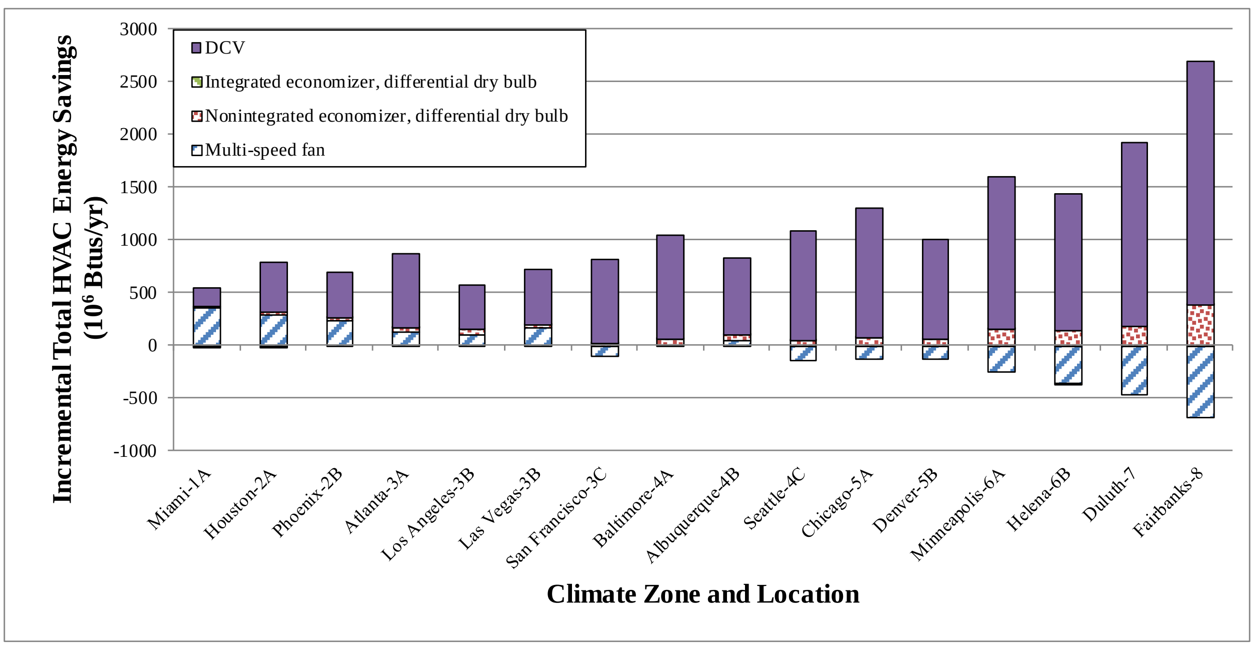

Figure 23: HVAC Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Supermarket Building

Figure 24 through Figure 27 show the incremental contributions of the sequential addition of advanced control strategies to annual fan energy savings for all 16 locations and 4 building types. These figures show the following:

- Multi-speed fan control contributes more than 95% of the annual fan energy savings for all investigated building types and locations.
- Applying an air economizer after multi-speed fan control may cause a small increase in fan energy use. This increase can be explained by two factors. First, with an economizer, the packaged unit operates in the economizing mode for some time and thereby decreasing the time in the ventilation-only mode. Second, the supply fan runs at 40% of its full design speed in the ventilation mode, while at 75% speed in the economizing mode. For example, for the stand-alone retail building in Los Angeles, the operation mode statistics show that about 84% of all system running time lies in the ventilation mode for Case 6, but the percentage decreases to 68% in Case 7 after applying an air-side economizer.
- Adding DCV after multi-speed fan control usually contributes an additional small amount (around 5%) to fan energy savings. Because DCV leads to a decrease in conditioning load from the outdoor-air intake, it may cause a small increase in the time when packaged single-zone systems operate in the ventilation-only mode, thus decreasing fan energy use.

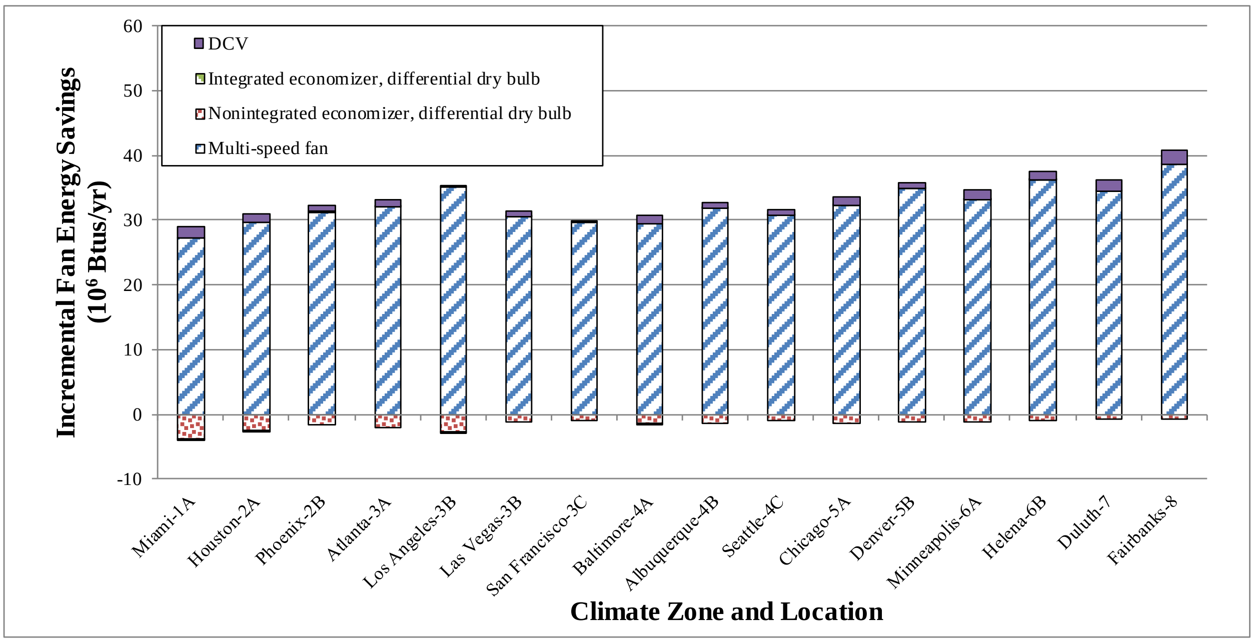

Figure 24 Annual Fan Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Small Office Building

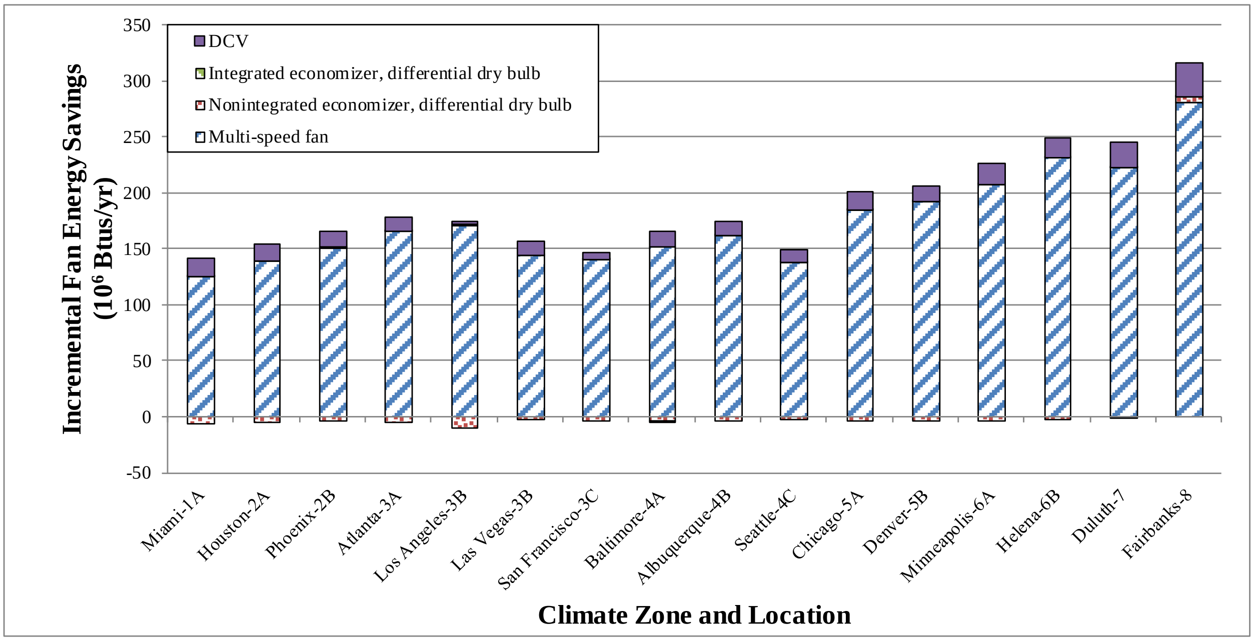

Figure 25: Annual Fan Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Stand-alone Retail Building

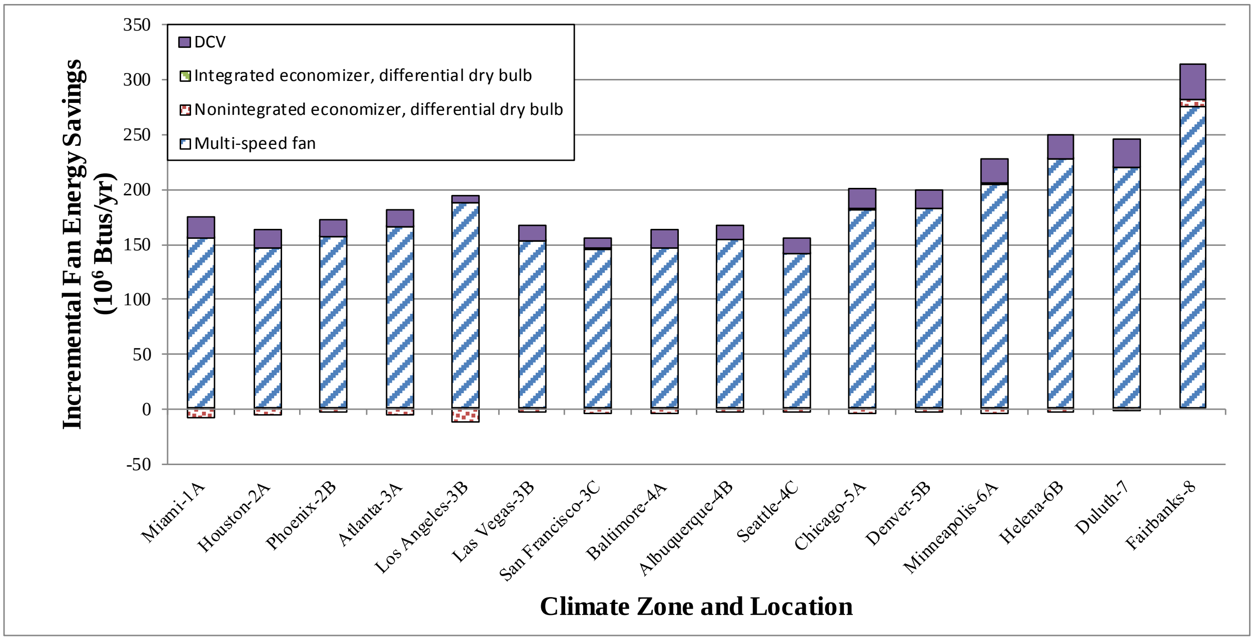

Figure 26: Annual Fan Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Strip Mall Building

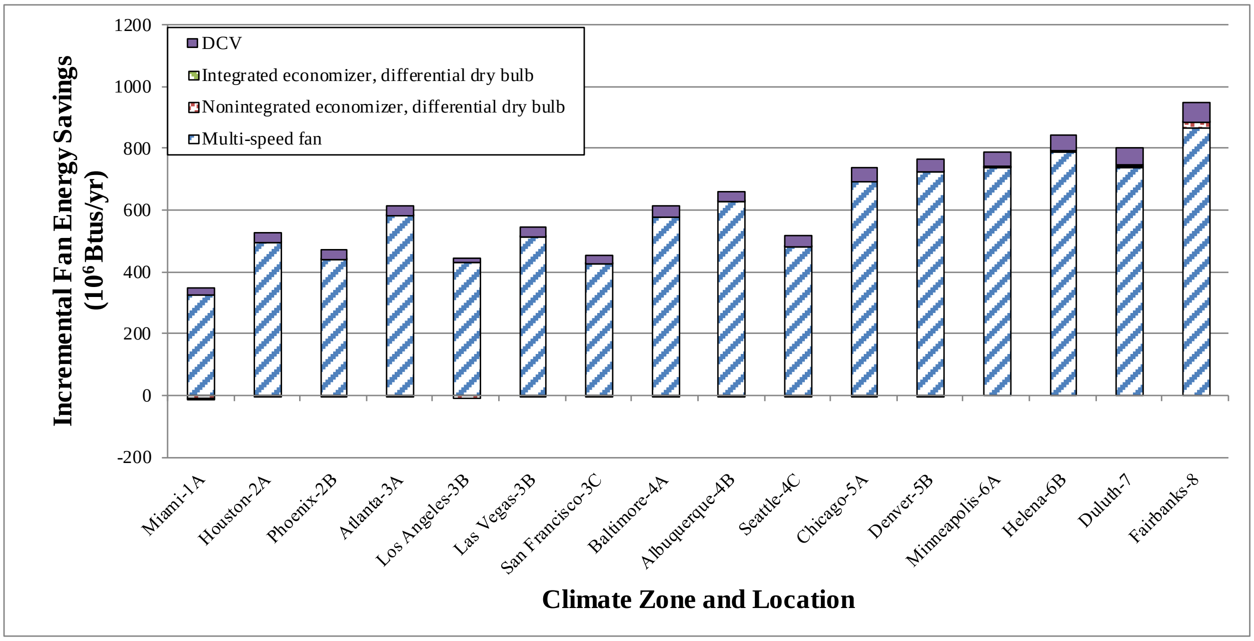

Figure 27: Annual Fan Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Supermarket

Figure 28 through Figure 31 show the annual cooling energy savings resulting from the incremental addition of advanced control strategies for all 16 locations and 4 building types. These figures show the following:

- Both multi-speed supply-fan control and the air-side economizer make noticeable contributions to annual cooling energy savings. In particular, for all four building types, the combination of those two control strategies leads to savings of more than 80% of the total cooling energy in Los Angeles, San Francisco, Seattle, and Helena, Duluth and Fairbanks.
- The air-side economizer dominates the cooling energy savings in Los Angeles and Fairbanks. However, as shown from the incremental change from Case 7 to Case 9, integrating air economizer with DX cooling has little impact on cooling energy consumption. These observations are consistent with those found previously in Section 5.2.
- DCV has significant impact on cooling energy savings in Miami, Houston, Phoenix, Las Vegas, Atlanta, and Baltimore. DCV may contribute more than 70% of the total cooling energy savings in some cases, such as the two retail buildings in Miami, Houston, Phoenix, and Las Vegas.

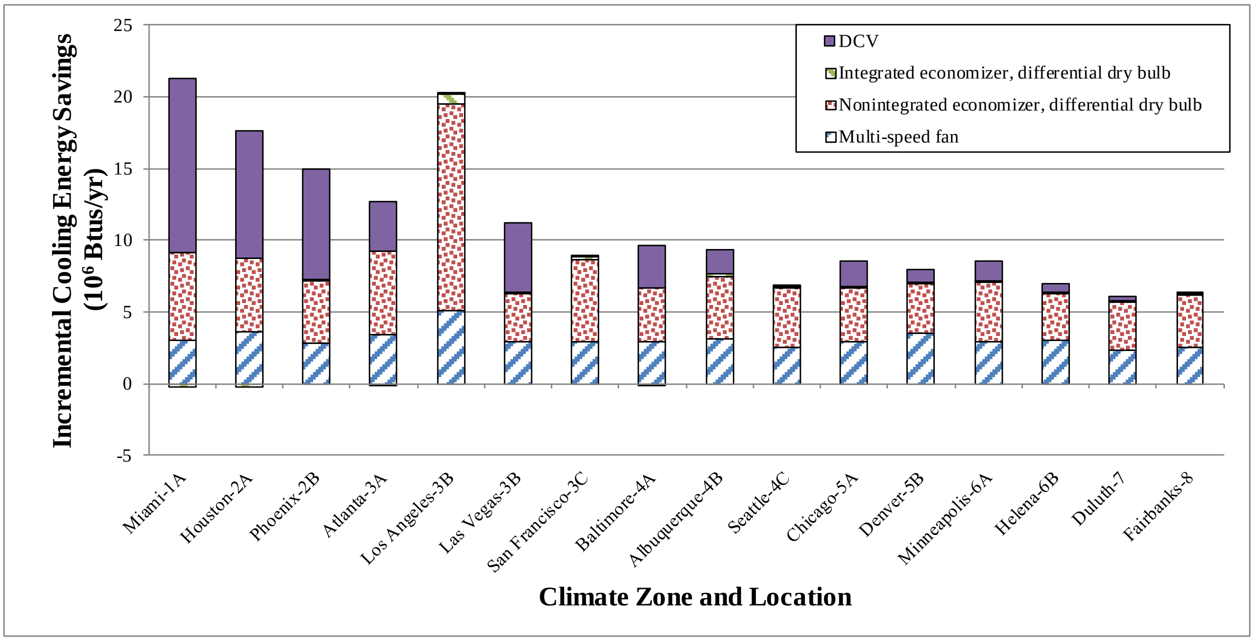

Figure 28: Annual Cooling Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Small Office Building

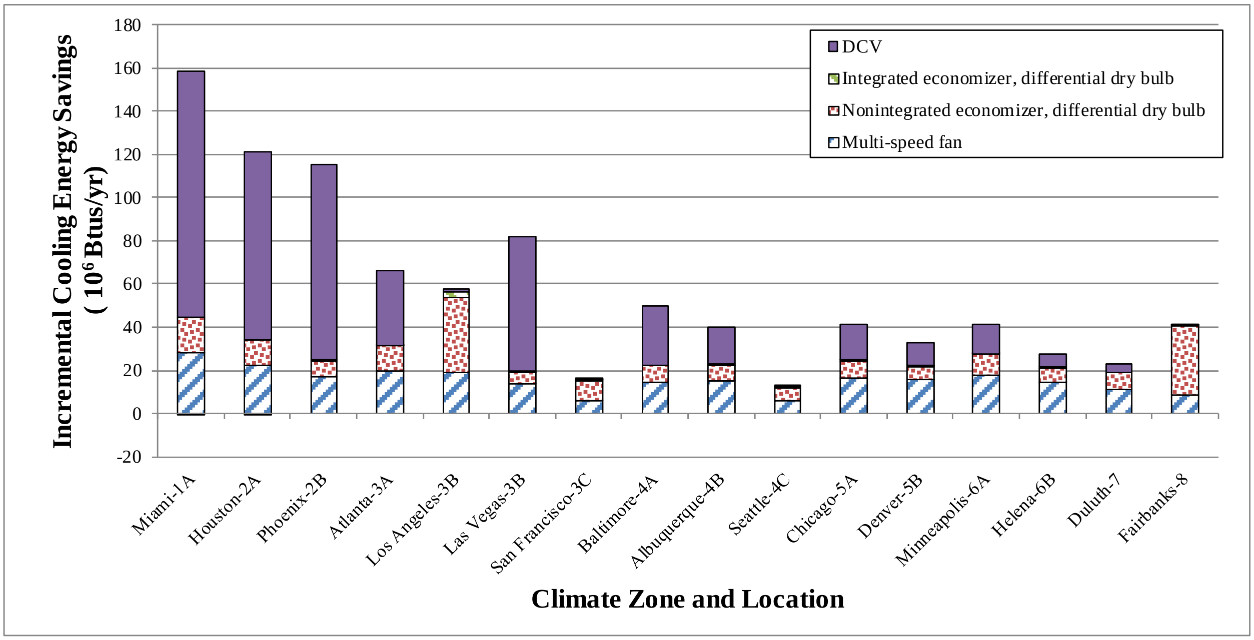

Figure 29: Annual Cooling Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Stand-alone Retail Building

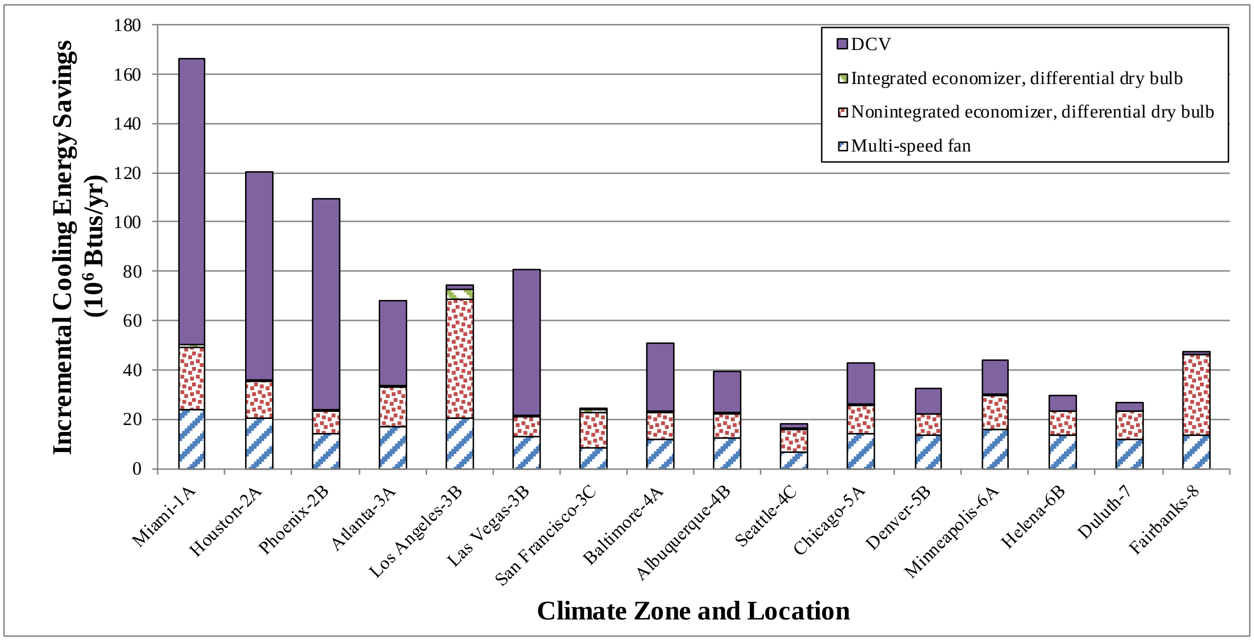

Figure 30: Annual Cooling Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Strip Mall Building

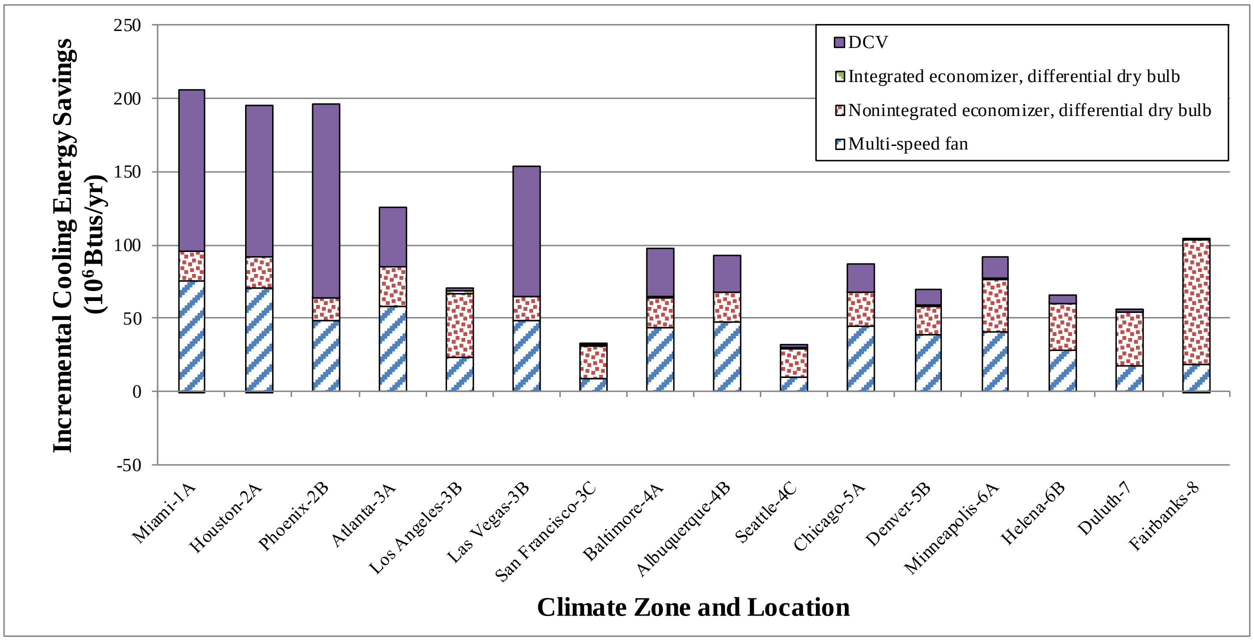

Figure 31: Annual Cooling Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Supermarket Building

Figure 32 through Figure 35 show the annual heating energy savings across all 16 locations resulting from the incremental addition of advanced control strategies. These figures show the following:

- Multi-speed fan control increases heating energy consumption in all cases. By lowering the fan speed, multi-speed fan control decreases the heat loss from the fan motor to the supply-air stream. During heating mode operation, this decrease in heat gain from the supply fan must be compensated by an increase in heating energy.

- DCV contributes almost all the heating energy savings because it decreases outdoor air intake.
- The impact of multi-speed fan control and DCV on heating energy consumption (either savings or penalties) generally increases from hot to cold climates. Because Miami has negligible heating loads, the impact of control strategies on heating can be ignored there.

Theoretically, adding air-side economizer control should not impact heating energy consumption. However, a small amount of gas saving is observed in Fairbanks for the two retail buildings and in a couple of additional cold climates for supermarket. The EnergyPlus programs sometimes can oversize equipment, especially in extreme cold or hot climates. The oversized equipment capacity may cause the space to overcool if the time step is small, say 3 minutes used for the current work. Use of the energy management system control can avoid heating immediately after cooling by tracking the operation mode in previous time steps. If the packaged unit is in cooling mode in the previous steps, heating can be curtailed even if the space temperature is below the heating set point. For the current analysis heating was curtailed if there was any cooling in the two previous time steps. For extreme cold climates, like Fairbanks, use of two time steps was not sufficient. Thus, space heating sometimes was turned on shortly after cooling. Because the overcooling problem never occurs in the economizing mode, small gas savings from the use of air-side economizer may be observed in a few cases[2].

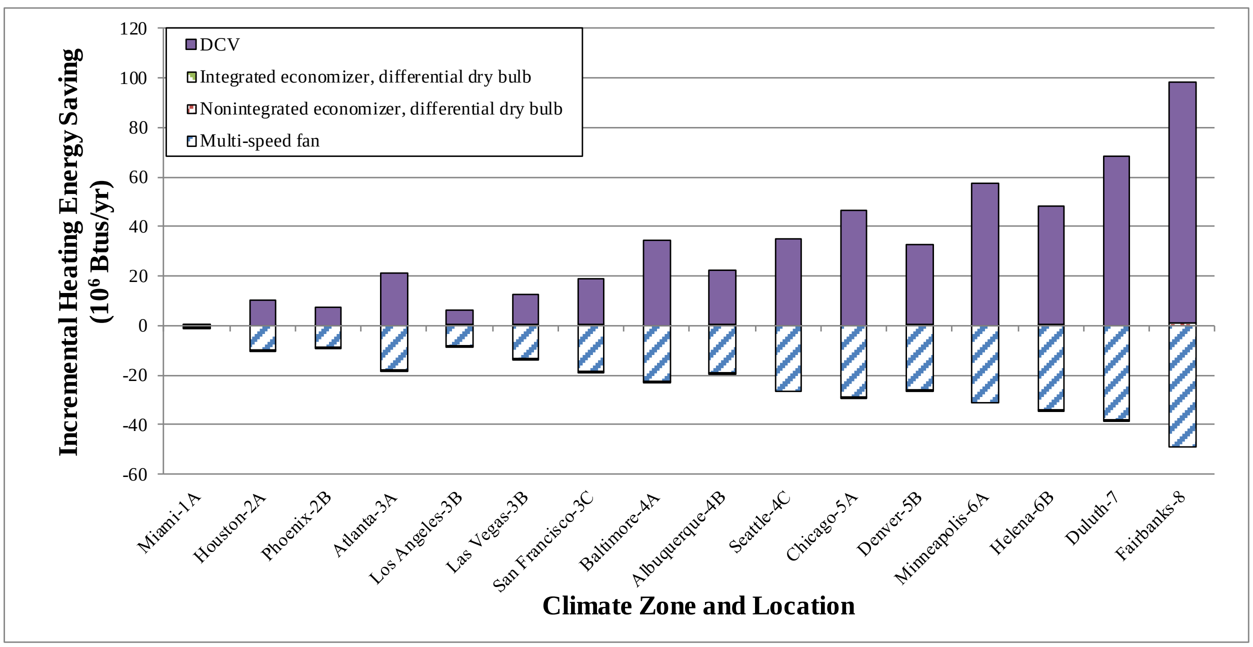

Figure 32: Annual Heating Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Small Office Building

[2]We tested the stand-alone retail model and found use of four previous time steps would avoid the issue of space heating shortly after cooling. This minor impact does not affect the conclusions made in this report.

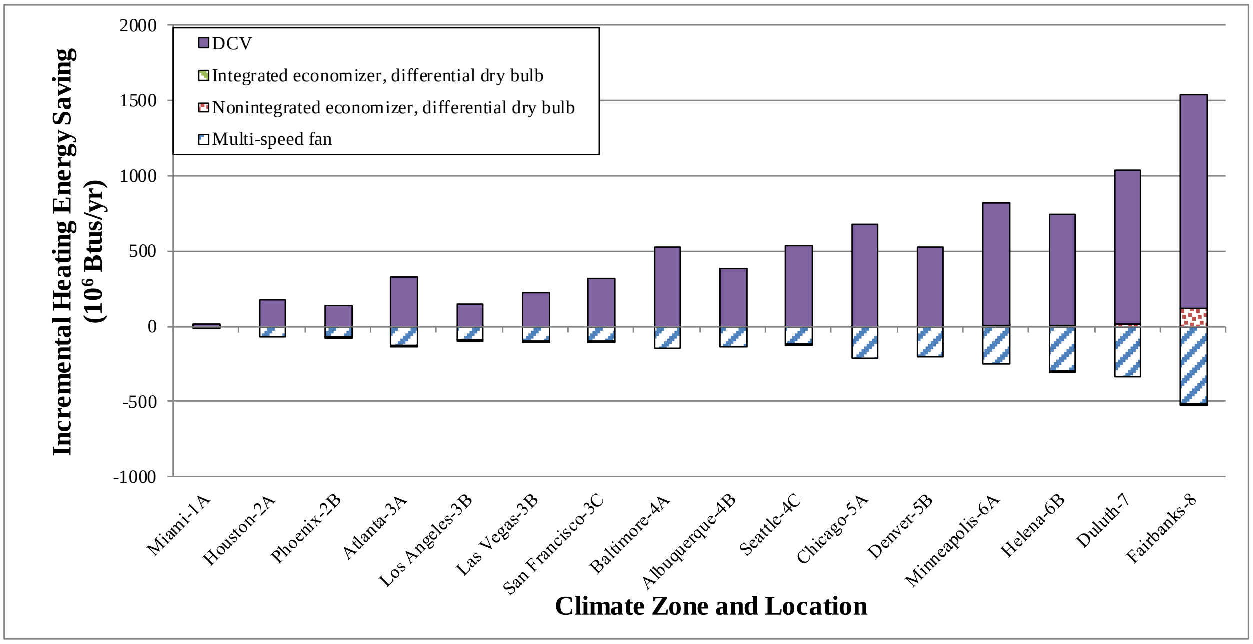

Figure 33: Annual Heating Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Stand-alone Retail Building

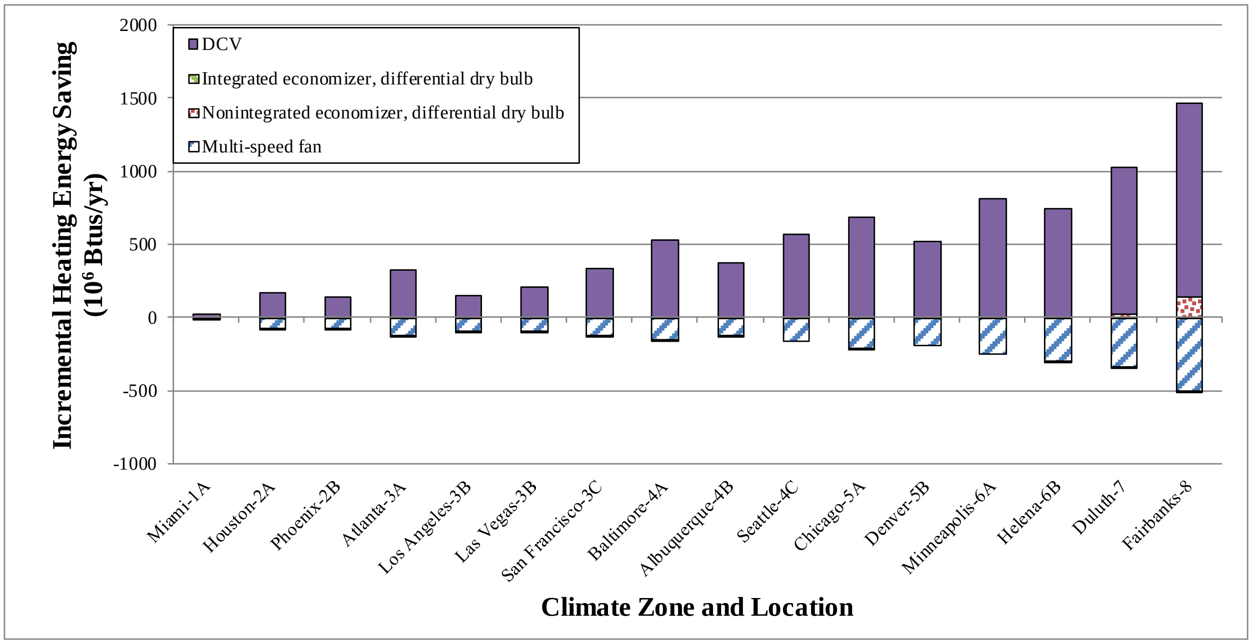

Figure 34: Annual Heating Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Strip Mall

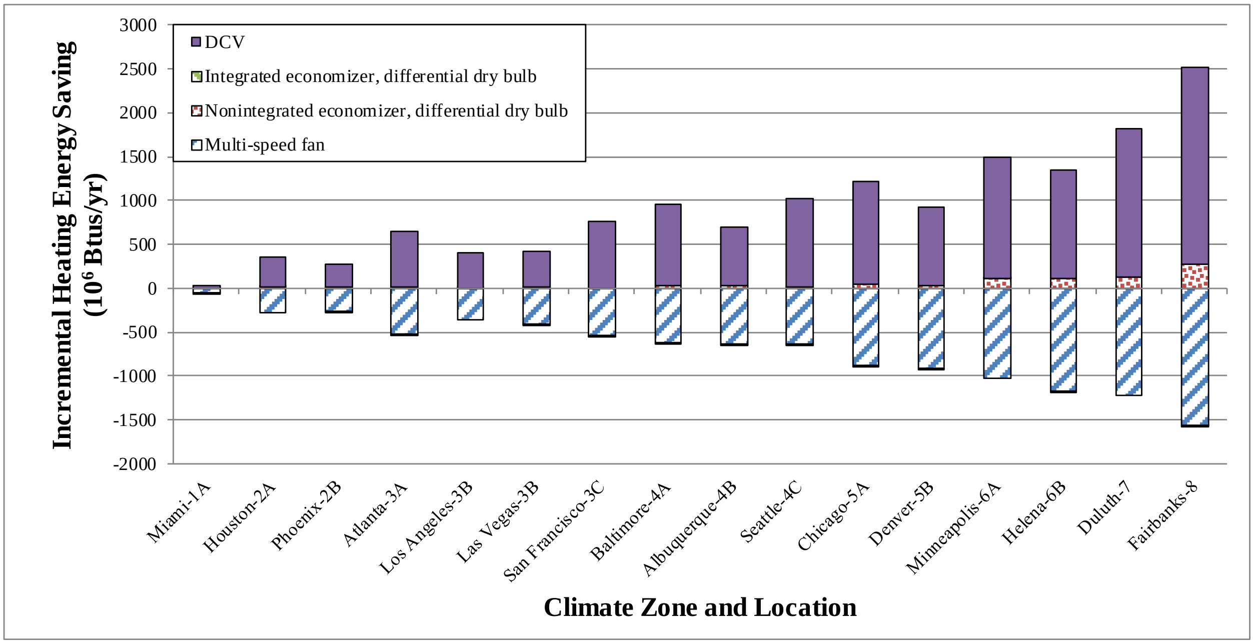

Figure 35: Annual Heating Energy Savings Resulting from Incremental Addition of Advanced Control Strategies for the Supermarket

5.4 Comparison of Energy Consumption between Case 18 and Case 4

Many existing packaged units may only have single-stage cooling and also may have an air-side economizer control. For these units, multi-speed fan control and DCV are the two strategies that can be easily added, which can result in significant energy savings. Hence, comparing a case with only air-side economizer and another case with multi-speed fan control and DCV added provides insights into a typical scenario for existing buildings. Case 4 (single-stage cooling with integrated differential dry-bulb economizer) and Case 18 (single-stage cooling, integrated differential dry-bulb economizer, multi-speed fan controls and DCV) are selected for comparison. For the four building types, Figure 36 through Figure 39 show the HVAC energy consumption (fan and cooling electricity and gas heating) of Case 18 and Case 4 for all 16 locations. The HVAC energy saving as a percentage of the energy consumption for Case 4 is also shown for each location (above the bars of the histograms). The following findings can be drawn from these figures:

- The largest absolute energy savings are obtained for Fairbanks for all building types, simply because Fairbanks has the largest HVAC loads by far. The annual absolute savings are about 91 MMBtu for the small office building, 1,268 MMBtu for the stand-alone retail building, 1,165 MMBtu for the strip mall, and 1,770 MMBtu for the supermarket. The differences in these savings among the building types attributable to both differences in the size of the buildings and also the impact of multi-speed fan and DCV on the different types of buildings.
- The smallest absolute energy savings per year are obtained for San Francisco for the small office buildings (29 MMBtu), and Los Angeles for the other three building types (232 MMBtu for stand-alone retail building, 237 MMBtu for the strip mall, and 500 MMBtu for the supermarket).

- The changes in total HVAC energy savings as a percentage of the energy consumption for Case 4 have similar variations with location (and climate) for the small office, stand-alone retail, and strip mall buildings. The percentage generally decreases from mild (Los Angeles, San Francisco and Seattle) to hot and then from hot to cold climates. Such trends can be explained by a couple of factors. First, the energy use intensity (EUI) for Case 4 (baseline in this comparison) is greater in cold climates but small in mild climates, and therefore, the same absolute energy savings corresponds to a smaller percentage of the baseline energy use for locations with larger values of the baseline energy consumption (or EUI). Second, as reported in Section 5.3, multi-speed fan control contributes significantly to the decrease in energy use for cooling. On the other hand, when fan energy use decreases, more heating energy is needed during heating mode to compensate for lower heat gains from the supply-fan motor. Because the space heating energy consumption is low in hot and mild climates, the overall impact of a multi-speed fan is more favorable in hot and mild climates.
- The results for the supermarket building in Figure 39 show variations with location different than those for the other three building types. The percentage of energy savings generally decreases from the hot and humid climate (Miami–Zone 1A) to the extreme cold climate (Fairbanks – Zone 8). For this trend, similar explanations can be given as those for the other three building types. First, the annual energy use of the supermarket generally increases from hot to cold climates because cooling provided by refrigerated cases and freezers contributes to cooling the store under hot outdoor conditions but also contributes to the need for heat during cold outdoor conditions. Second, because supermarket heating needs are more significant than for the other building types, reduced heat gains from multi-speed fans increase the heating energy consumption in the supermarket building.
- The percentage of HVAC energy savings lies in the range between 20% and 42% for the small office building, 23% and 40% for the stand-alone retail building, 21% and 40% for the strip mall, and 14% and 41% for the supermarket. The maximum HVAC energy saving as a percentage of the energy consumption for Case 4 occurs in Los Angeles for the small office building and the retail building, in San Francisco for the strip mall, while it occurs in Miami for the supermarket. The minimum percentage savings occurs in Fairbanks for all four building types. For all 16 locations (15 climates), Case 18 has an average HVAC energy savings of about 28% for small office, 32% for the stand-alone retail and strip mall buildings, and 24% for the supermarket. A summary of these savings is provided in Table 8.

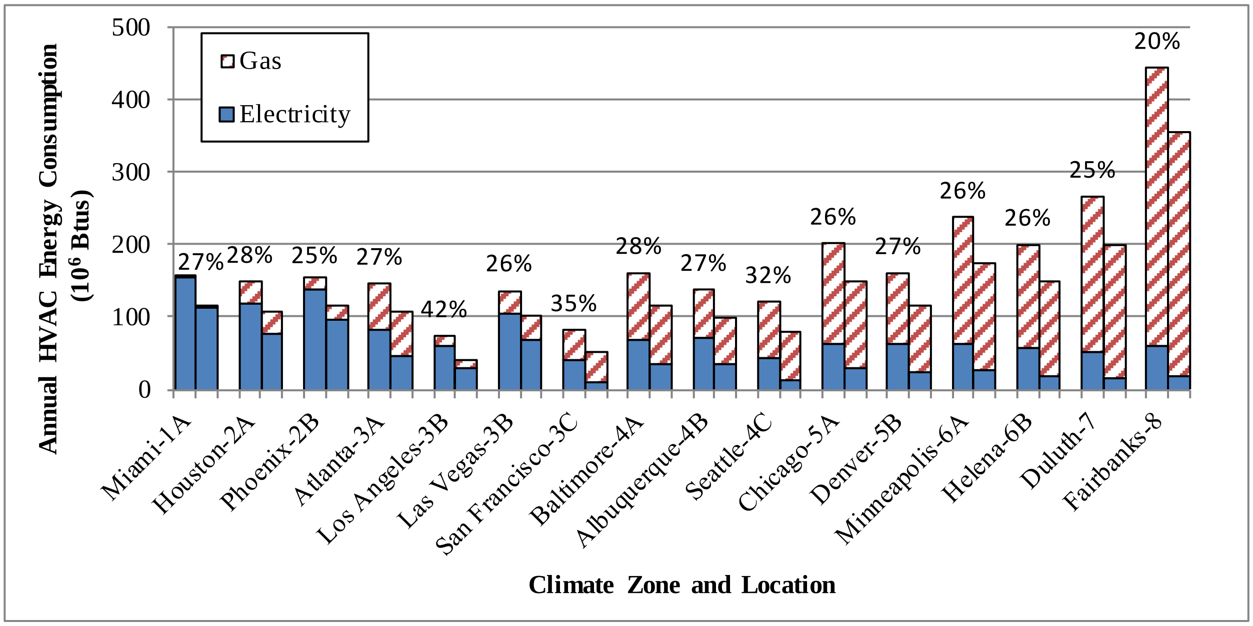

Figure 36: Comparison of HVAC Energy Consumption between Case 4 (left bar for each location) and Case 18 (right bar for each location) for the Small Office Building. Percent Difference in the Total Energy Consumption between Case 4 and Case 18 is also shown for Each Location.

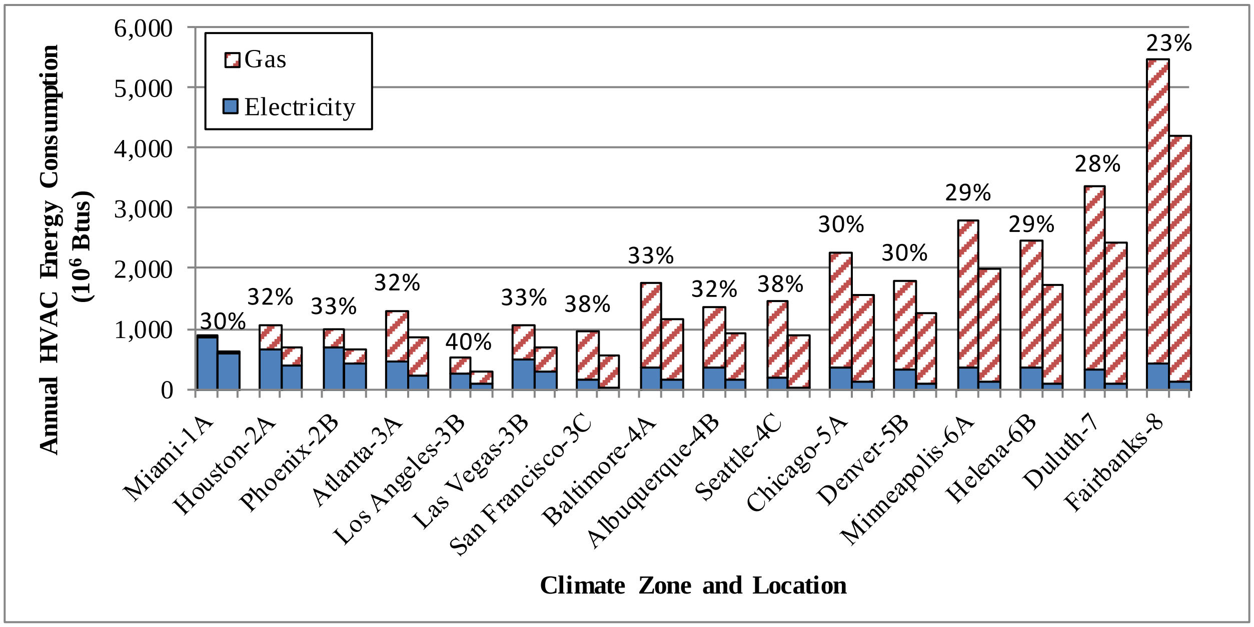

Figure 37: Comparison of HVAC Energy Consumption between Case 4 (left bar for each location) and Case 18 (right bar for each location) for the Stand-alone Retail Building. Percent Difference in the Total Energy Consumption between Case 4 and Case 18 is also shown for Each Location.

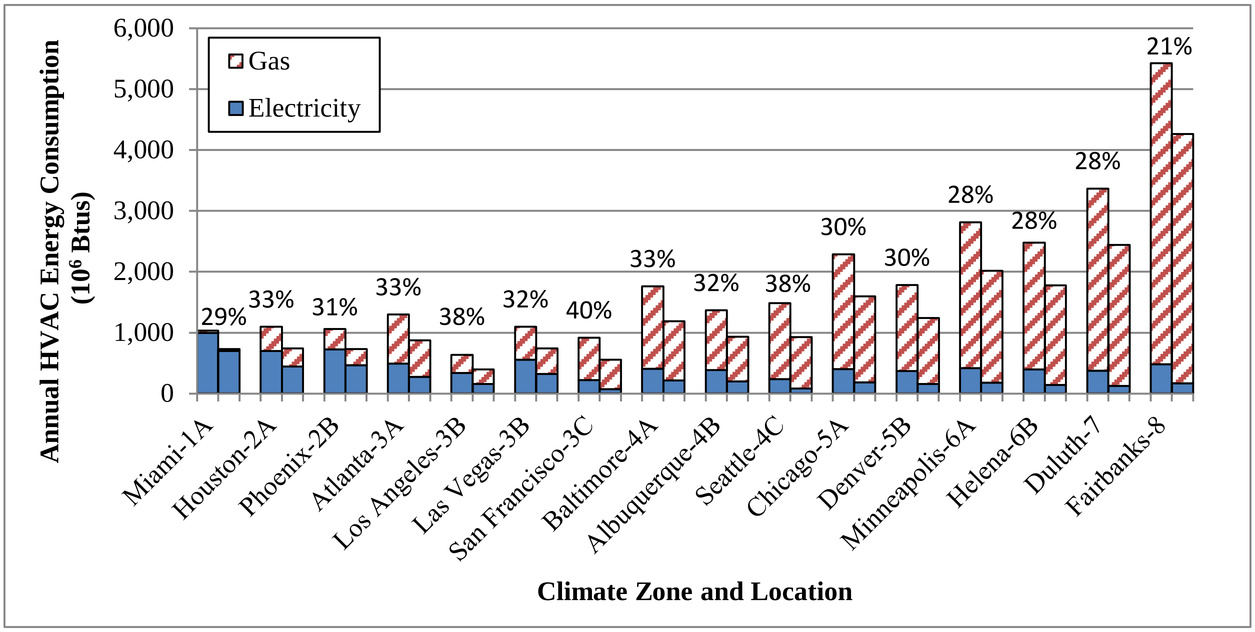

Figure 38: Comparison of HVAC Energy Consumption between Case 4 (left bar for each location) and Case 18 (right bar for each location) for the Strip Mall Building. Percent Difference in the Total Energy Consumption between Case 4 and Case 18 is also shown for Each Location.

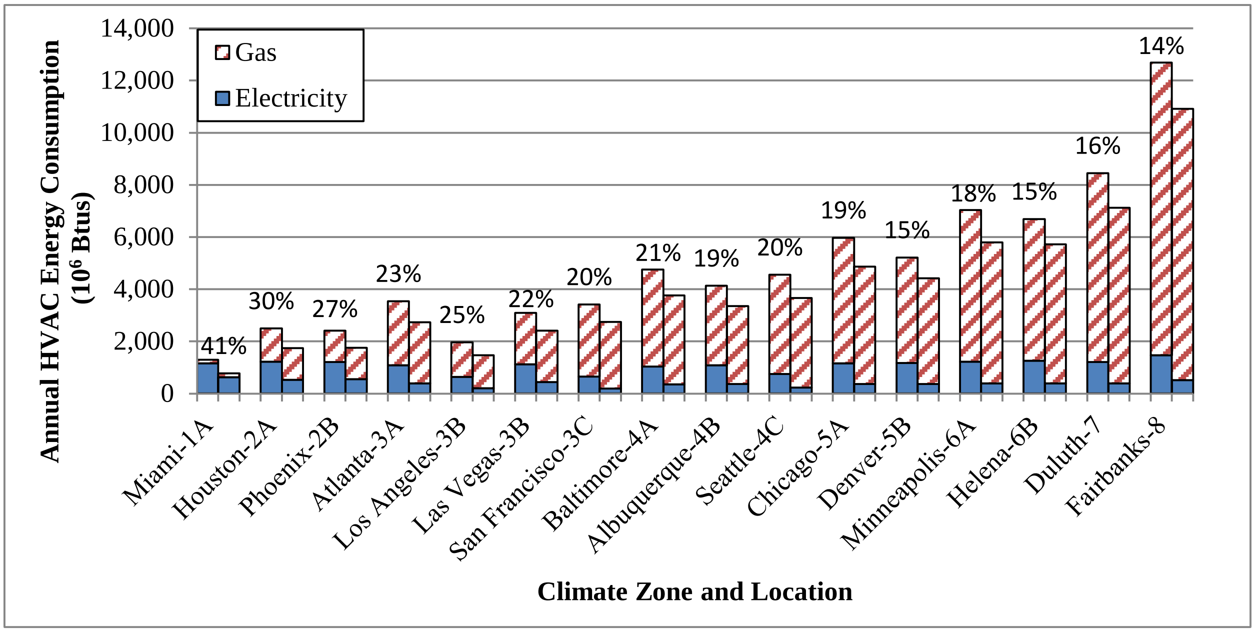

Figure 39: Comparison of HVAC Energy Consumption between Case 4 (left bar for each location) and Case 18 (right bar for each location) for the Supermarket Building. Percent Difference in the Total Energy Consumption between Case 4 and Case 18 is also shown for Each Location.

Table 8: Summary of HVAC Energy Savings for Case 18 Relative to Case 4

	Building Type			
	Small office	**Stand-alone retail**	**Strip mall**	**Supermarket**
Maximum percentage savings	42%	40%	40%	41%
Location for maximum percentage savings	Los Angeles	Los Angeles	San Francisco	Miami
Minimum percentage savings	20%	23%	21%	14%
Location for minimum percentage savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Average percentage savings	28%	32%	32%	22%
Maximum absolute savings (MMBtu/yr)	91	1268	1165	1770
Location for maximum absolute savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Minimum absolute savings (MMBtu/yr)	29	232	237	500
Location for minimum absolute savings	San Francisco	Los Angeles	Los Angeles	Los Angeles
Average absolute savings (MMBtu/yr)	46	560	547	906

5.5 Comparison of Energy Consumption between Case 22 and the Base Case (Case 1)

Of all control combinations listed in Table 4, Case 22 combines the most advanced control strategies. It includes multi-speed supply-fan control, demand controlled ventilation, two-stage compressor control, and integrated differential enthalpy economizer control. In contrast, the base case (Case 1) does not include any advanced control strategies. Therefore, comparing the two extreme cases provides the maximum energy savings that can be achieved with the most advanced control strategies of all examined cases. For the four building types, Figure 40 through Figure 43 show the HVAC energy consumption (fan and cooling electricity and gas heating) of Case 22 and the base case for all 16 locations. The HVAC energy saving as a percentage of the base case energy consumption is also shown for each location. The following findings can be drawn from these figures:

- The largest absolute energy savings are obtained for Fairbanks for all building types, which is the same as observed from the comparison between Case 18 and Case 4. The annual absolute savings are about 97 MMBtu for the small office building, 1,388 MMBtu for the stand-alone retail building, 1,333 MMBtu for the strip mall, and 2,029 MMBtu for the supermarket. The differences in these savings among the building types are attributable to both differences in the size of the buildings and also the impact of the advanced control strategies on the different types of buildings.

- The smallest absolute energy savings per year are obtained for San Francisco for the small office buildings (40 MMBtu), and Los Angeles for the other three building types (300 MMBtu for stand-alone retail building, 324 MMBtu for the strip mall, and 582 MMBtu for the supermarket).
- The changes in energy savings as a percentage of the base case energy consumption follow the same patterns as those found when comparing Case 18 and Case 4 in Section 5.4. For the small office, stand-alone retail, and strip mall buildings, the percentage of energy savings generally decreases from mild (Los Angeles, San Francisco and Seattle) to hot and then from hot to cold climates. For the supermarket building (Figure 43), the percentage generally decreases from the hot and humid climate (Miami–Zone 1A) to the extreme cold climate (Fairbanks – Zone 8). Such trends can be explained the same as given in Section 5.4.
- The percentage of HVAC energy savings lies in the range between 22% and 56% for the small office building, 25% and 47% for the stand-alone retail building, 24% and 46% for the strip mall, and 16% and 47% for the supermarket. The maximum HVAC energy saving as a percentage of the base case energy consumption (Case 1 without advanced control options) occurs in Los Angeles for the small office building, the retail building and the strip mall, while it occurs in Miami for the supermarket. The minimum percentage savings occurs in Fairbanks for all four building types. For all 16 locations (15 climates), Case 22 has an average HVAC energy savings of about 35% for small office, stand-alone retail and strip mall buildings and 24% for the supermarket. A summary of these savings is provided in Table 9.

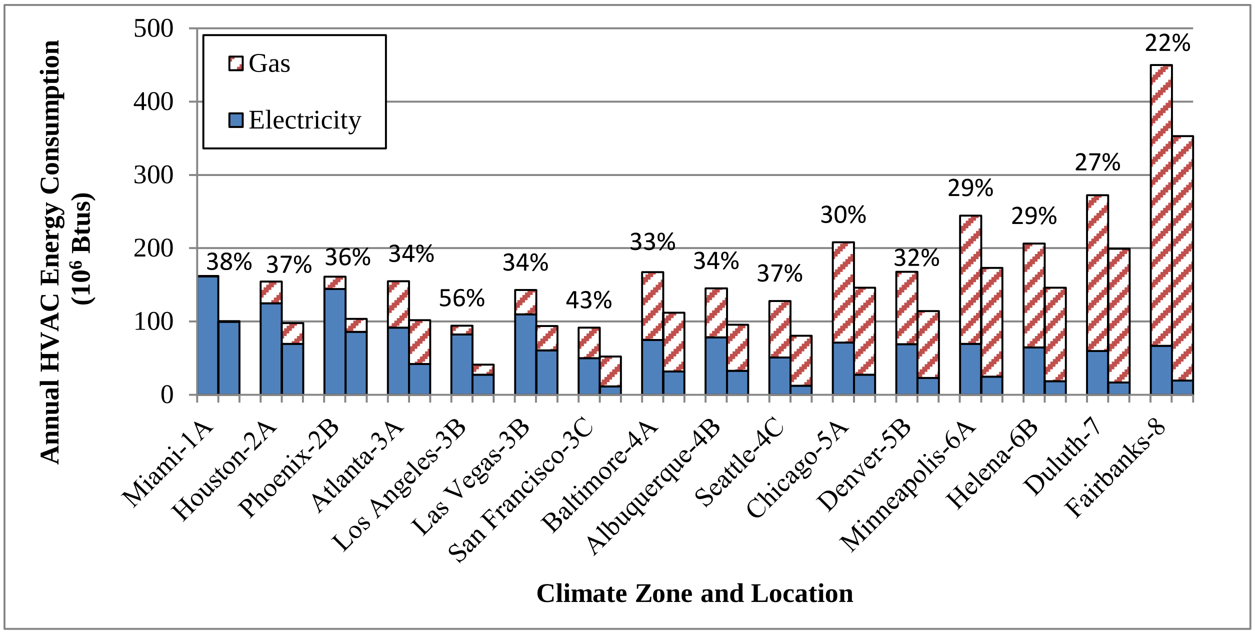

Figure 40: Comparison of HVAC Energy Consumption between the Baseline (Case 1; left bar for each location) and Case 22 (right bar for each location) for the Small Office Building. Percent Difference in the Total Energy Consumption between Case 1 and Case 22 is also shown for Each Location.

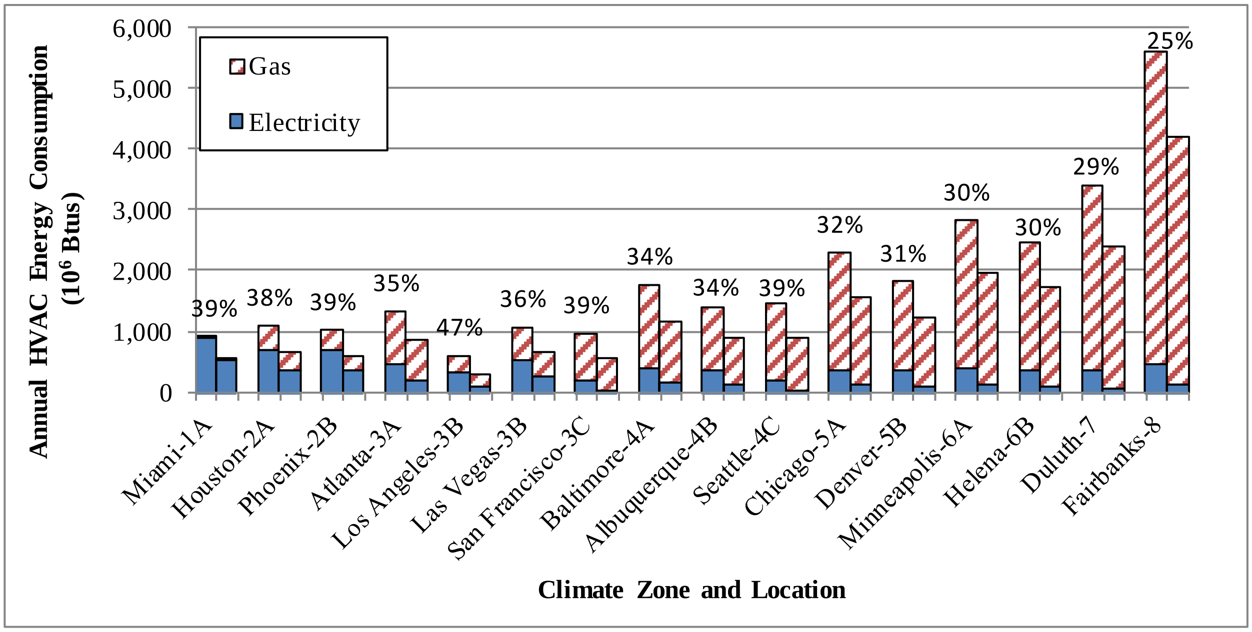

Figure 41: Comparison of HVAC Energy Consumption between the Baseline (Case 1; left bar for each location) and Case 22 (right bar for each location) for the Stand-alone Retail Building. Percent Difference in the Total Energy Consumption between Case 1 and Case 22 is also shown for Each Location.

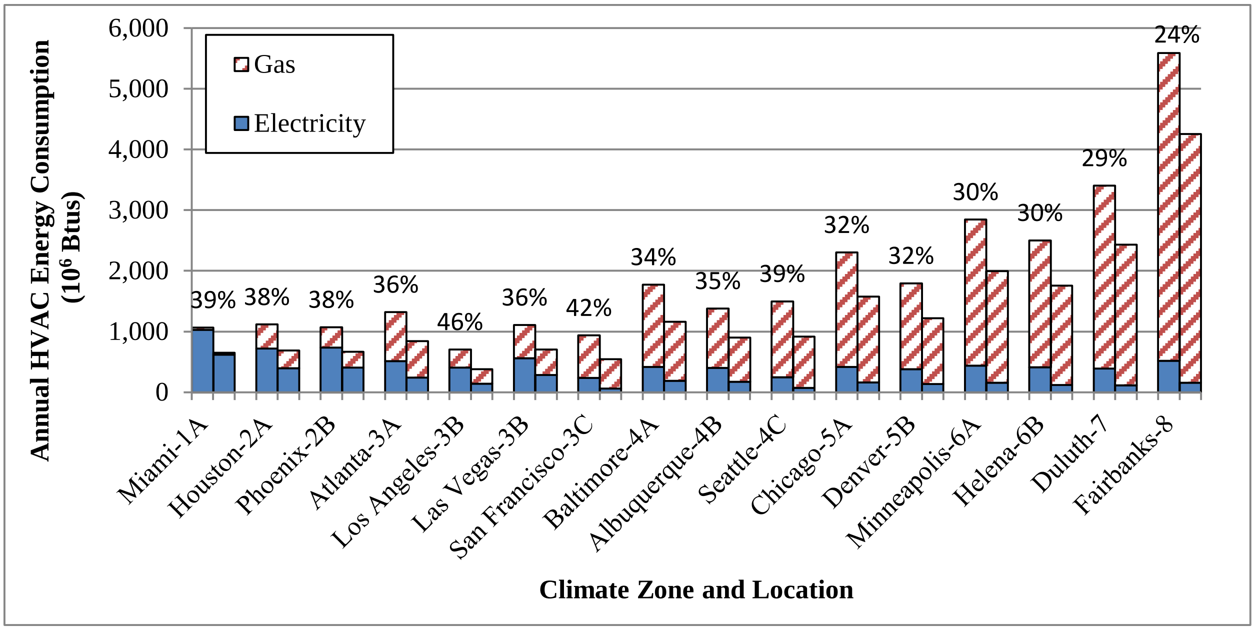

Figure 42: Comparison of HVAC Energy Consumption between the Baseline (Case 1; left bar for each location) and Case 22 (right bar for each location) the Strip Mall Building. Percent Difference in the Total Energy Consumption between Case 1 and Case 22 is also shown for Each Location.

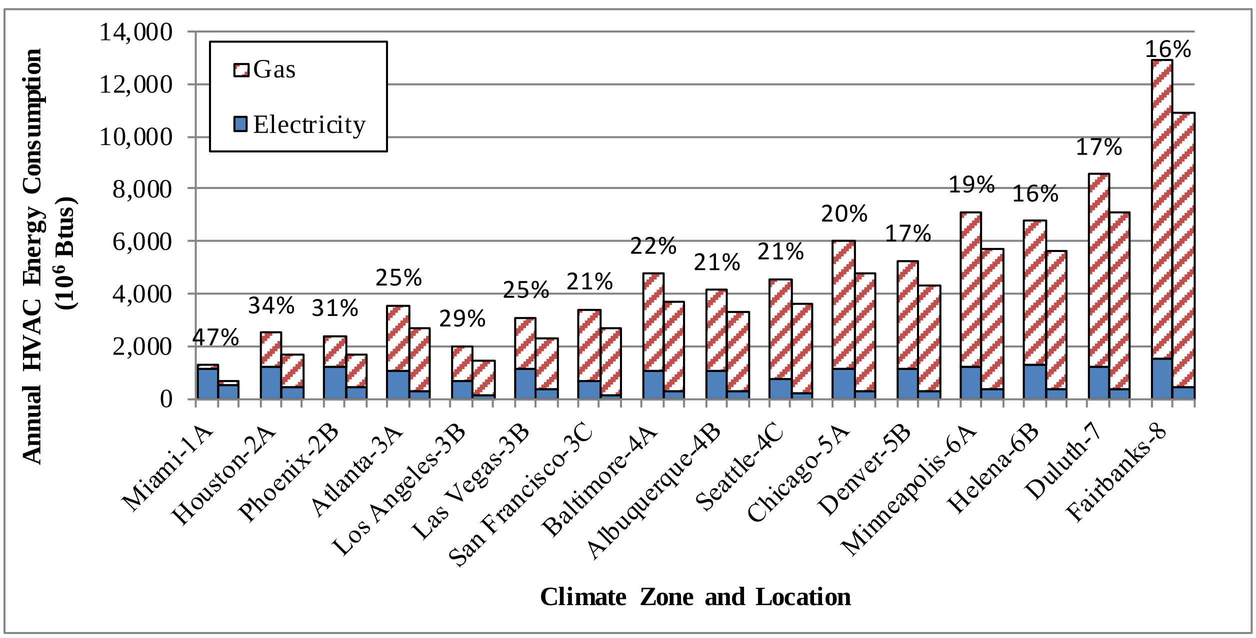

Figure 43: Comparison of HVAC Energy Consumption between the Baseline (Case 1; left bar for each location) and Case 22 (right bar for each location) for the Supermarket Building. Percent Difference in the Total Energy Consumption between Case 1 and Case 22 is also shown for Each Location.

Table 9: Summary of HVAC Energy Savings for Case 22 Relative to the Base Case (Case 1)

	Building Type			
	Small office	**Stand-alone retail**	**Strip mall**	**Supermarket**
Maximum percentage savings	56%	47%	46%	47%
Location for maximum percentage savings	Los Angeles	Los Angeles	Los Angeles	Miami
Minimum percentage savings	22%	25%	24%	16%
Location for minimum percentage savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Average percentage savings	35%	35%	35%	24%
Maximum absolute savings (MMBtu/yr)	97	1388	1333	2029
Location for maximum absolute savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Minimum absolute savings (MMBtu/yr)	40	300	324	582
Location for minimum absolute savings	San Francisco	Los Angeles	Los Angeles	Los Angeles
Average absolute savings (MMBtu/yr)	59	609	608	1010

6. Economic Analysis

This section presents and discusses the energy cost saving results from different combinations of packaged rooftop unit control strategies. Based on the energy cost saving, the maximum total installed cost for the add-on controller to achieve a specific simple payback period is determined for several combinations of advanced control strategies.

6.1 Impact Assessment of Individual Control Strategies on HVAC Energy Cost

The annual HVAC energy cost is estimated using the methodology presented in Section 4. With the HVAC energy costs for all 22 cases, the annual energy cost savings for each of the 21 advanced control combinations (cases) can be easily calculated as the difference of energy cost between the base case and an advanced case for a given building type. The results are provided in Appendix D. To provide insights into the impact of advanced control combinations on the savings of different fuel costs, the results are presented for the total energy cost savings (Table D1 through D16), the electricity cost savings (Table D17 through D32), and the gas cost savings (Table D33 through D48). In all tables, the cost savings are shown as both absolute values and the percentages of the base case (Case 1) annual energy cost. The difference between the tabulated cost savings for any two cases for a specific building type and location provides the average annual HVAC energy cost savings when changing from one combination of packaged-unit control strategies to another. Based on these results, the impact of air-side economizer, multi-speed fan control, DCV, and staged cooling is evaluated individually below.

The impact of air-side economizer on energy savings made in Section 5.2 has shown that there is negligible difference between examined economizer control options, including nonintegrated vs. integrated and differential dry-bulb vs. differential enthalpy. Therefore, the impact of air-side economizers on energy cost is investigated for only one economizer control option: the integrated air-side economizer using differential dry-bulb as the control variable. This impact assessment can be made by comparing the energy cost of Case 4 with the baseline (Case 1). As shown in Figure 44, the following observations can be made:

- In terms of the percentage savings (the upper part in Figure 44), the integrated air-side economizer has much greater energy cost savings potential in warm climates (Los Angeles and San Francisco) than it has in other climates. In Los Angeles, for example, energy cost savings of about 25% of the Case 1 energy cost are achieved for the small office building. In contrast, much smaller (less than 5% of the Case 1 HVAC energy cost) energy cost savings are observed for the locations with hot (e.g., Miami and Houston) or cold climates (e.g., Minneapolis and Duluth).

- The percentage savings also vary with the building type. The small office building almost always has a higher percentage of energy cost saving than the other three building types. The energy cost for cooling as a fraction of the total HVAC energy cost is greatest for the small office building compared to the other types of buildings. When cooling represents a greater fraction of the total HVAC energy cost, as with the small office building, the impact of the economizer on percentage cost savings is also greater.

- In terms of the absolute energy cost savings, the supermarket almost always has higher energy cost savings than other building types, which is simply because it has the largest floor area among the four building types.

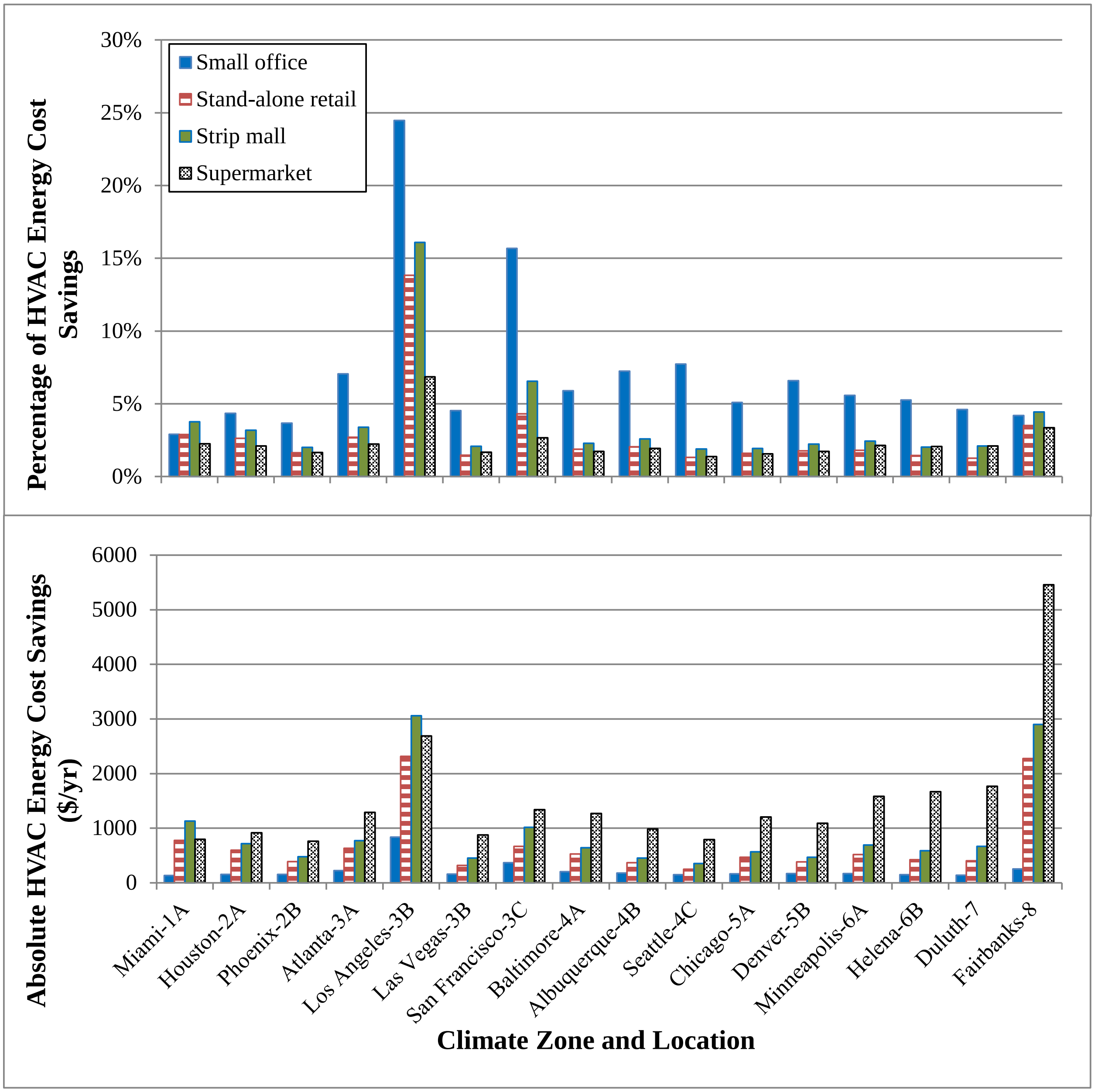

Figure 44: HVAC Energy Cost Savings from the Use of an Integrated Air-Side Differential Dry-Bulb Economizer (Case 4) Compared to the Base Case without an Air-Side Economizer

The impact of supply-fan control on HVAC energy cost can be investigated by comparing two cases, one using single-speed fan control and the other using multi-speed fan control. Following the approach used to study the impact of multi-speed fan control on energy consumption (Section 5.2), the same two cases, Case 6 and the base case, are compared to evaluate the supply-fan control in terms of energy cost. The upper part of Figure 45 shows the energy cost savings as percentages of the base case HVAC energy cost, whereas the lower part shows the energy cost savings as absolute values. From Figure 45, the following observations are made:

- For all four building types, replacement of constant-speed fan control with multi-speed fan control yields energy cost savings for all 16 locations. This observation differs from that found for energy savings in Section 5.2, where there was an increase of HVAC energy consumption in cold climates. The phenomenon of having energy penalties but cost savings in cold climates can be explained from the impact of multi-speed fan control on different energy end uses and different fuel prices. The use of multi-speed fan control decreases fan energy but increases heating energy. Although overall annual HVAC energy consumption increases in cold climates, the decrease in the cost for highly priced electricity used for fan operation is greater than the cost increase for lower-priced gas used for heating. Hence, positive energy cost savings are observed even in cold climates.
- For all four building types, using multi-speed fan control has about 18% or more cost savings for the locations in climate zones 1 to 4B. The percentage cost savings become smaller in cold climates, but around 10% savings are still observed in most cases. The percentage savings in Seattle (zone 4C) is small because it has the lowest electricity price among all examined locations.
- The impact of multi-speed fan control on energy cost varies with building type. In terms of the percentage energy saving relative to the base case (Case 1) energy cost, the office building has the highest savings for the locations in climate zone 3 through 8, while the supermarket building has the highest percentage savings in climate zone 1 and 2. In terms of the absolute values of energy cost changes, the use of multi-speed fan control has the largest impact on the supermarket building, while it has the smallest impact on the small office building. This difference in absolute energy cost savings among the building types is mainly caused by the difference in building size.

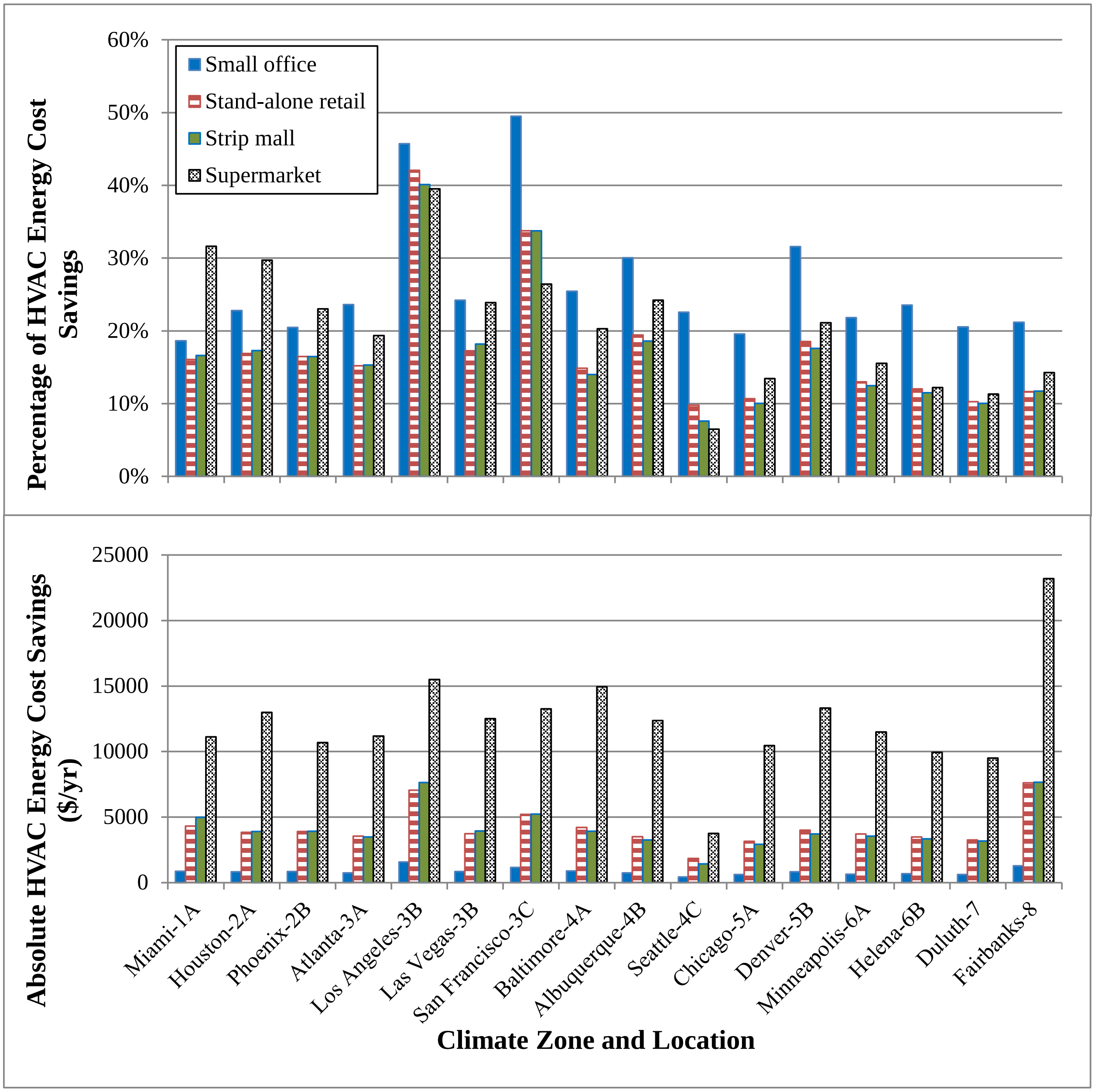

Figure 45: HVAC Energy Cost Savings from the Use of Multi-speed Supply-Fan Control (Case 6) Compared to the Base Case with Constant-Speed Fan Control

Following the approach used to study the impact of DCV on energy consumption (Section 5.2), Case 14 and the base case are compared to investigate the impact of DCV on HVAC energy cost. Case 14 differs from the base case only by the presence of DCV. The upper part of Figure 46 shows the energy cost savings as percentages of the base case HVAC energy cost, whereas the lower part shows the energy cost savings as absolute values. It can be seen from Figure 46 that the two retail buildings have a larger percentage cost savings resulting from DCV than the other two building types. Around 15% cost savings are observed in the two retail buildings for most locations. The small office building has the smallest percentage cost savings in all locations except Fairbanks. A small increase in energy cost is even observed in Los Angeles and San

Francisco for the small office building, although positive energy savings are observed in these two locations (see Section 5.2). This can be explained from the combined impact of DCV on HVAC energy end uses and different fuel prices. For example, for the small office building in Los Angeles, applying DCV (in Case 14) shows an increase in electricity consumption by 1.8 MMBtu and decrease in gas consumption by 3 MMBtu. The overall energy cost increases because the electricity price (0.138 $/kWh = $40.4/MMBtu) is much higher than the gas price ($8.30 MMBtu) in Los Angeles.

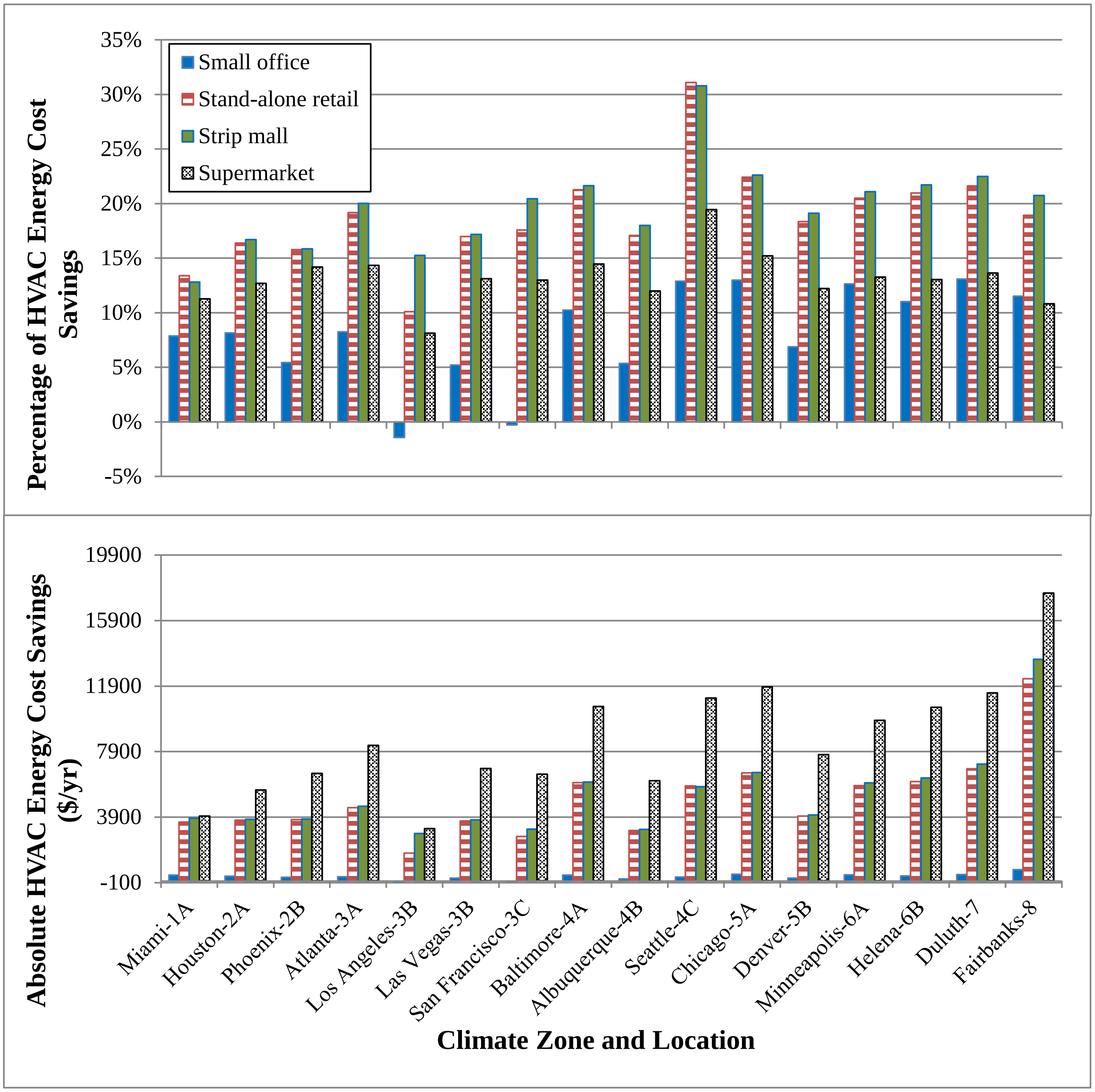

Figure 46: HVAC Energy Cost Savings from the Use of Demand Controlled Ventilation (Case 14) Compared to the Base Case with Constant Outdoor-Air Supply

Figure 47 shows the change in total HVAC energy cost by upgrading from single-stage cooling (Case 6) to two-stage cooling (Case 11). As shown, two-stage cooling is more effective in hot climates. It can save up to approximately 16% of the total HVAC energy cost for the small office building in Los Angeles. In comparison with the energy savings shown in Figure 19, the percentage cost savings is much greater than the percentage energy savings because staged cooling reduces cooling electricity and the electricity price is higher than the gas price.

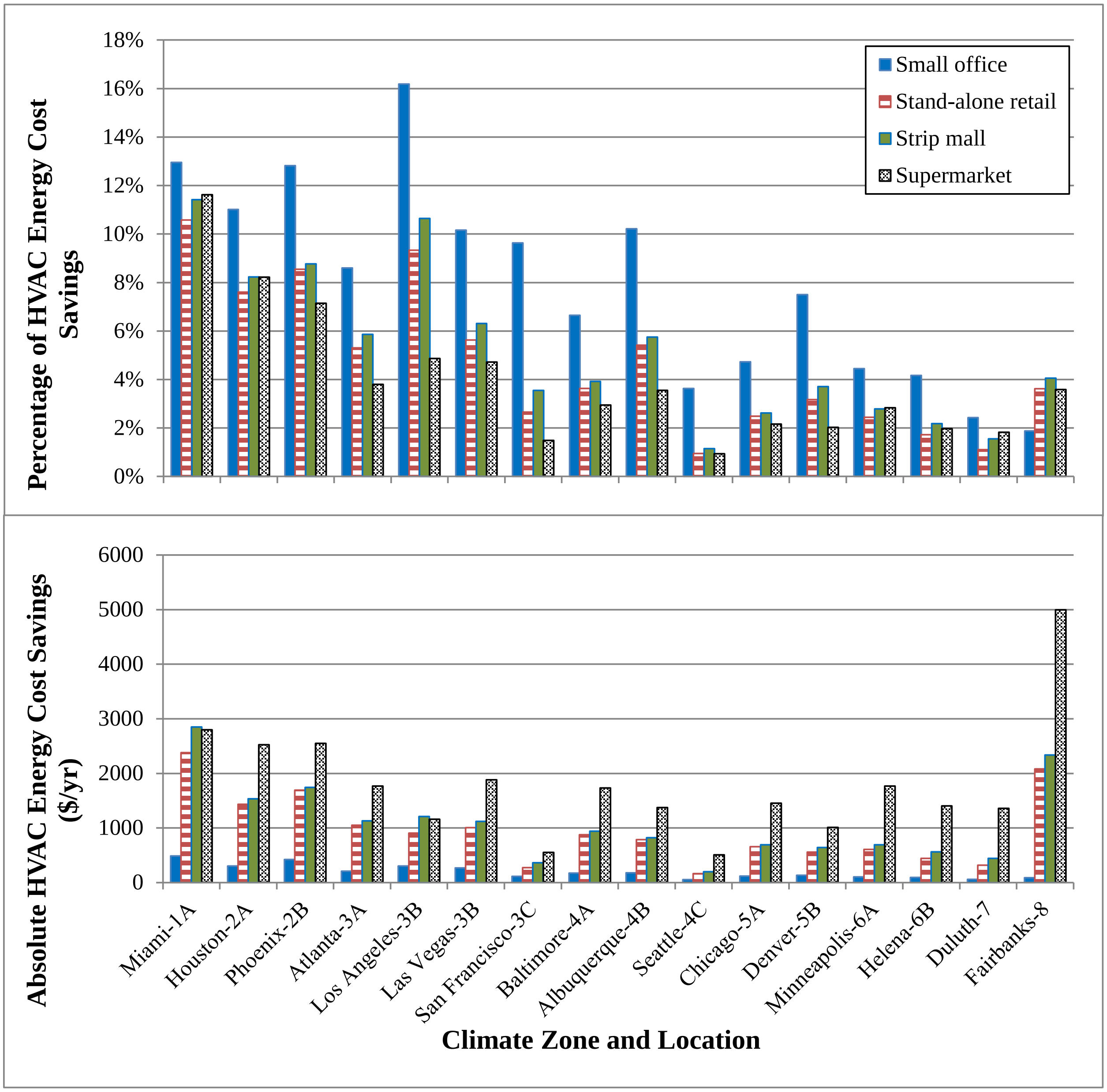

Figure 47: HVAC Energy Cost Savings from the Use of Two-Stage Cooling (Case 11) Compared to Single-Stage Cooling (Case 6)

6.2 Incremental Impact of Selected Control Strategies on HVAC Energy Cost

Following the approach used to study the incremental impact on energy savings in Section 5.4, the same five cases (Case 1, 6, 7, 9 and 18) are used in this section to illustrate the incremental impact of control strategies on energy cost savings. Sequentially comparing these cases reveals the incremental impact from adding the following control strategies in the order listed: supply fan with multiple speed control (from Case 1 to Case 6), nonintegrated air-side economizer based on differential dry-bulb temperature control (from Case 6 to Case 7), integrated economizer control (from Case 7 to Case 9), and DCV (from Case 9 to Case 18). The energy cost savings are broken down by fuel type (electricity and gas) to better characterize how each control strategy affects each fuel type.

Figure 48 through Figure 51 show the incremental total energy cost savings for all 16 locations. The incremental energy cost savings may be negative if adding a control strategy increases energy cost. The sum of these incremental savings (both positive and negative) on energy cost equals to the total energy cost savings. The following observations can be made from these figures:

- Multi-speed fan control and DCV are the two control strategies that dominate the impact on energy cost savings for almost all cases. The only two exceptions occur for the small office building in Los Angeles and San Francisco, where air-side economizer control contributes to more energy cost savings than DCV.
- Of all four control strategies used in this incremental impact analysis, the multi-speed fan control strategy usually contributes the most energy cost savings in hot and warm climates (e.g., Miami, Houston, and Los Angeles), while DCV contributes most in cold climates (e.g., Chicago and Duluth).
- Adding an air-side economizer after multi-speed fan control does not have a large impact on HVAC energy cost savings except for a few cases, like Los Angeles. Furthermore, in comparison with the nonintegrated air-side economizer, the integrated air-side economizer has a small impact on energy cost savings.
- In contrast with the incremental impact on energy savings (Figure 20 through Figure 23), multi-speed fan control plays a more important role in cost savings. Because electricity prices are generally higher than natural gas prices (per equivalent amount of energy), the use of multi-speed fan control significantly reduces electricity consumption for all locations, leading to significant cost impacts.

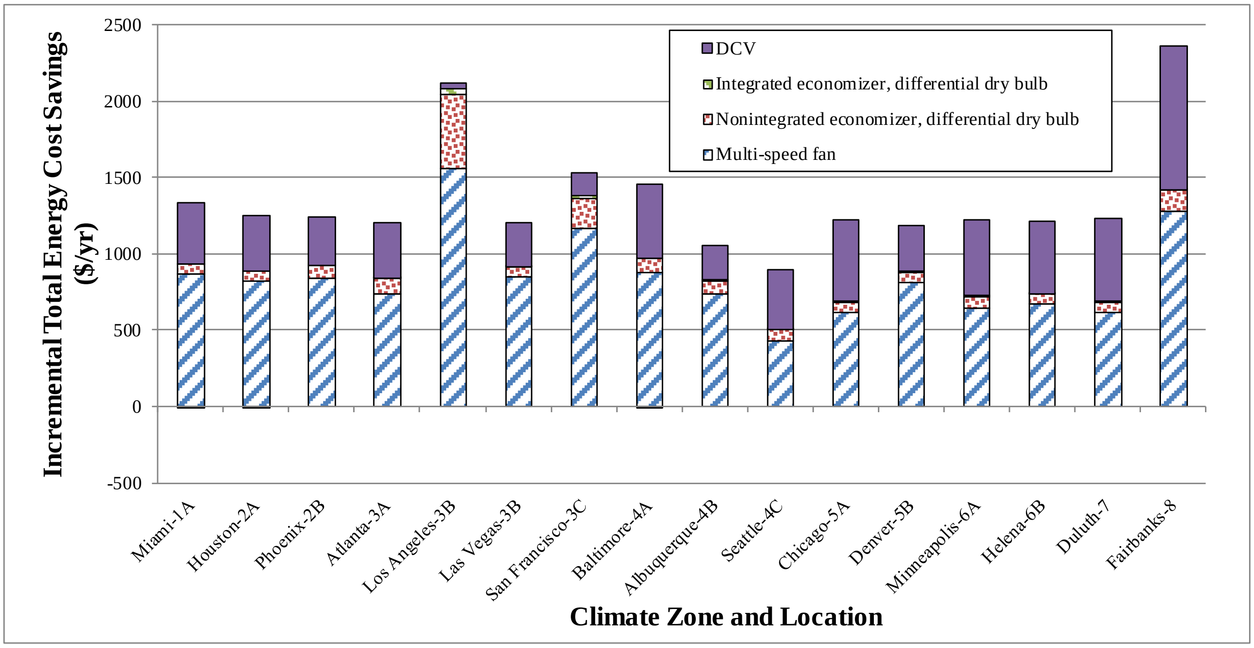

Figure 48: Total Energy Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Small Office Building

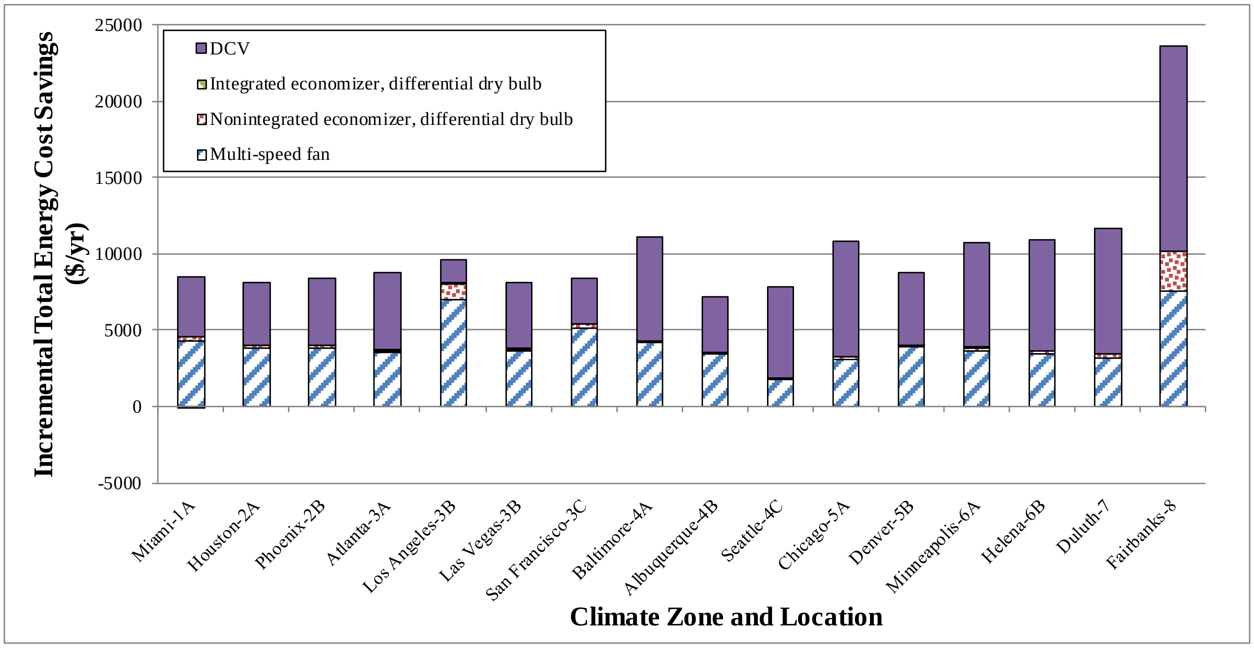

Figure 49: Total Energy Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Stand-alone Retail Building

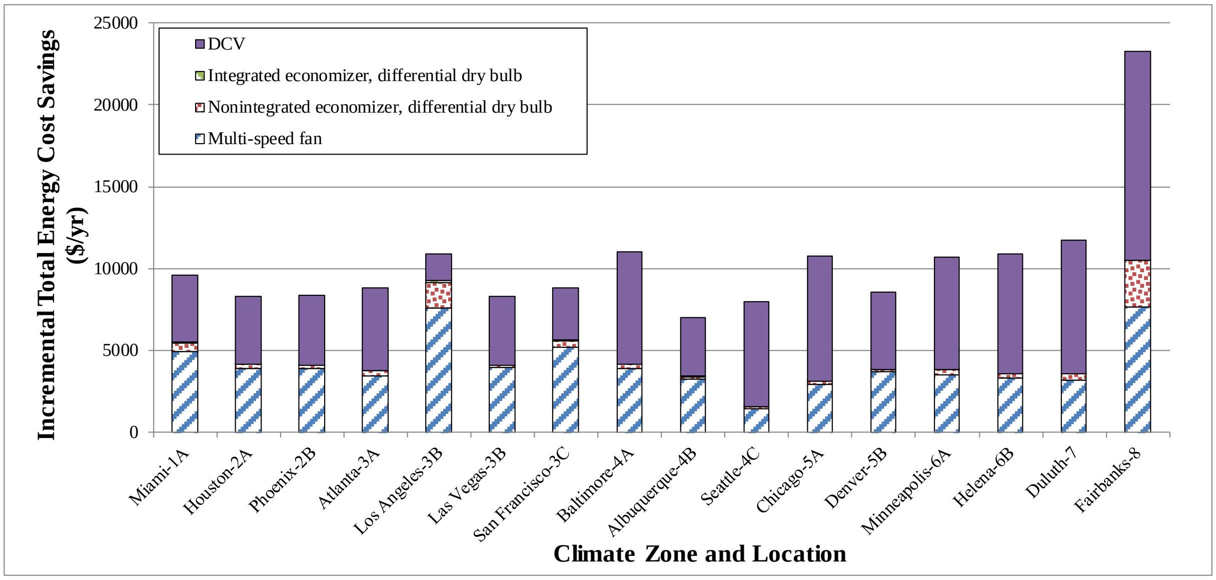

Figure 50: Total Energy Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Strip Mall Building

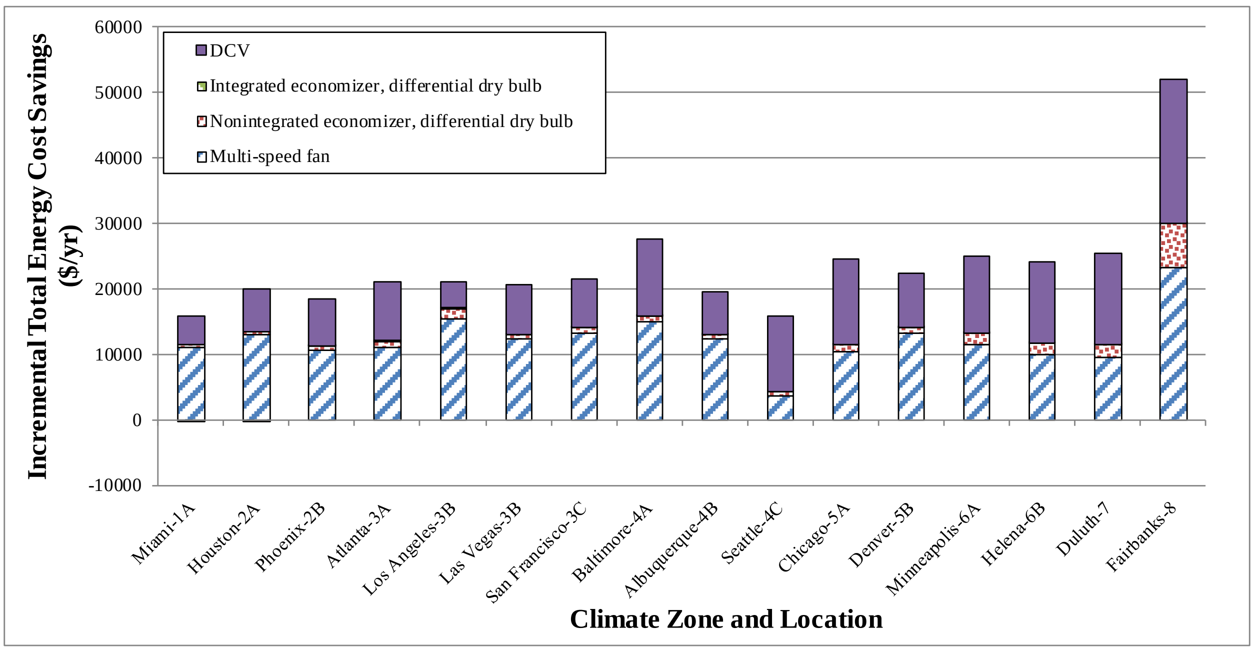

Figure 51: Total Energy Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Supermarket Building

Figure 52 through Figure 55 show the annual savings of electricity cost resulting from the incremental addition of advanced control strategies for all 16 locations and 4 building types. These figures show the following:

- Multi-speed fan control dominates the impact on electricity cost savings in all 16 locations for the four building types. It contributes to more than 80% of the total electricity savings in the following locations: San Francisco in climate zone 3B and all examined locations in climate zones 4B through 8.

- In most climates, DCV has a secondary but noticeable impact on electricity savings. For all four building types, DCV contributes to between 15% and 40% of the total electricity savings in Miami, Houston, Phoenix and Las Vegas.
- Adding an air-side economizer after multi-speed fan control does not have a large impact on electricity cost savings except for a few cases, such as all four building types in Los Angeles and Fairbanks. Furthermore, in comparison with the nonintegrated air-side economizer, the integrated air-side economizer has a small impact on electricity cost savings.

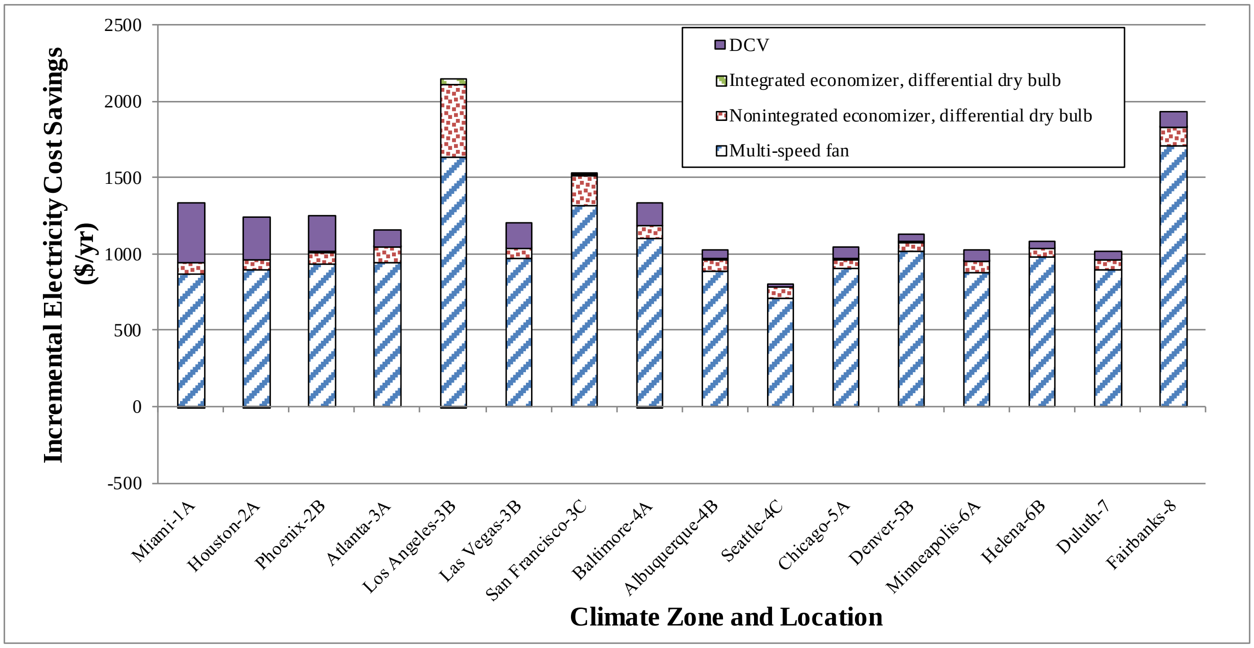

Figure 52: Electricity Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Small Office Building

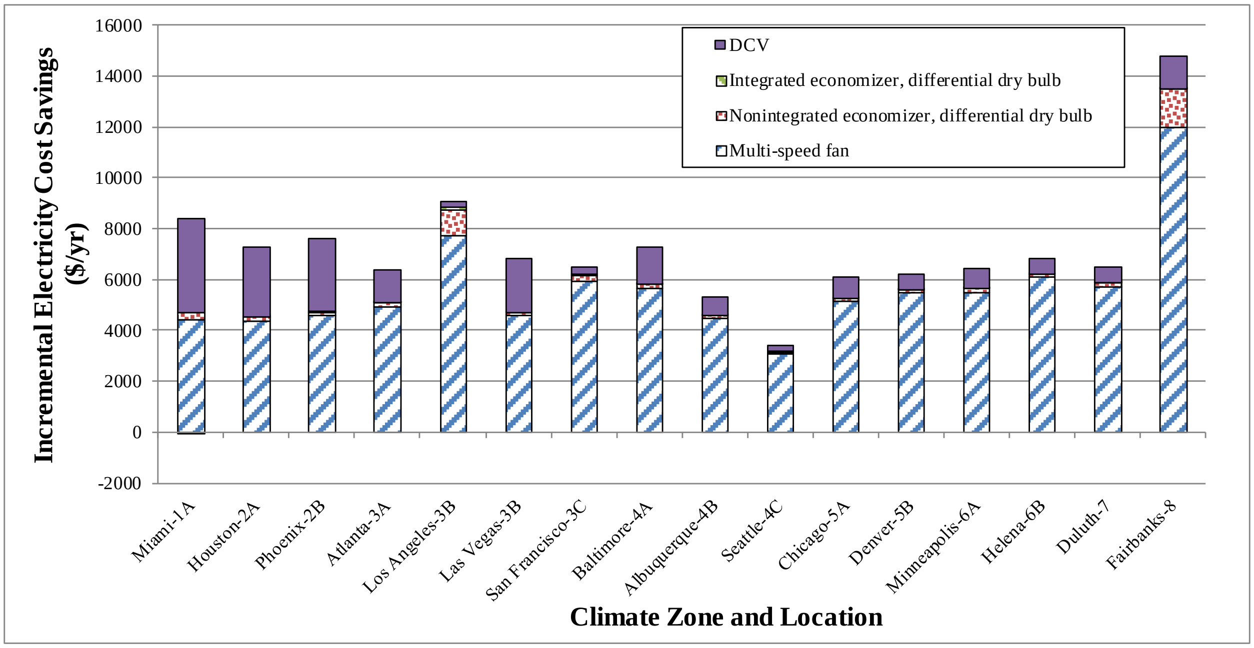

Figure 53: Electricity Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Stand-alone Retail Building

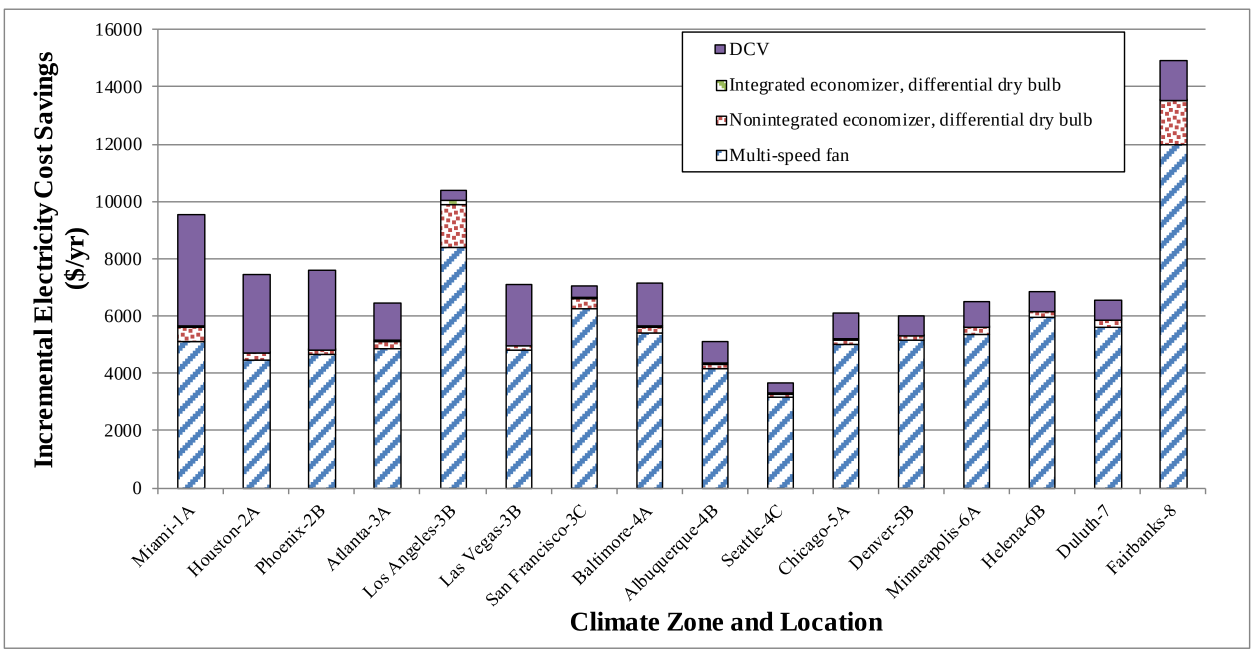

Figure 54: Electricity Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Strip Mall Building

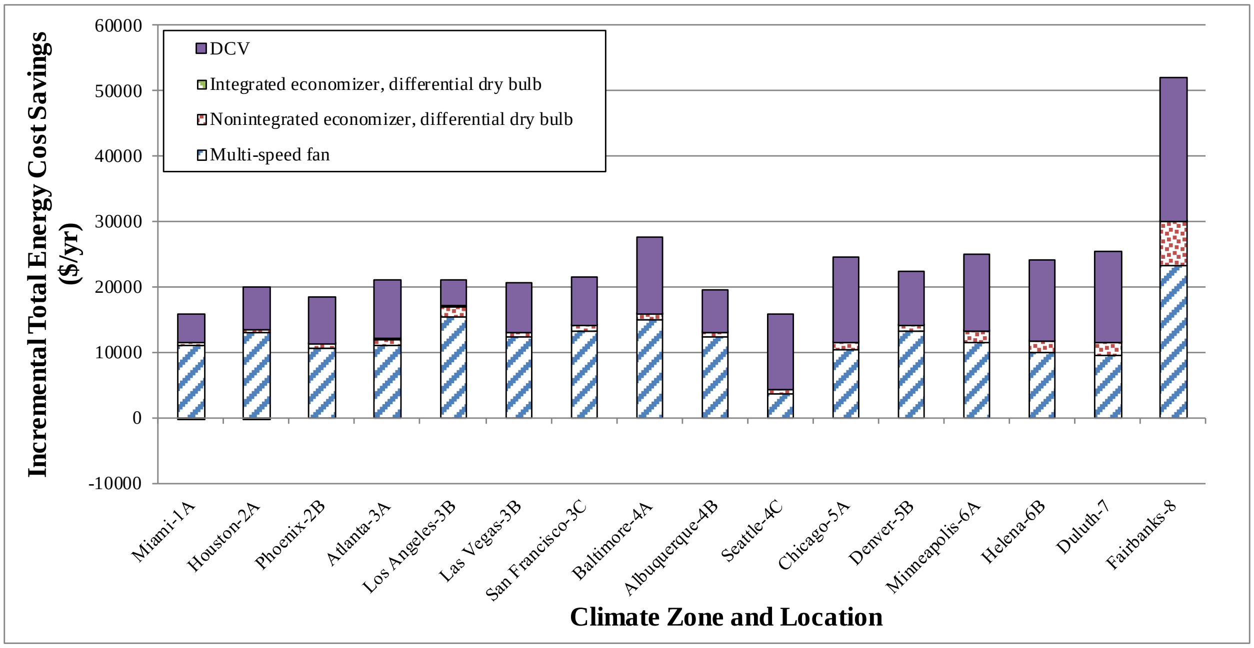

Figure 55: Electricity Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Supermarket Building

Figure 56 through Figure 59 show the annual savings of gas cost resulting from the incremental addition of advanced control strategies for all 16 locations and 4 building types. These figures show the following:

- Multi-speed fan control increases gas cost in all 16 locations for the four building types. This can be simply explained by the heating energy increase resulting from the multi-speed fan control, as discussed previously in Section 5.3. Similarly, DCV contributes almost all gas cost savings because it can significantly reduce heating energy consumption, as discussed in Sections 5.2 and 5.3.
- The impact of multi-speed fan control and DCV on gas cost (either savings or penalties) generally increases from hot to cold climates. However, because of the variation of gas prices, the sequence may not necessarily follow that found for heating energy savings. For example, in Figure 32 through Figure 35, the use of multi-speed fan control increases less heating energy in Helena than it has in Duluth. Because Helena has a higher gas price ($0.895/Therm) than Duluth ($0.736/Therm), there is more gas cost increase in Helena resulting from multi-speed fan control.

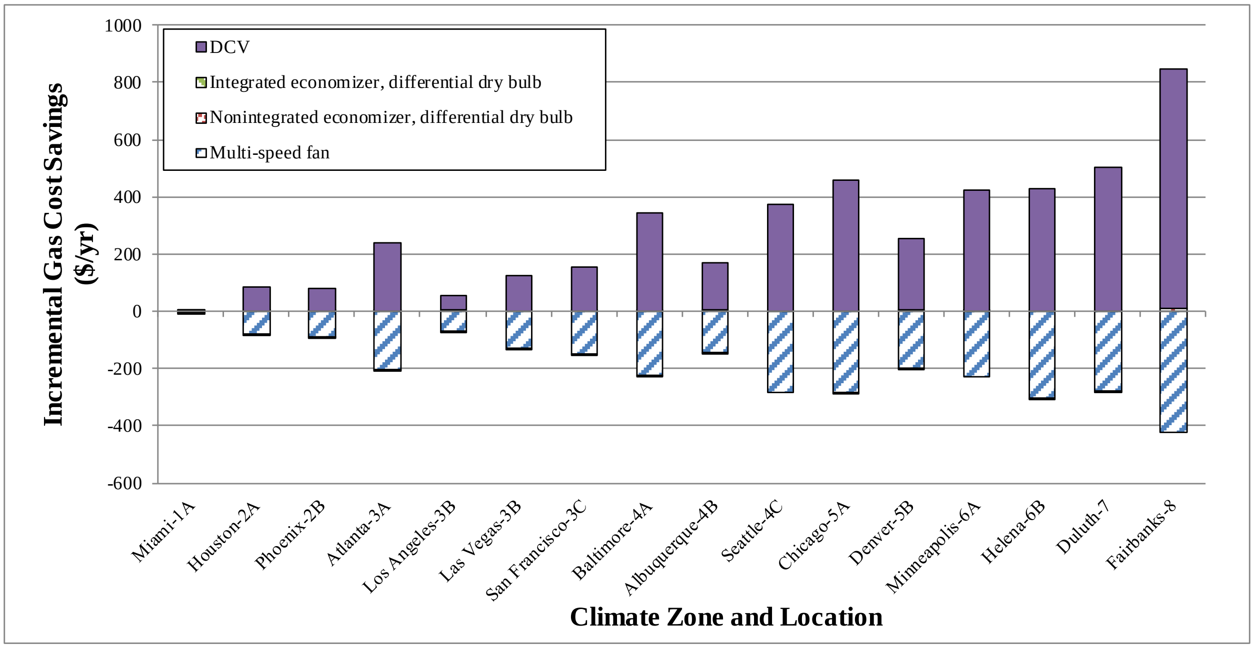

Figure 56: Gas Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Small Office Building

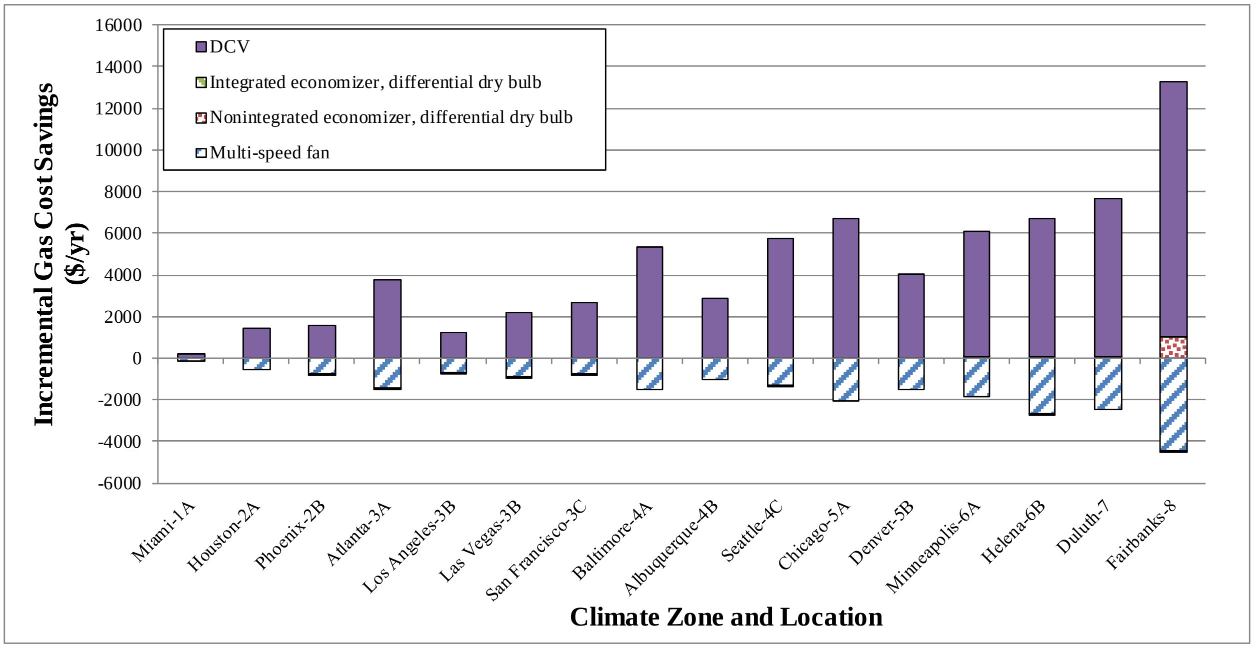

Figure 57: Gas Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Stand-alone Retail Building

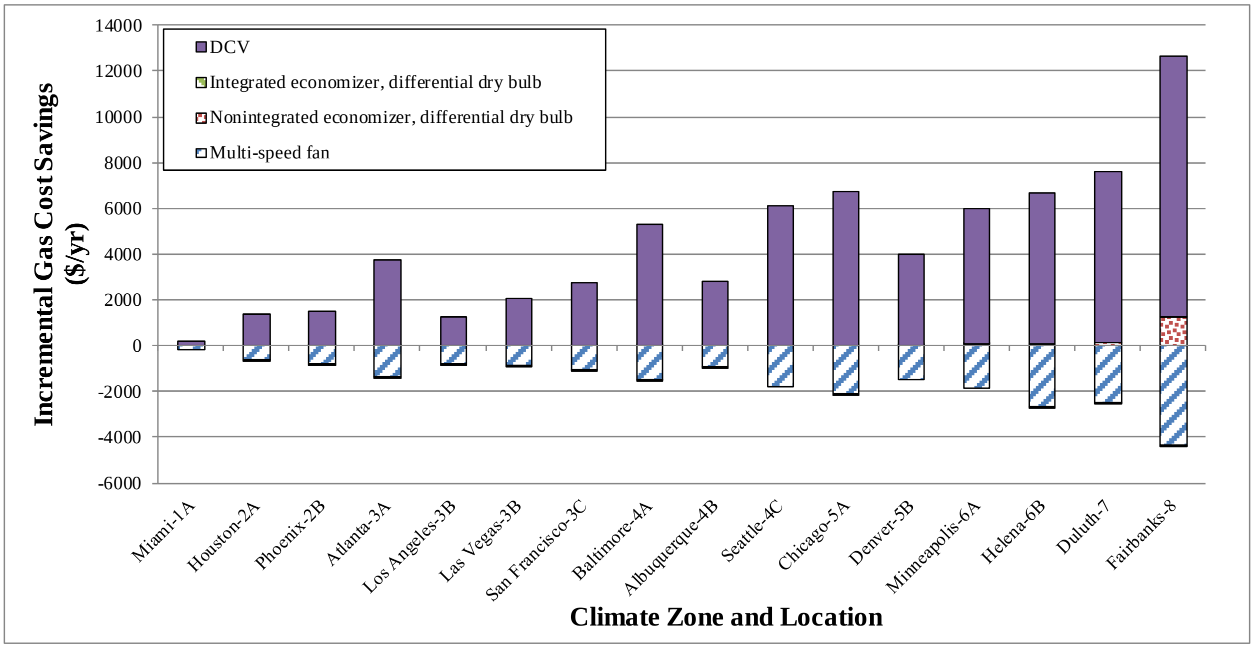

Figure 58: Gas Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Strip Mall Building

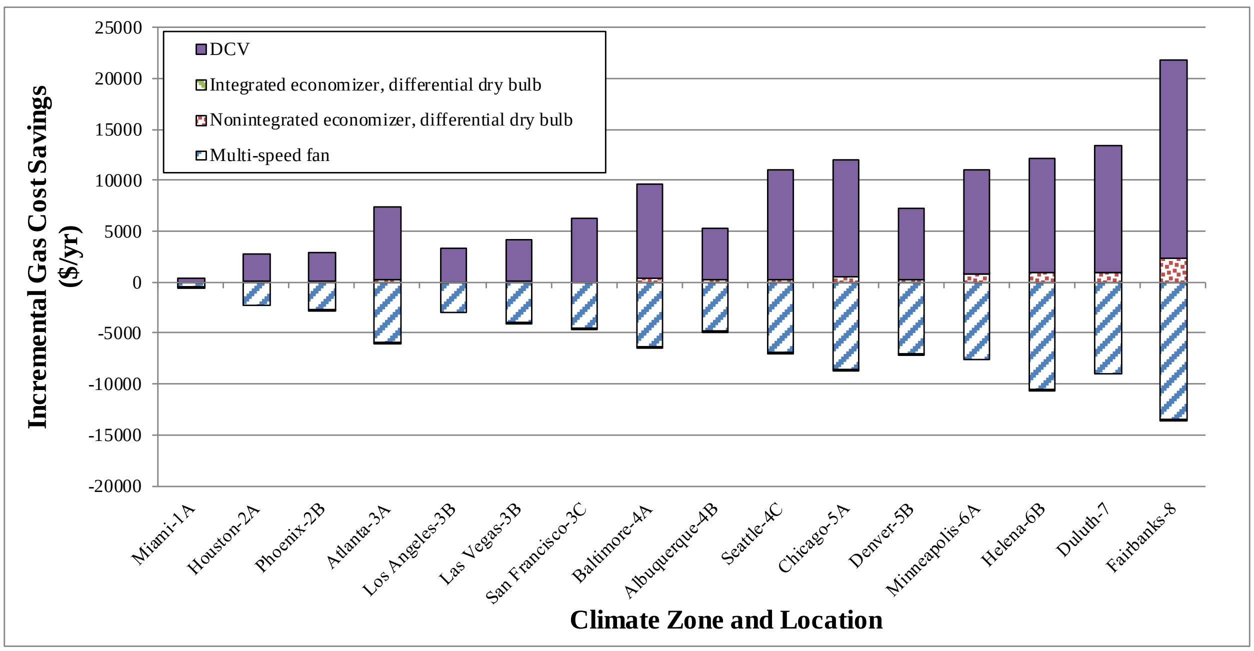

Figure 59: Gas Cost Savings Resulting from Incremental Addition of Advanced Control Strategies for the Supermarket Building

6.3 HVAC Energy Cost Comparison between Case 18 and Case 4

As explained in Section 5.4, comparing a case with only air-side economizers and another case with multi-speed fan control and DCV added provides insights into a typical scenario for existing buildings. Therefore, Case 4 and Case 18 are selected to compare their HVAC energy costs. Case 4 has integrated differential dry-bulb economizer control, single-stage cooling, constant-speed fan and no DCV. Case 18 differs from Case 4 only by the presence of multi-speed fan control and DCV. For the four building types, Figure 60 through Figure 63 show the HVAC energy costs (both electricity and gas costs) of Case 18 and Case 4 for all 16 locations. The energy cost saving as a percentage of the energy cost for Case 4 is also shown for each location. These figures show two bars for each location. The left bar corresponds to Case 4 and the right one to Case 22. These figures lead to the following observations:

- The lowest annual energy costs for all building types except the supermarket occur for either Los Angeles or San Francisco, which also have the lowest EUI, or for Seattle, which has the lowest electricity price. This is reasonable because energy cost depends on both energy consumption and the prices of energy. The supermarket building has its lowest energy cost for Miami, which also has the lowest EUI (Figure 9). As expected, all four building types have the largest energy cost in the coldest climate examined (i.e., Fairbanks) primarily from gas heating.
- For all four building types, the largest absolute energy cost savings are obtained in Fairbanks. This is simply because Fairbanks has the largest absolute energy savings, as presented in Section 5.4. The annual absolute savings are $2,108 for the small office building, $21,383 for the stand-alone retail building, $20,370 for the strip mall, and $46,605 for the supermarket. The differences in these savings among the building types area attributable to both differences in the size of the buildings and also the impact of the advanced control strategies on the different types of buildings.
- The smallest absolute energy cost savings per year are obtained for Seattle for the supermarket ($15,046) and Miami for the other three building types ($752 for the small office building, $6,868 for the stand-alone retail and $6,556 for the strip mall). Recall from Section 5.4 that the smallest energy savings are obtained in either Los Angeles or San Francisco. These two locations do not have the smallest energy cost savings because their high electricity prices make the cost savings more pronounced than the energy savings.
- The HVAC energy cost savings as a percentage of the base case energy cost lies in the range between 27% and 59% for the small office building, 30% and 53% for the stand-alone retail building, 29% and 54% for the strip mall, and 27% and 50% for the supermarket (see Table 10). The maximum HVAC energy cost savings as a percentage of Case 4 energy cost occurs in Los Angeles for the supermarket building and in San Francisco for the other three building types. The minimum percentage savings occurs in Seattle for the supermarket building and in Miami for the other three building types. For all 16 locations, Case 18 has average HVAC energy cost savings of about 38% for all four building types. A summary of these statistics is given in Table 10.
- For Case 4, the electricity cost usually takes a large portion (more than 50%) of the total utility cost in the warmer climates (1A through 4B), while the gas cost is larger in most

cold climates with predominated heating loads and in Seattle with the lowest electricity price. Case 18 has a smaller percentage of the total energy cost associated with electricity than Case 4. This is primarily because the DCV and multi-speed fan controls, which are added in Case 18, decrease electricity use considerably, and the price of electricity is greater than the price of natural gas, thus decreasing the fraction of the total cost attributable to electricity use. Except for the two retail buildings in Seattle, most cost savings come from electricity savings.

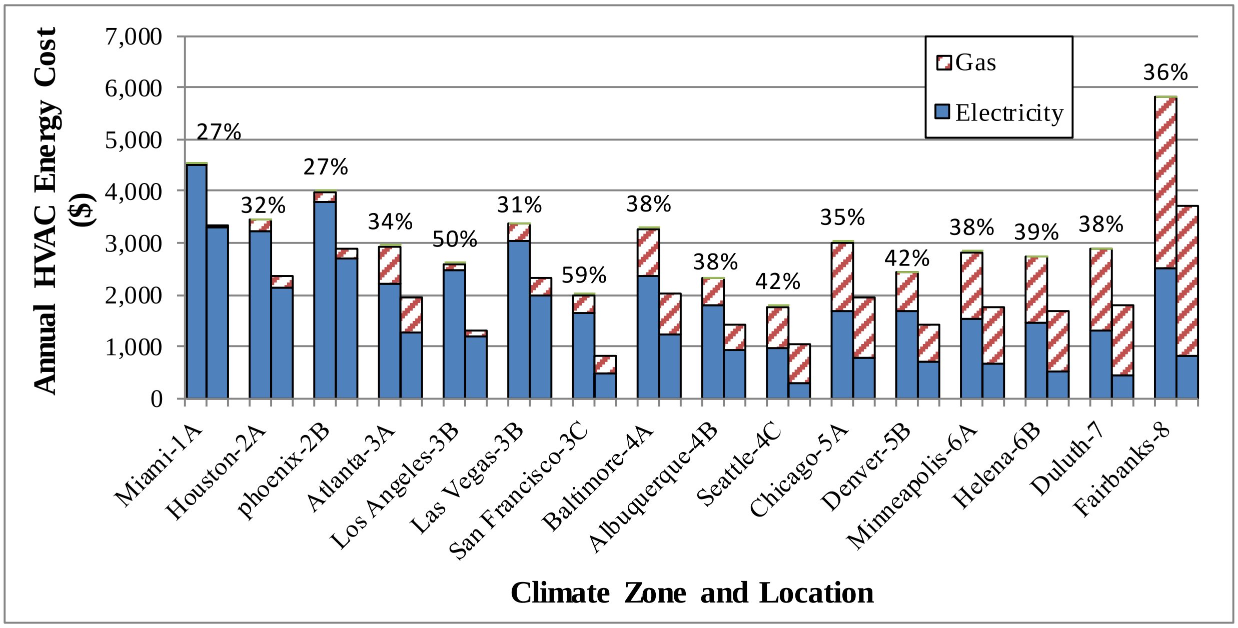

Figure 60: Comparison of HVAC Energy Cost between Case 4 (left bar for each location) and Case 18 (right bar for each location) for the Small Office Building. Percent Difference in the Total Energy Cost between Case 4 and Case 18 is also shown for Each Location.

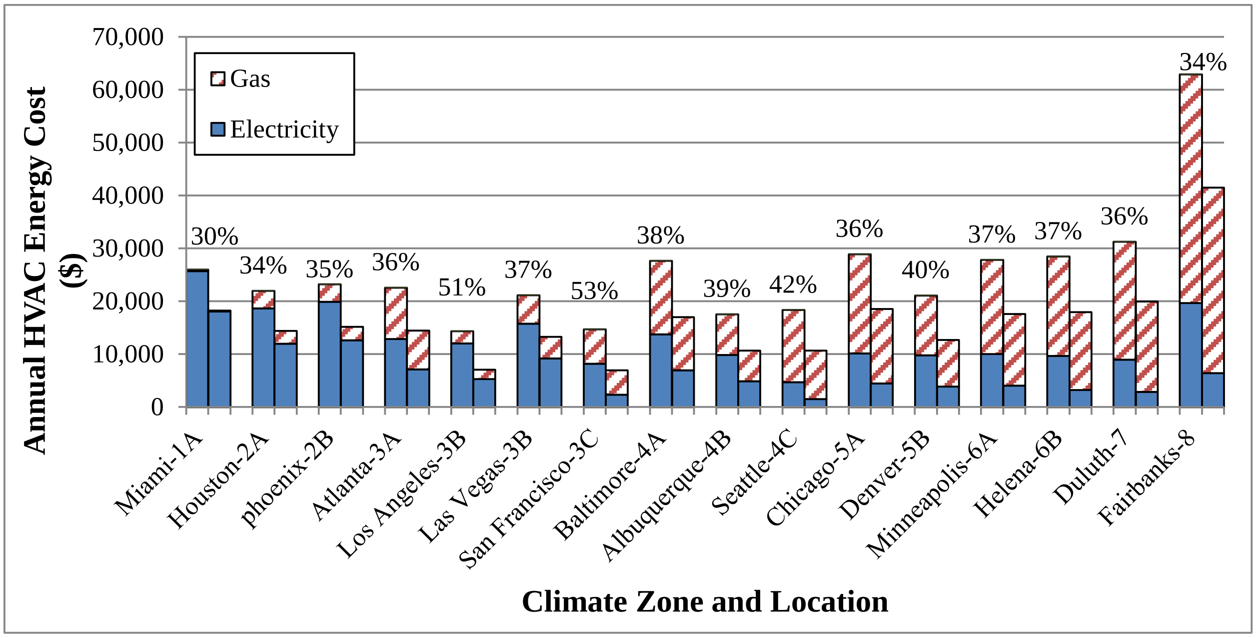

Figure 61: Comparison of HVAC Energy Cost between Case 4 (left bar for each location) and Case 18 (right bar for each location) for the Stand-alone Retail Building. Percent Difference in the Total Energy Cost between Case 4 and Case 18 is also shown for Each Location.

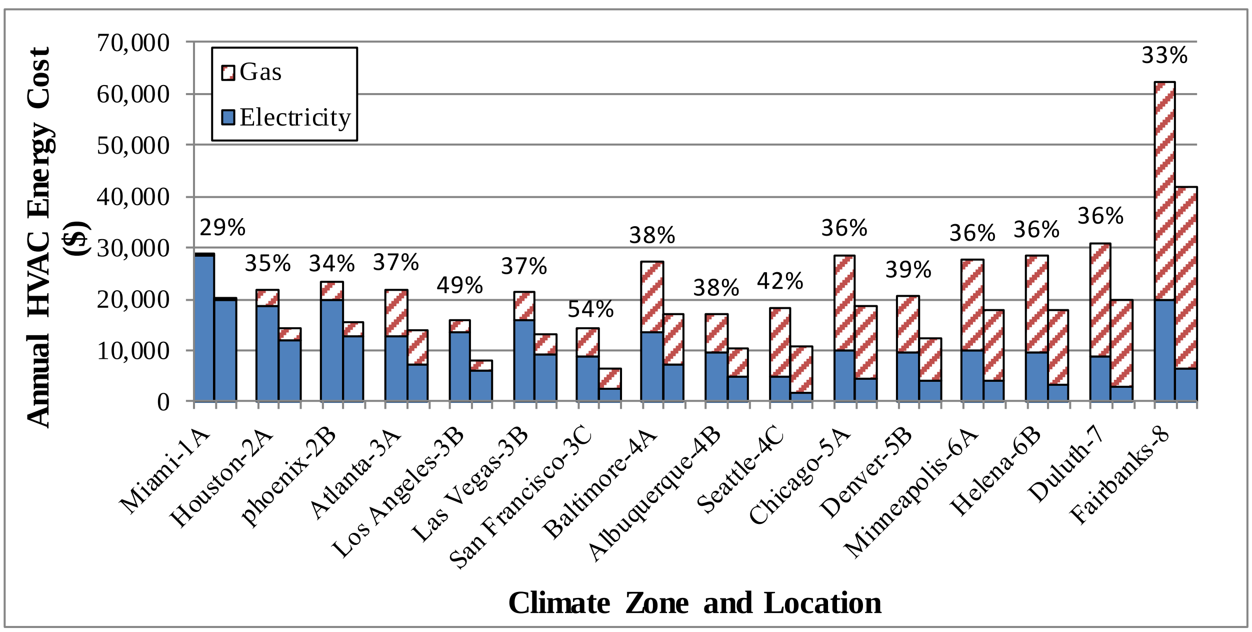

Figure 62: Comparison of HVAC Energy Cost between Case 4 (left bar for each location) and Case 18 (right bar for each location) for the Strip Mall Building. Percent Difference in the Total Energy Cost between Case 4 and Case 18 is also shown for Each Location.

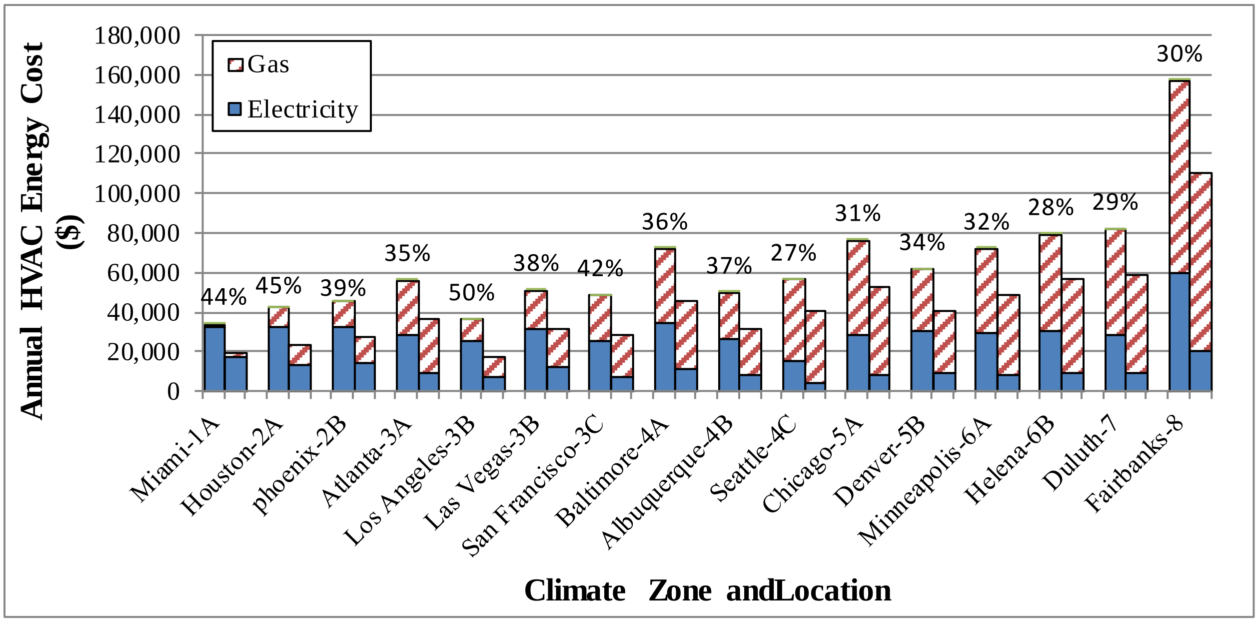

Figure 63: Comparison of HVAC Energy Cost between Case 4 (left bar for each location) and Case 18 (right bar for each location) for the Supermarket Building. Percent Difference in the Total Energy Cost between Case 4 and Case 18 is also shown for Each Location.

Table 10: Summary of Energy Cost Savings for Case 18 Relative to Case 4

	Building Type			
	Small Office	**Stand-alone Retail**	**Strip Mall**	**Supermarket**
Maximum savings	59%	53%	54%	50%
Location for maximum savings	San Francisco	San Francisco	San Francisco	Los Angeles
Minimum savings	27%	30%	29%	27%
Location for minimum savings	Miami	Miami	Miami	Seattle
Average savings	38%	38%	38%	36%
Maximum absolute savings ($/yr)	2,108	21,383	20,370	46,605
Location for maximum absolute savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Minimum absolute savings ($/yr)	752	6,868	6,556	15,046
Location for minimum absolute savings	Seattle	Albuquerque	Albuquerque	Miami
Average absolute savings ($/yr)	1,134	9,481	9,390	21,960

6.4 HVAC Energy Cost Comparison between Case 22 and the Base Case (Case 1)

Following the same approach used in Section 5.5, the two extreme cases, Case 1 and Case 22, are compared to provide the maximum energy savings that can be achieved with the most advanced control strategies of all examined cases. For the four building types, Figure 64 through Figure 67 show the HVAC energy costs (both electricity and gas costs) of Case 1 and Case 22 for all 16 locations. The energy cost saving as a percentage of the baseline energy cost is also shown for each location. These figures show two bars for each location. The left bar corresponds to the baseline (Case 1) and the right one to Case 22. The following findings can be drawn from these figures:

- For the base case, the electricity cost usually takes a large portion (more than 50%) of the total utility cost in the warmer climates (1A through 4B), while the gas cost dominates in most cold climates with significant heating loads and in Seattle where the electricity price is the lowest among the examined locations. Case 22 has a smaller percentage of the total energy cost associated with electricity than the base case. This is primarily because the DCV and multi-speed fan controls, which are added in Case 22, decrease electricity use considerably, and the price of electricity is greater than the price of natural gas, thus decreasing the fraction of the total cost attributable to electricity use. Except for the two retail buildings in Seattle, most cost savings come from electricity savings.
- The largest absolute energy cost savings are obtained for Fairbanks for all building types, simply because Fairbanks has the largest HVAC loads by far. The annual absolute savings are $2,393 for the small office building, $23,779 for the stand-alone retail building, $23,414 for the strip mall, and $52,217 for the supermarket. The differences in these savings among the building types are attributable to both differences in the size of the buildings and also the impact of the advanced control strategies on the different types of buildings.
- The smallest annual absolute energy cost savings are obtained for Seattle for the small office buildings ($923), Albuquerque for the stand-alone retail building ($7,864), Albuquerque for the strip mall building ($7,633), and Seattle for the supermarket ($16,087). Because of differences in fuel prices, the above locations with the smallest cost savings are not the same as those with the smallest energy savings.
- The HVAC energy cost savings as a percentage of the base case energy cost lies in the range between 38% and 67% for the small office building, 36% and 60% for the stand-alone retail building, 36% and 59% for the strip mall, and 28% and 55% for the supermarket (see

Table 11). The maximum HVAC energy cost savings as a percentage of the base case energy cost occurs in San Francisco for the small office building and in Los Angeles for the other three building types. The minimum percentage savings occurs in Miami for the small office, in Fairbanks for the two retail buildings, and in Seattle for the supermarket. For all 16 locations, Case 22 has average HVAC energy cost savings of about 46%, 43%, 43%, and 39%, respectively, for the small office building, retail building, strip mall, and supermarket. A summary of these statistics is given in Table 11.

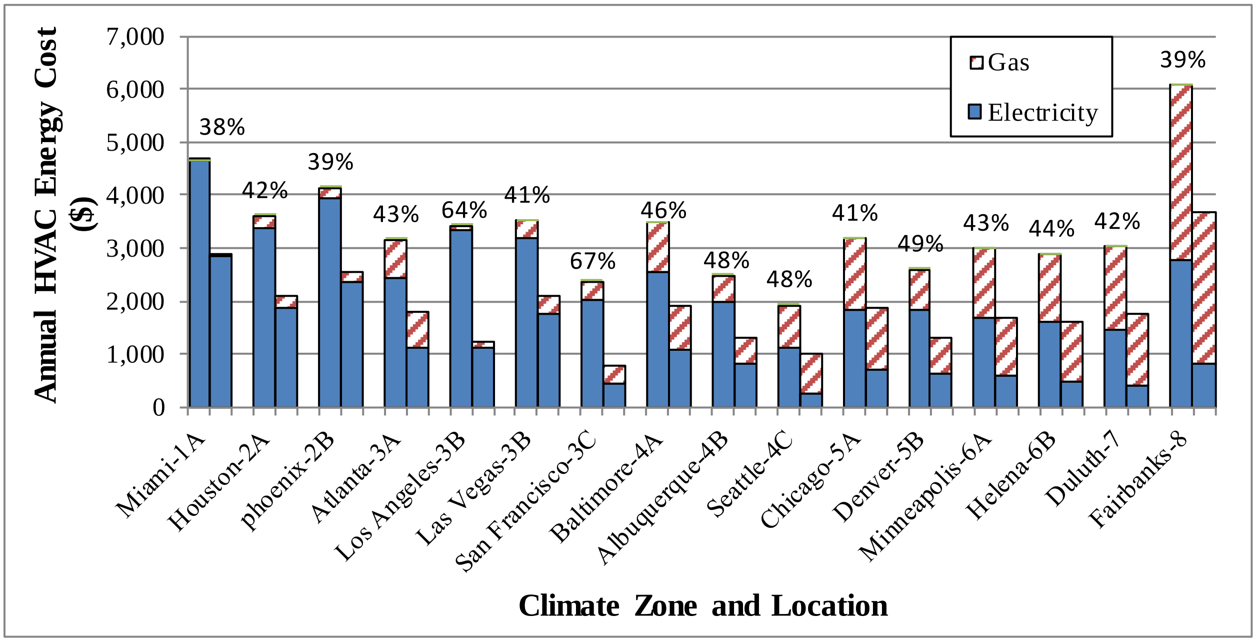

Figure 64: Comparison of HVAC Energy Cost between Case 1(left bar for each location) and Case 22 (right bar for each location) for the Small Office Building. Percent Difference in the Total Energy Cost between Case 1 and Case 22 is also shown for Each Location.

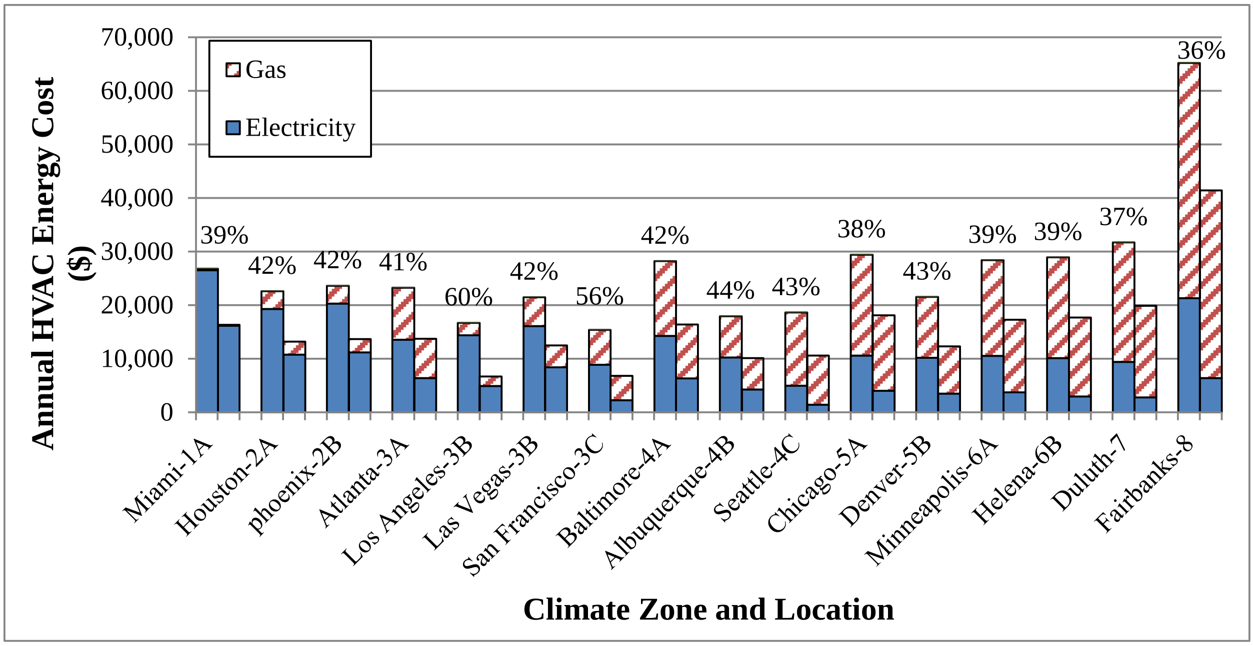

Figure 65: Comparison of HVAC Energy Cost between Case 1(left bar for each location) and Case 22 (right bar for each location) for the Stand-alone Retail Building. Percent Difference in the Total Energy Cost between Case 1 and Case 22 is also shown for Each Location.

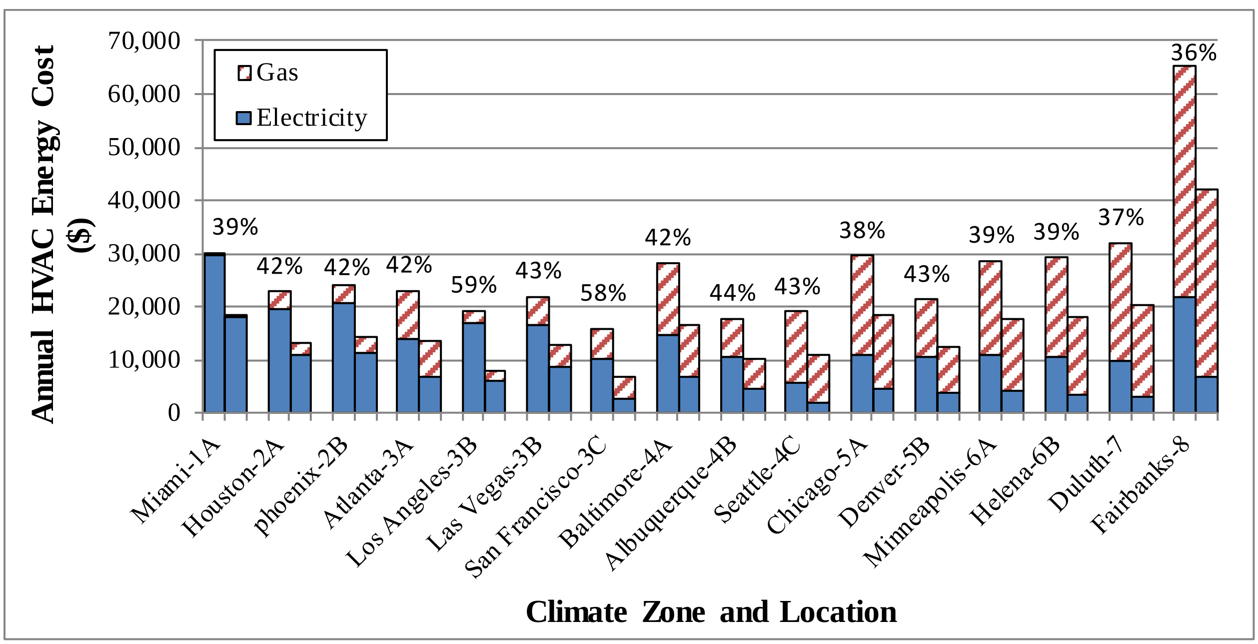

Figure 66: Comparison of HVAC Energy Cost between Case 1 (left bar for each location) and Case 22 (right bar for each location) for the Strip Mall Building. Percent Difference in the Total Energy Cost between Case 1 and Case 22 is also shown for Each Location.

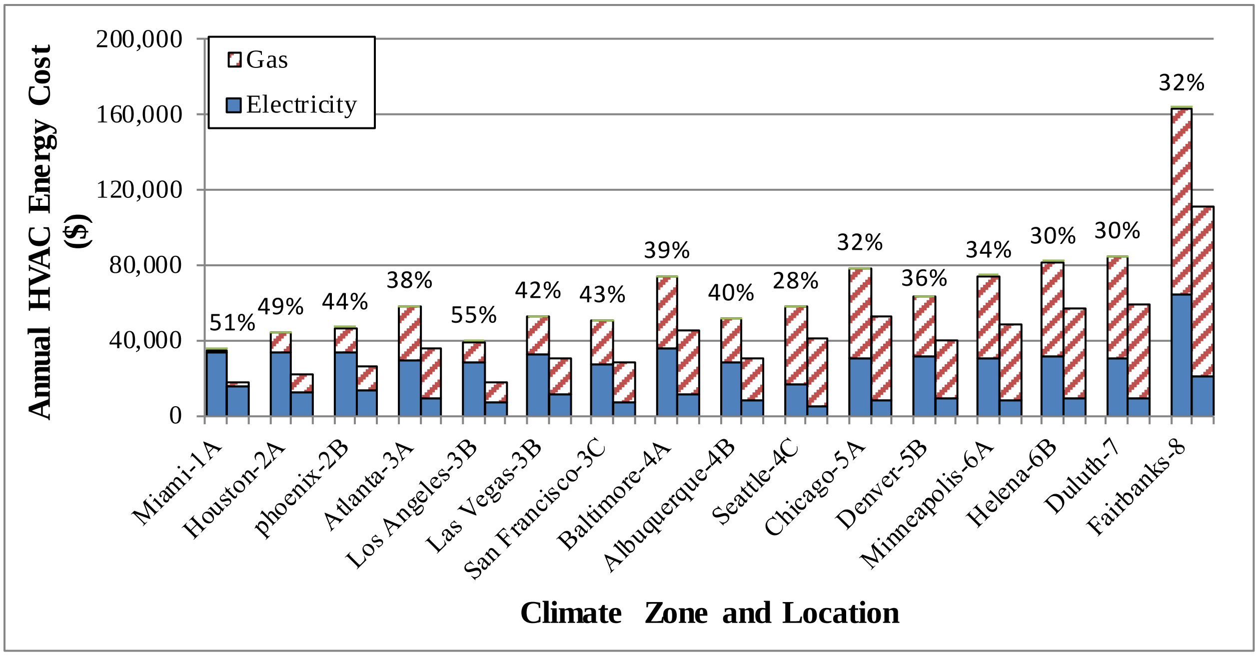

Figure 67: Comparison of HVAC Energy Cost between Case 1(left bar for each location) and Case 22 (right bar for each location) for the Supermarket Building. Percent Difference in the Total Energy Cost between Case 1 and Case 22 is also shown for Each Location.

Table 11: Summary of Energy Cost Savings for Case 22 Relative to the Base Case (Case 1)

	Building Type			
	Small Office	**Stand-alone Retail**	**Strip Mall**	**Supermarket**
Maximum savings	67%	60%	59%	55%
Location for maximum savings	San Francisco	Los Angeles	Los Angeles	Los Angeles
Minimum savings	38%	36%	36%	28%
Location for minimum savings	Miami	Fairbanks	Fairbanks	Seattle
Average savings	46%	43%	43%	39%
Maximum absolute savings ($/yr)	2393	23779	23414	52217
Location for maximum absolute savings	Fairbanks	Fairbanks	Fairbanks	Fairbanks
Minimum absolute savings ($/yr)	923	7,864	7,633	16,087
Location for minimum absolute savings	Seattle	Albuquerque	Albuquerque	Seattle
Average absolute savings ($/yr)	1,496	10,820	11,000	24,200

6.5 Controller Cost

One major objective of this study is to support the development of cost-effective controller that saves significant energy for packaged units on existing buildings. The maximum installed cost of advanced controllers that will yield a specific simple payback period is important for potential users to evaluate the financial merits of installing advanced controllers but also for vendors and developers in pricing their advanced control products. Because an add-on controller is usually associated with each rooftop unit, the total energy cost savings for a whole building needs to be normalized before calculating the maximum acceptable controller installed cost. Based on the cost savings per unit and the assumed simple payback period, the maximum total installed cost per controller can be calculated according to Equation 3. Table D49 through Table D52 in Appendix D lists the results that achieve a 3-year simple payback period for different cases covering all 21 advanced control combinations, 16 locations, and 4 building types. The results are based on the numbers of packaged units specified for the prototype buildings in Table 2 (five for the small office building, 4 for the stand-alone retail building, 10 for the strip mall, and 6 for the supermarket). In addition, all packaged units on the building are assumed to be retrofitted with the advanced controller so that the total savings possible for the building are achieved.

Controllers with different combinations of advanced control capabilities are likely to have different manufacturing and installation costs. Controllers with greater functionality will likely cost more. On the other hand, the examined control strategies have different degrees of impact on energy cost savings, as discussed in Section 6.1. Controllers with greater functionality (actually, the best combination of functionality) provide greater energy and cost savings. Therefore, analysis of the savings provided by a controller relative to its cost is important. We examine this by determining the maximum total installed cost per controller that yields specific simple payback periods for controllers with different combinations of control functionality. A total of four scenarios are considered:

- **Scenario 1**: the advanced controller with only multi-speed supply-fan control (Case 6) is retrofit to an existing packaged unit having a base case controller with no advanced control capabilities (including no economizer).
- **Scenario 2**: the advanced controller with only DCV is retrofit to an existing packaged unit (Case 14) having a base case (Case 1) controller with no advanced control capabilities (including no economizer)
- **Scenario 3**: the advanced controller with both multi-speed fan control and DCV (Case 18) is retrofit to an existing packaged unit with a controller having an integrated differential dry-bulb economizer, single-speed fan control, one-stage cooling, and no DCV (Case 4).
- **Scenario 4**: the advanced controller with an integrated differential dry-blub differential economizer control, multi-speed supply fan control, two-stage compressor control and DCV (Case 22) is retrofit to existing packaged units having a base case (Case 1) controller with no advanced control capabilities (including no economizer).

The maximum total installed costs per advanced controller for the above four scenarios are compared in Figure 68 through Figure 71for the four building types (The results are also provided in Table D49 through Table D60 in Appendix D). These figures show that the maximum total installed controller cost per packaged unit providing a 3-year payback period varies with the four scenarios. For all four building types, Scenarios 3 and 4 sequentially have the first two largest maximum cost per controller for all 16 locations. Because these two scenarios differ only in air-side economizer control, the magnitude of their maximum controller cost differences largely depends on the impact of air-side economizer control and the electricity prices. The maximum acceptable controller cost is larger in those locations, where the air-side economizer control contributes to significant cooling energy savings and the electricity price is high (such as Los Angeles, San Francisco, and Fairbanks). The order of Scenarios 1 and 2 in terms of the maximum controller cost depends on both locations and building types. For the small office building, Scenario 1 with multi-speed fan control achieves a higher maximum controller cost than Scenario 2 with DCV for all 16 locations. For the two retail buildings, Scenario 1 usually has a higher maximum controller cost than Scenario 2 in hot (e.g., Miami, Houston, Phoenix) or warm climates (e.g., Los Angeles, Las Vegas, and San Francisco), while the reverse is true in cold climates (e.g., Chicago, Helena, and Duluth). For the supermarket building, Scenario 2 has a higher maximum controller cost than Scenario 1 only in four locations including Seattle, Chicago, Helena, and Duluth.

As indicated in Figure 68 through Figure 71, the maximum total installed controller cost per packaged unit that provides a 3-year payback period varies significantly with the building type. For a given scenario and location, the maximum acceptable installed cost decreases in the order supermarket, stand-alone retail building, strip mall, and small office building. For example, for Scenario 4, the calculated maximum controller cost lies in the range between $8,040 and $26,110 for the supermarket building, $5,900 and $17,830 for the stand-alone retail building, $2,290 and $7,020 for the strip mall building, and $550 and $1,435 for the small office building. Two causes drive these differences. First, the maximum controller installed cost per packaged unit providing the designated payback period is proportional to the energy cost saving of each specific building. Figure 64 through Figure 67 show that for a specific location, the supermarket has the largest energy cost savings, the small office building has the smallest cost savings, and the two retail buildings have comparable cost savings that in magnitude are between the values for the supermarket and the small office building. Second, the maximum controller installed cost per packaged unit providing the designated payback period is inversely proportional to the number of the packaged units on that building. Because each unit requires a controller, the number of controllers required is identical to the number of packaged units. As the number of units (and, therefore, advanced controllers required) increases, the cost savings for the building are distributed among more controllers and the savings per controller decreases. In the four building models, the small office building has 5 packaged units and the stand-alone retail building, the strip mall and the supermarket, respectively, have 4, 10, and 6 packaged units. The fraction of building savings per unit decreases as the number of units increases but not sufficiently, for example, to make the maximum controller installed cost per unit providing the designated payback period for the strip mall (with 10 units) to be less than that for the office building (with 6 units).

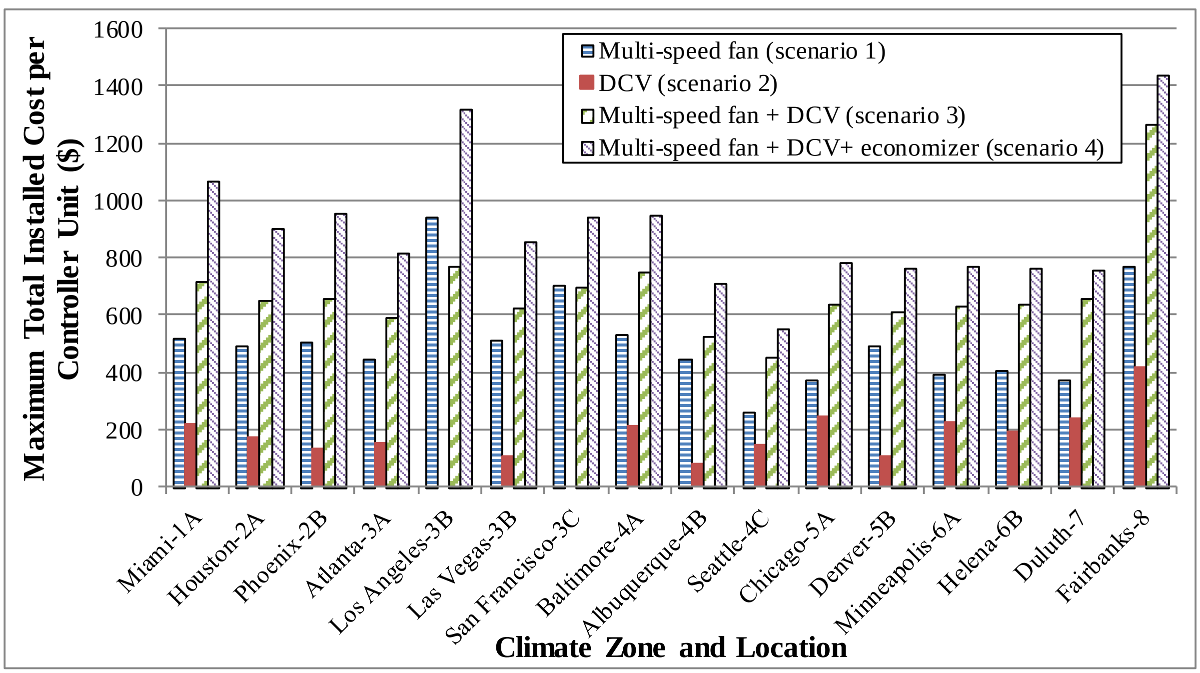

Figure 68: Maximum Total Installed Cost per Controller Unit to Achieve a Payback Period of 3 Years for the Small Office Building with Different Control Capabilities Added to an Existing Packaged Unit That Has Integrated Dry-Bulb Economizer for Scenario 3 but No Advanced Control in the Other Three Scenarios

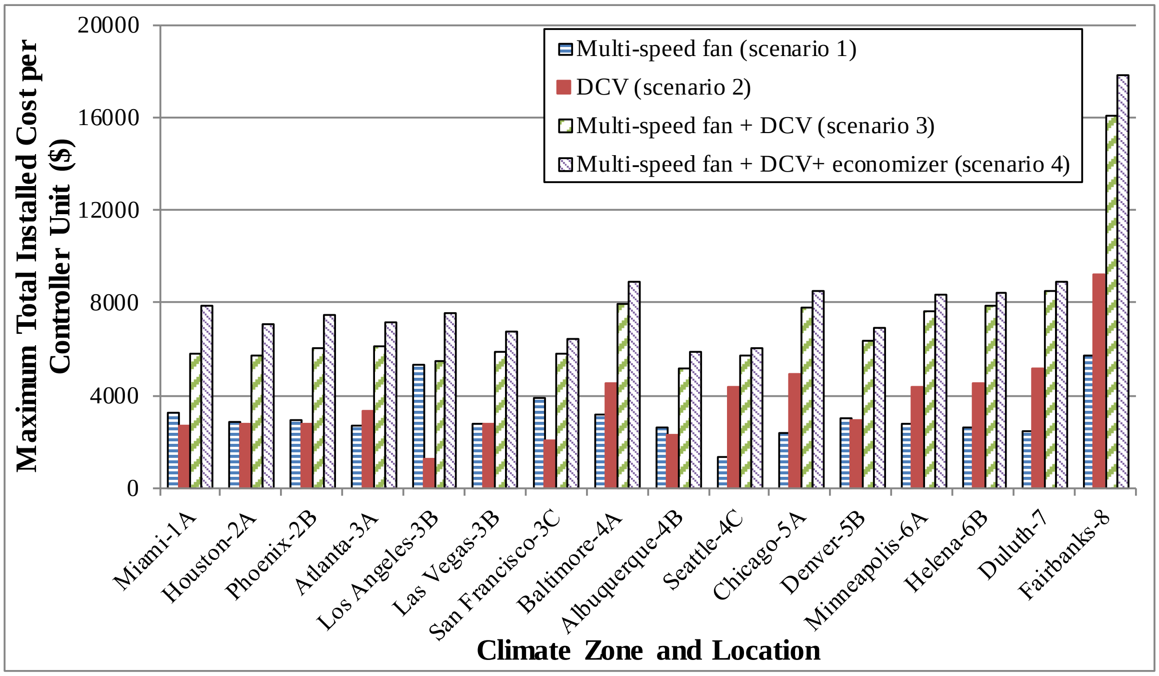

Figure 69: Maximum Total Installed Cost per Controller Unit to Achieve a Payback Period of 3 Years for the Stand-alone Retail Building with Different Control Capabilities Added to an Existing Packaged Unit That Has Integrated Dry-Bulb Economizer for Scenario 3 but No Advanced Control in the Other Three Scenarios

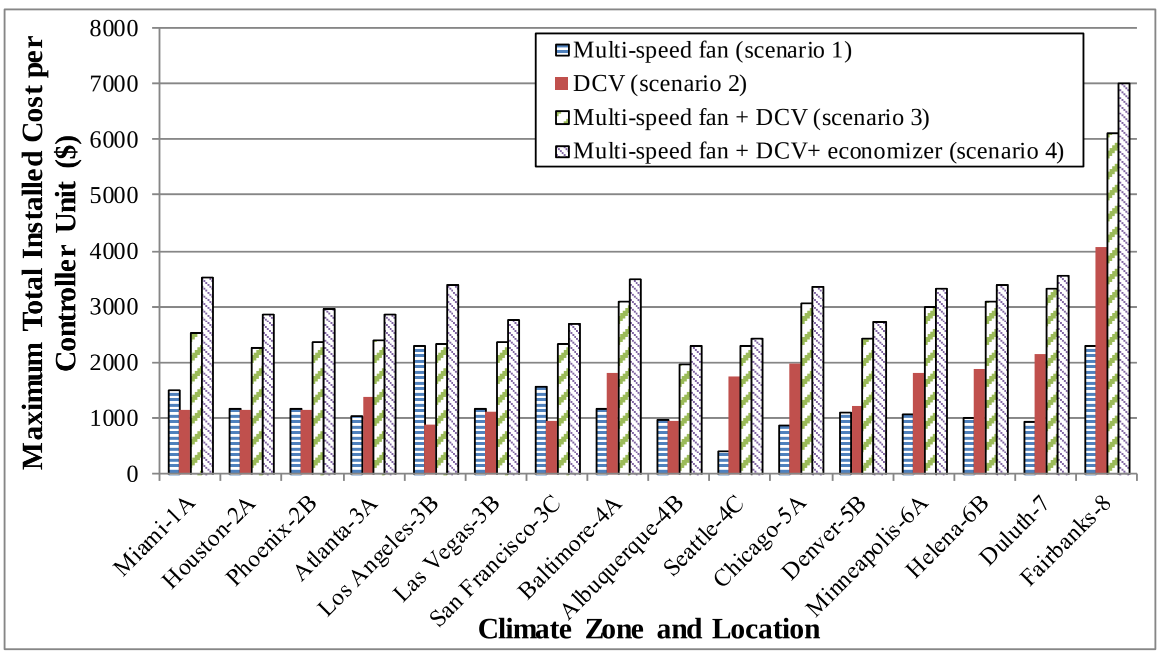

Figure 70: Maximum Total Installed Cost per Controller Unit to Achieve a Payback Period of 3 Years for the Strip Mall Building with Different Control Capabilities Added to an Existing Packaged Unit That Has Integrated Dry-Bulb Economizer for Scenario 3 but No Advanced Control in the Other Three Scenarios

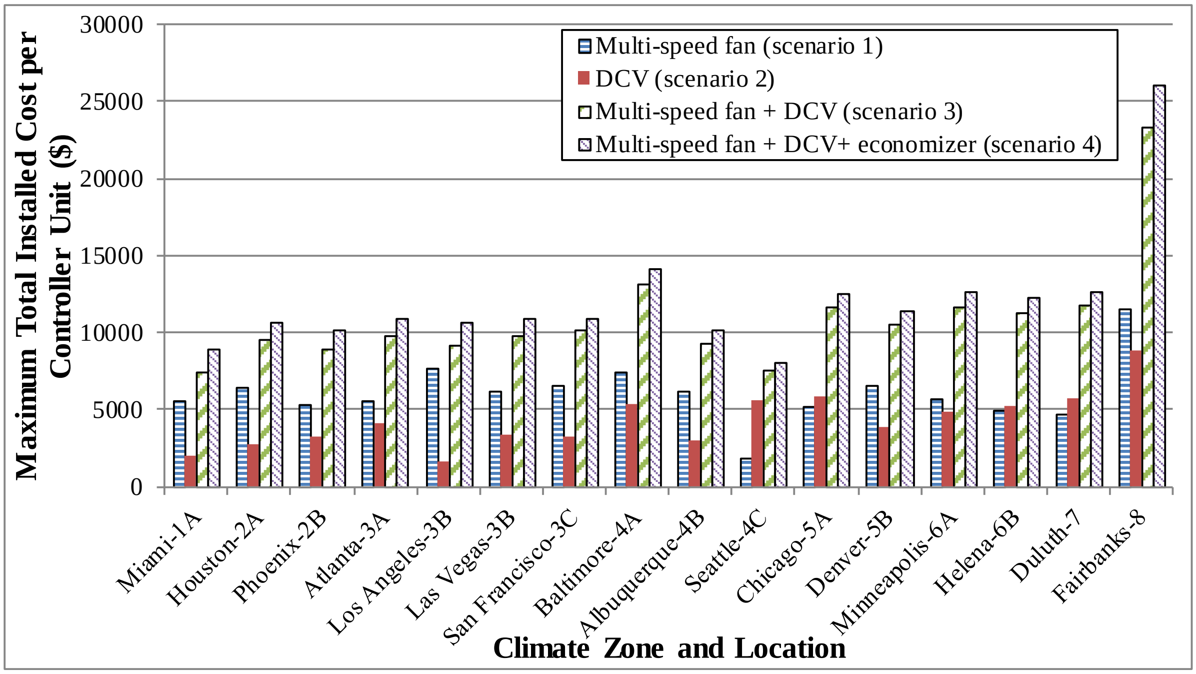

Figure 71: Maximum Total Installed Cost per Controller Unit to Achieve a Payback Period of 3 Years for the Supermarket Building with Different Control Capabilities Added to an Existing Packaged Unit That Has Integrated Dry-Bulb Economizer for Scenario 3 but No Advanced Control in the Other Three Scenarios

Based on the results in Table D49 through D52 that are calculated from the simple payback period of 3 years and the blended utility rates in the year of 2010 (Table 7), the maximum installed cost per controller can be easily calculated for other payback periods and utility rates. For example, for the small office building in Miami, if the maximum total installed controller cost assuming a 3-year simple payback period at the original utility rate is known to be $1,065 (Table D49) for Scenario 4 retrofit, the controller cost for 1-year simple payback at the original utility rate is equal to 1065/3=$355; the cost for 3-year simple payback at 5% increased rate equals $1065 x (1+0.05) = $1,118. As an illustration, Figure 72 through Figure 75 shows the maximum total installed controller cost per packaged unit that provides a 5-year payback period for the same four scenarios covered by Figure 68 through Figure 71.

In addition, for the convenience, the maximum installed controller cost per rooftop unit providing designated payback periods of 1, 3 and 5 years with different utility rates are provided in Appendix D for all 16 locations and four building types. The utility rates include the rates for both electricity and gas at ±5% and ±10% from the original rates (see Table 7). Table D53 through D56 lists the maximum installed cost per controller for Scenario 3 retrofit, which has multi-speed fan control and DCV added to an existing packaged unit with a controller having an integrated dry-bulb economizer, single-speed fan control, single-stage cooling and no DCV. Table D57 through D60 lists the maximum installed cost per controller for Scenario 4 retrofit, which has integrated dry-bulb economizer control, multi-speed fan control, and DCV added to an existing packaged unit with no advanced control capabilities.

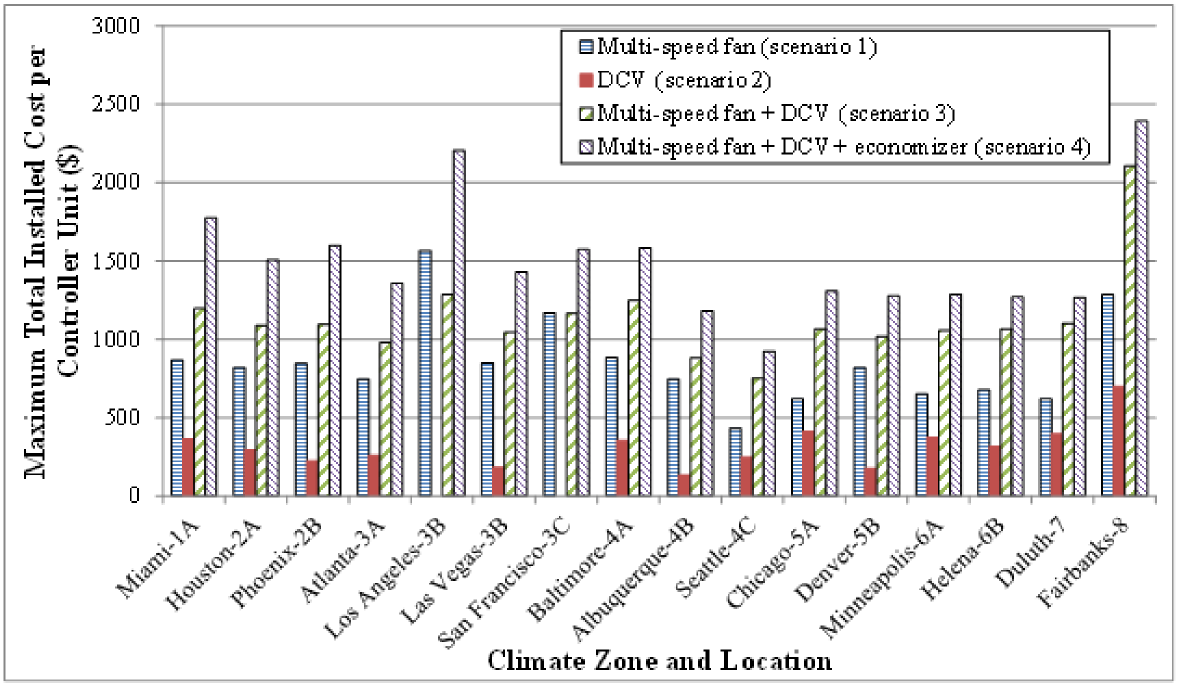

Figure 72: Maximum Total Installed Cost per Controller that Provides a Payback of 5 Years for the Small Office Building with Different Control Capabilities Added to an Existing Packaged Unit that has Integrated Differential Dry-Bulb Economizer for Scenario 3 but no Advanced Control in the Other 3 Scenarios

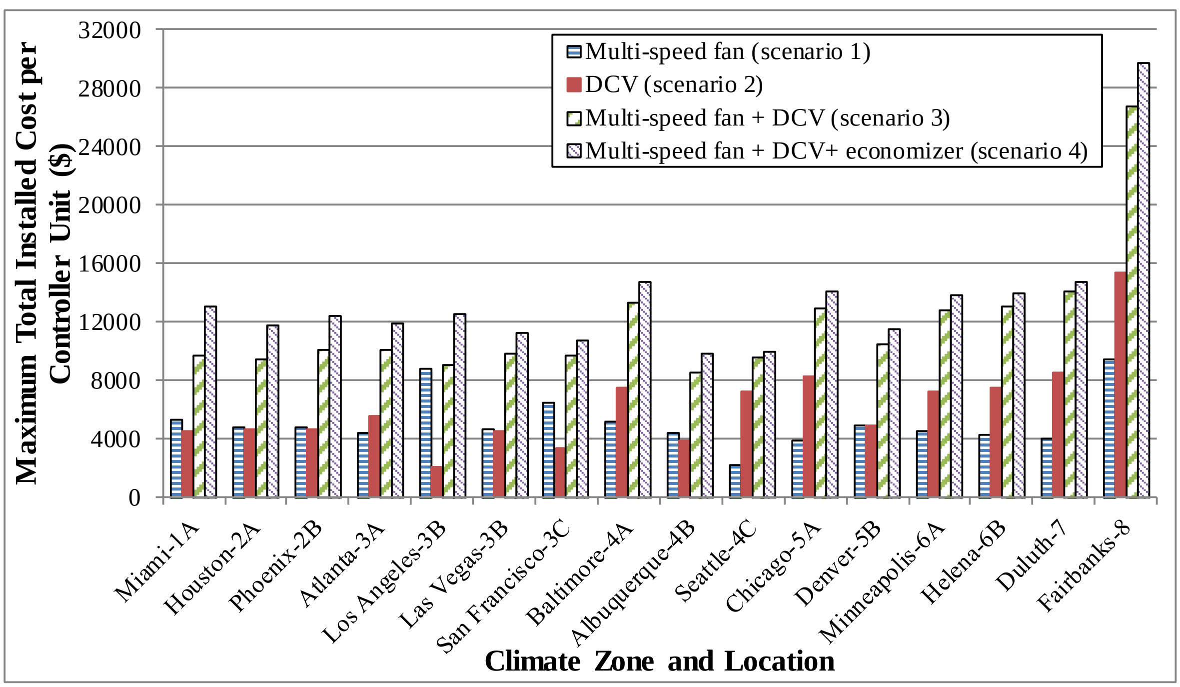

Figure 73: Maximum Total Installed Cost per Controller that Provides a Payback of 5 Years for the Stand-alone Retail Building with Different Control Capabilities Added to an Existing Packaged Unit that has Integrated Differential Dry-Bulb Economizer for Scenario 3 but no Advanced Control in the Other 3 Scenarios

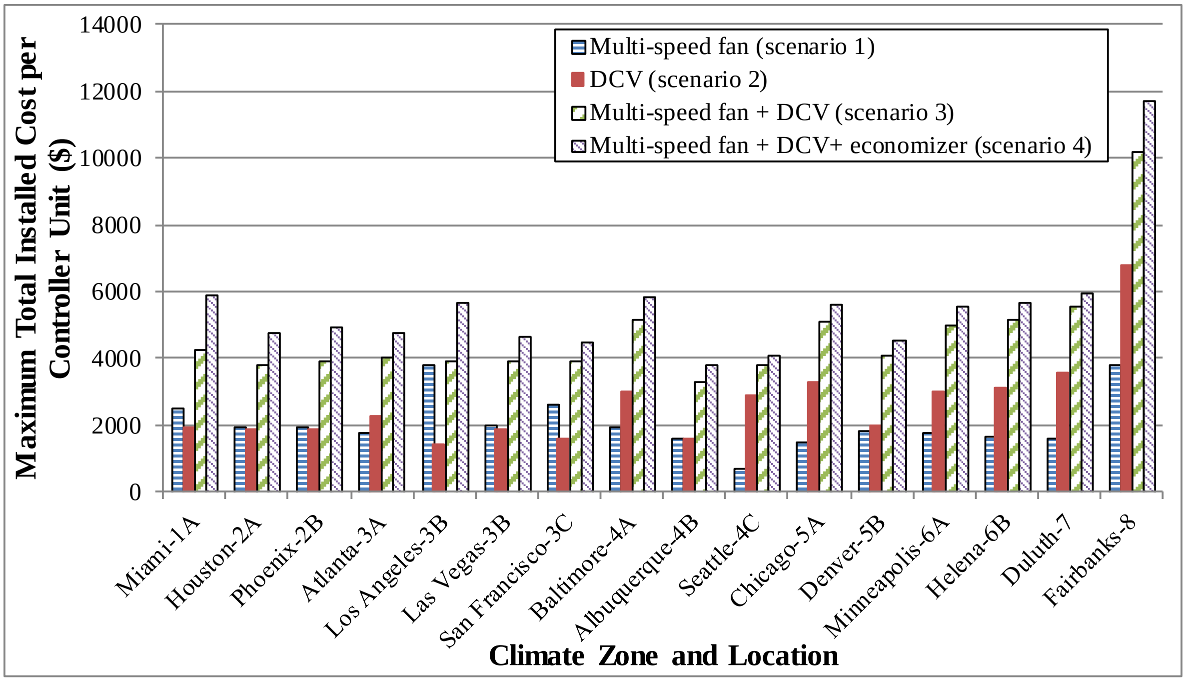

Figure 74: Maximum Total Installed Cost per Controller Unit that Provides a Payback of 5 Years for the Strip Mall Building with Different Control Capabilities Added to an Existing Packaged Unit that has Integrated Differential Dry-Bulb Economizer for Scenario 3 but no Advanced Control in the Other 3 Scenarios

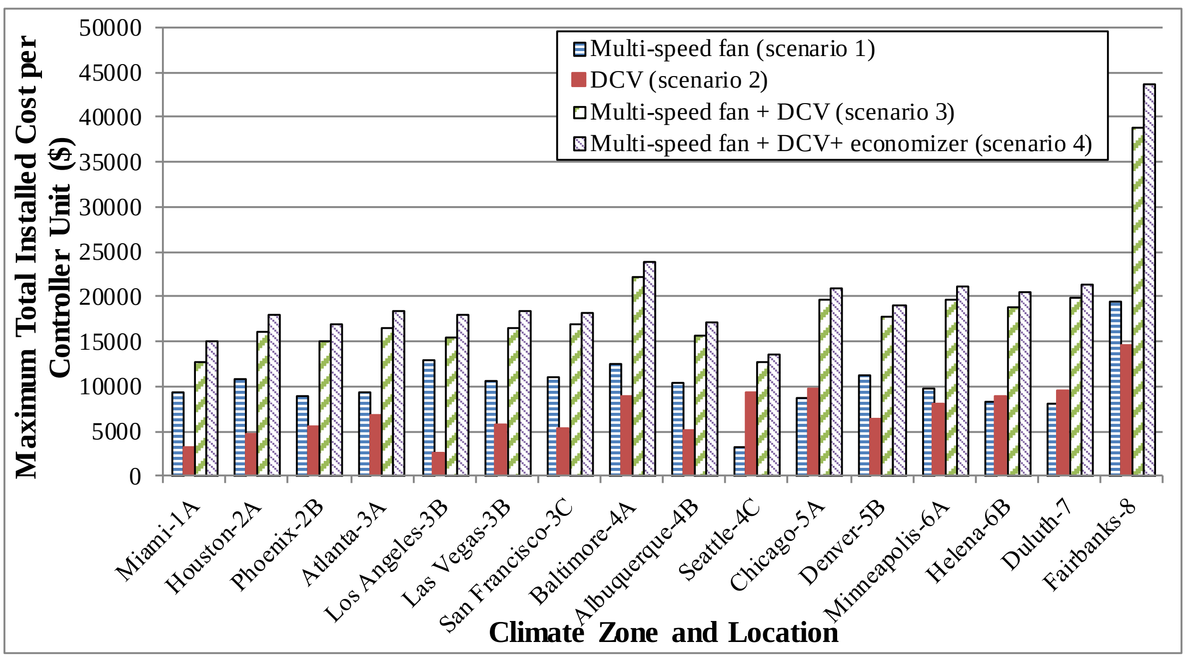

Figure 75: Maximum Total Installed Cost per Controller Unit that Provides a Payback of 5 Years for the Supermarket Building with Different Control Capabilities Added to an Existing Packaged Unit That has Integrated Differential Dry-Bulb Economizer for Scenario 3 but no Advanced Control in the Other 3 Scenarios

Table 12 shows the smallest values of the maximum installed cost for advanced controllers across all locations and climate zones that provide simple payback periods of 3 and 5 years and the corresponding specific locations and climate zones where they occur. Results are shown for two retrofit scenarios that the authors consider common opportunities: 1) retrofit of a unit having differential dry-bulb temperature-based integrated economizer, single-speed fan, and single-stage compressor control (and no DCV) with an advanced controller that adds multi-speed fan and DCV control (Scenario 3) and 2) retrofit of a unit having no advanced controls with an advanced controller having differential enthalpy-based integrated economizer, multi-speed fan, two-stage compressor control, and DCV (Scenario 4). These results are particularly important because they establish the maximum total installed cost that makes advanced controllers for packaged air conditioners with gas heating economic to building owners for all four building types that predominately use packaged units in all climate zones across the U.S. Vendors of advanced controllers can use this information to determine the maximum price that can be charged for these controllers to compete in the marketplace.

On a national basis, the maximum total installed cost for stand-alone retail, strip mall and supermarket buildings is $1,967 per controller, which is found for Scenario 3 for the strip mall in Albuquerque to achieve a 3-year payback period. For a 5-yar payback period, the maximum installed cost is $3,278 per controller, which also is found for Scenario 3 in Albuquerque. For the small office building the maximum total installed costs are $451 and $752 per controller for 3-year and 5-year paybacks, respectively, which are found for Scenario 3 in Seattle.

The results for Seattle are very low because the small office building model used for analysis has a floor area of only 5500 ft^2 but uses 5 packaged units to provide space conditioning. The results can be approximately scaled by multiplying the cost results by the ratio (5 packaged units)/(number of packaged unit on average found on a 5500 ft^2 building). For two units per 5500 ft^2 this ratio is 2.5, yielding maximum costs per control of $1,128 and $1,880 per controller for 3-year and 5-year payback periods, respectively.

Vendors could choose to target specific building types rather than all building types on which packaged units are commonly installed. For example, the most favorable market for use of the advanced controllers is supermarkets for which the maximum total cost per advanced controller is $7,523 for a 3-year payback period and $12,539 for a 5-year payback period. Likewise, vendors could decide to target only specific geographic regions, choosing those with the largest savings. These decisions would likely consider many additional factors such as the cost of manufacturing the advanced controllers, the cost of controller installation, and the size of the market in various geographic regions (and climate zones). The information provided here can be used as input for vendors to use in making these decisions.

Table 12: Maximum Values of the Installed Cost for Advanced Controllers that Provide Simple Payback Periods of 3 and 5 Years across the U.S. and the Specific Locations and Climate Zones to which these Values Correspond

	Scenario*	Small Office	Standalone Retail	Strip mall	Supermarket
3-year payback	*Scenario 3*	451 [Seattle-4C]	5,151 [Albuquerque-4B]	2,967 [Albuquerque-4B]	7,523 [Miami-1A]
	Scenario 4	554 [Seattle-4C]	5,898 [Albuquerque-4B]	2,290 [Albuquerque-4B]	8,044 [Seattle-4C]
5-year payback	*Scenario 3*	752 [Seattle-4C]	8,585 [Albuquerque-4B]	3,278 [Albuquerque-4B]	12,539 [Miami-1A]
	Scenario 4	923 [Seattle-4C]	9,830 [Albuquerque-4B]	3,817 [Albuquerque-4B]	13,406 [Seattle-4C]

* Scenario 3: retrofit of a unit having dry-bulb temperature-based integrated economizer, single-speed fan, and single-stage compressor control (and no DCV) with an advanced controller that adds multi-speed fan and DCV control (Case 4 to Case 18); Scenario 4: retrofit of a unit having no advanced controls with an advanced controller having integrated enthalpy-based economizer, multi-speed fan, two-stage (speed) compressor control, and DCV (Case 1 to Case 22)

As noted above, the maximum controller cost per unit for each building type is based on the number of packaged units used in the simulation model, which may not reflect the actual numbers of units in a building with similar size, use pattern and climate condition. For example, the simulation model used for small office buildings use 5 packaged units and all controller costs for small office building are calculated based five packaged units. If the number of packaged units where to be reduced from 5 to 2, the maximum installed cost per controller units (Figure 76) are increased by a factor of 2.5 in comparison with the results shown in Figure 68.

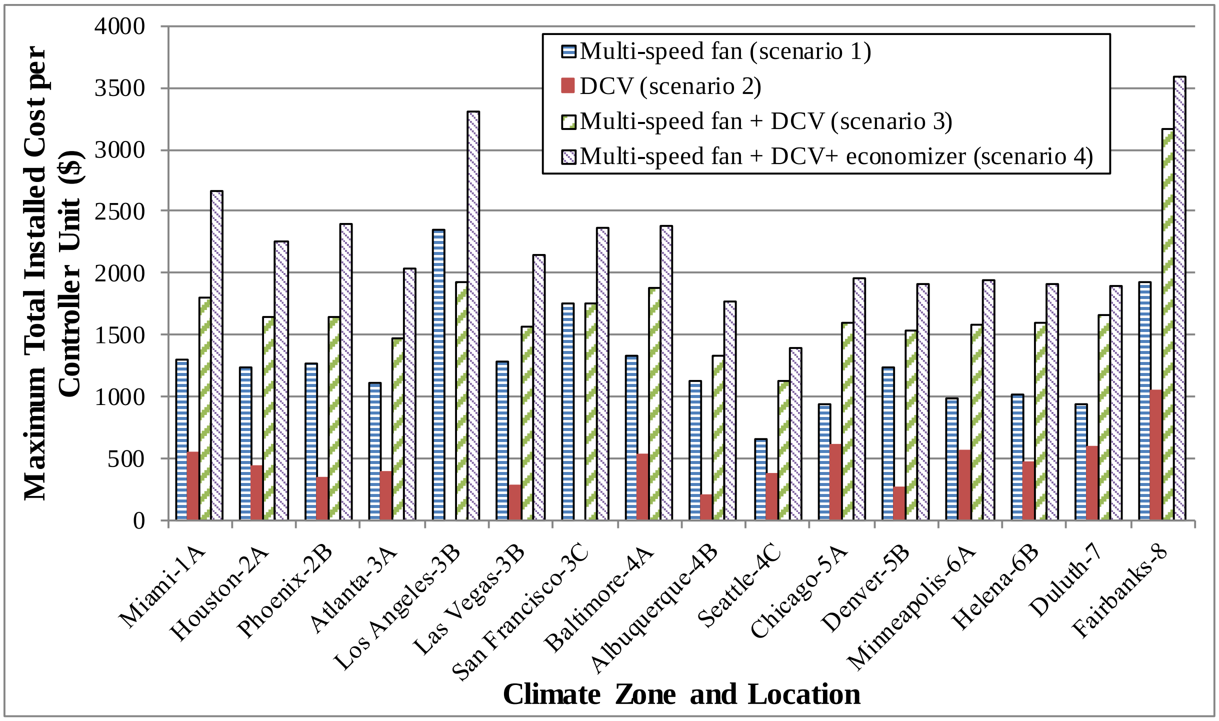

Figure 76: Maximum Total Installed Cost per Controller Unit that Provide Simple Payback of 3 Years for the Small Office Building with Different Control Capabilities and the Number of Packaged Units is reduced from 5 to 2

7. Conclusions and Future Planned Work

The conclusion from the energy savings and economics of advanced control strategies for packaged air-conditioning units with gas heat and the recommend future work is presented in this section.

7.1 Conclusions

The results based on simulations presented in Sections 5 and 6 show that advanced control combining an air-side economizer, DCV, multi-speed supply fan, and staged cooling achieves significant energy and cost savings across all locations and building types. The maximum percentage of HVAC energy savings relative to the base case is more than 45% for all four building types. This maximum occurs in Los Angeles for small office, stand-alone retail and strip mall buildings; the maximum occurs in Miami for the supermarket. The smallest percentage savings is about 16%, estimated for the supermarket in Fairbanks. For Case 22 with the fullest set of advanced control strategies (integrated differential enthalpy economizer, multi-speed fan, 2-stage cooling capacity and DCV) the average percentage HVAC energy savings across the 16 locations representing all US climate zones is around 24% for the supermarket and around 35% for the other three building types.

The annual absolute HVAC energy savings relative to the base case lies in the ranges between 40 and 100 MMBtu for the small office building, 300 and 1,390 MMBtu for the stand-alone retail building, 320 and 1,320 MMbtu for the strip mall, and 580 and 2,030 MMBtu for the supermarket. The maximum absolute energy savings relative to the base case all occur for Fairbanks. The average absolute savings across the 16 locations is about 60 MMBtu for the small office building, 610 MMBtu for the two retail buildings, and 1,010 MMBtu for the supermarket building.

For Case 22, the most energy efficiency package considered, the HVAC energy cost savings as a percentage of the base case energy cost lies in the range between 38% and 67% for the small office building, 36% and 60% for the stand-alone retail building, 36% and 59% for the strip mall, and 28% and 55% for the supermarket. The maximum percentage of HVAC energy cost saving relative to the base case occurs either in San Francisco or Los Angeles, where the electricity prices are high and the baseline building energy consumption is low. The smallest percentage energy cost savings is about 28% for the supermarket in Seattle, where the electricity price is low. The average percentage cost savings across the 16 locations is about 46% for the small office building, 43% for the two retail buildings, and 39% for the supermarket building.

With the fullest set of advanced control options, the annual absolute energy cost savings relative to the base case lies in the ranges between $920 and $2,390 for the small office building, $7,860 and $23,780 for the stand-alone retail building, $7,600 and $23,410 for the strip mall, and $16,090 and $52,220 for the supermarket. The maximum absolute cost savings relative to the base case all occur for Fairbanks. The average percentage cost savings across the 16 locations is about $1,500 for the small office building, $11,000 for the two retail buildings, and $24,200 for the supermarket building.

A more realistic comparison is with a unit with integrated dry-bulb differential economizer, single-stage compressor and constant speed fan (Case 4) to a unit that has integrated dry-bulb differential economizer, single-state compressor, multi-speed fan and DCV (Case 18), which achieves more than 40% HVAC energy savings for all four building types. This maximum occurs in Los Angeles for the small office and stand-alone retail buildings, in San Francisco for the strip mall building, in Miami for the supermarket building. The smallest percentage savings is about 14%, estimated for the supermarket in Fairbanks. Relative to Case 4, the average percentage HVAC energy savings across the 16 locations for Case 18 is around 28% for the small office building, 32% for the two retail buildings, and 22% for the supermarket building.

For Case 18, the annual absolute HVAC energy savings relative to Case 4 lies in the range between 30 and 90 MMBtu for the small office building, 230 and 1,270 MMBtu for the stand-alone retail building, 240 and 1,170 MMbtu for the strip mall, and 500 and 1,770 MMBtu for the supermarket. The maximum absolute energy savings relative to Case 4 all occur in Fairbanks. The average absolute savings across the 16 locations is about 46 MMBtu for the small office building, 550 MMBtu for the two retail buildings, and 910 MMBtu for the supermarket building.

With multi-speed fan and DCV added to Case 4 that already has the air-side economizer, the HVAC energy cost savings as a percentage of Case 4 energy cost lies in the range between 27% and 59% for the small office building, 30% and 53% for the stand-alone retail building, 29% and 54% for the strip mall, and 27% and 50% for the supermarket. The maximum percentage of HVAC energy cost saving relative to Case 4 occurs either in San Francisco or Los Angeles, where the electricity prices are high and the building energy consumption is low. The smallest percentage energy cost savings occurs in either Miami or Seattle. The average percentage cost savings across the 16 locations is about 36% for the supermarket building and 38% for the other three building types.

The annual absolute energy cost savings of Case 18 relative to Case 4 lies in the ranges between $750 and $2,110 for the small office building, $6,870 and $21,380 for the stand-alone retail building, $6,556 and $20,370 for the strip mall, and $15,050 and $46,600 for the supermarket. The maximum absolute cost savings relative to Case 4 all occur in Fairbanks. The average percentage cost savings across the 16 locations is about $1,130 for the small office building, $9,400 for the two retail buildings, and $22,000 for the supermarket building.

Individual control strategies have different degrees of impact on energy and cost savings. The simulation results indicate that multi-speed fan control and DCV are the two control strategies contributing the most to savings. In many cases, multi-speed fan control dominates the impact in hot and mild climates, such as Miami and Los Angeles, while DCV dominates the impact in mixed and cold climates, such as Seattle, Chicago, and Duluth. Applying multi-speed fan control alone may lead to an increase in overall HVAC energy consumption in cold climates, but that is not the case for energy cost. Following the sequence of operation as specified in this study, whether an air-side economizer is integrated with mechanical cooling or not has little if any noticeable impact on energy or cost savings.

The maximum installed cost per controller that can achieve a 3-year simple payback varies significantly with the building type. If the controller incorporates all considered control strategies (Case 22), the maximum total installed cost varies in the range $8,040 and $26,110 for the supermarket building to achieve a payback period of 3 years, between $5,900 and $17,830 for the stand-alone retail building, between $2,290 and $7,020 for the strip mall building, and between $550 and $1,435 for the small office building. Advanced controllers with the complete set of control features corresponding to Cases 22 will need to have a total cost less than these values to provide savings that justify the investment by building owners in the absence of an incentive that decreases the cost to the owner with a subsidy.

7.2 Future Work

Bringing retrofitable advanced control packages rapidly to the mass market to realize the large energy and cost savings potential found in this study will likely require additional information and further development of the technology. Some key needs identified by the project team include the following.

- The energy savings estimated with simulations in this study should be validated with field tests of retrofitable controllers for packaged units that are beginning to enter the marketplace. Testing can be used to validate overall energy savings as well as savings from individual control strategies and specific combinations of control strategies.
- As this study considered packaged rooftop air conditioners with direct expansion cooling and gas furnace heating, similar analyses of packaged air source heat pumps and air conditioners with electric resistive heating would prove valuable.
- The small office building model is a single-story building with just less than 5000 ft^2 floor area. The small size, together with its somewhat atypical attic roof construction, makes it not representative of most office buildings served by packaged rooftop units. Therefore, results may be improved by using an office building model that corresponds closer to the size and construction of the median office building that uses packaged rooftop units, such as the DOE reference building model for a medium office building, which has a conditioned floor area of about 50,000 ft^2.
- If the cost of advanced controllers on the market exceeds the maximum cost for a payback period commonly found acceptable by building owners, additional technological innovation may be required to lower the cost of advanced controllers to acceptable levels. This technology development may be best performed in government-industry collaborations (e.g., national laboratories with building controller manufacturers).
- Development of a guide or software tool for building owners and managers to assist them in making decisions to install advanced controllers may be important to accelerate the market penetration of advanced controllers, which based on this study can save considerable energy (approximately 25% to 60% of the energy consumption of rooftop units over a broad range of U.S. climates).
- In addition to the measures considered (air-side economizer, multiple supply-fan speed control, DCV and staged direct expansion cooling using multi-speed control of compressor motors), other advanced control technologies applicable to packaged rooftop units should be evaluated. Such technologies include optimal start times, closing outdoor-air dampers during morning warm up or cool down periods, and fully variable-speed control of the supply fan, condenser fan and compressor.
- The analysis in this report assumes that all sensors are accurate. However, sensors are rarely perfectly accurate and control precise in practice. For this reason, it is important to consider the uncertainty of sensor measurements. The impacts of uncertainty on energy savings, cost savings, and the maximum economical total cost of the control retrofits should be investigated.

- The impact assessment was made for a single set of predefined values for the key control parameters (Table 6). Because these values are likely to vary in field applications, it is worthwhile to investigate the impact on energy and cost savings of using different parameter values. The control parameters could even be optimized.
- The EnergyPlus program and DOE reference building models were used in the current work to evaluate the energy saving potential of advanced rooftop unit control strategies. The impact of compressor cycling on cooling efficiency was not considered in this analysis. Because ignoring cycling losses underestimates the savings potential from staged cooling, the simulation of control needs to be improved to incorporate compressor cycling.
- Based on the DOE reference models, EnergyPlus was used in the current work to evaluate the energy saving potential with advanced rooftop unit control strategies. The impact of compressor cycling on cooling efficiency was not considered in the current simulation. Because ignoring cycling losses underestimates the saving potential from staged cooling, the simulation control needs to be improved to incorporate compressor cycling.

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A. APPENDIX A
Prototype Building Characteristics

Table A-1: Key Geometric, Envelope, HVAC, Water Heating and Internal Load Characteristics for the Small Office Building Prototype

Geometry	
Floor area	5,500 ft^2
Aspect ratio	1.5
Number of floor	1
Window-to-wall ratio	21.2%
Floor-to-ceiling height	10.2 ft
Envelope	
Exterior Wall	Steel-frame wall (R-value: 4.35 to 8)
Roof	Insulation entirely above deck (IEAD) (R-value: 10 to 17)
Window	U-value 0.62 to 1.03 Solar heat gain coefficient (SHGC) 0.41 to 0.54 Visible transmittance (VT) 0.32 to 0.38
Foundation	Mass floor 4-in. slab with carpet
HVAC	
Type	Packaged single zone, constant air volume system
Heating	Gas furnace (80% efficiency)
Cooling	Unitary DX (3.07 COP)
Ventilation	20 cfm/person
System schedule	7am-11pm (weekdays) 7am-7pm (Saturday)
Cooling set point and setback	75˚F / 80 ˚F
Heating set point and setback	70 ˚F /60 ˚F
Service Water Heating	
Type	Gas (80% efficiency)
Temperature set point	140˚F
Water usage	11.4 L/h
Internal Load	
Occupancy density	200 ft^2/per person (total 28 persons in the building)
Lighting	1.8 W/ft^2
Plug equipment	1.0 W/ft^2

Table A-2: Key Geometric, Envelope, HVAC, Water Heating and Internal Load Characteristics for the Stand-alone Retail Building Prototype

Geometry	
Floor area	25,000 ft^2
Aspect ratio	1.3
Number of floor	1
Window-to-wall ratio	7.1%
Floor-to-ceiling height	20 ft
Envelope	
Exterior wall	Steel-frame wall (R-value: 2.4 to 22)
Roof	IEAD (R-value: 10 to 33)
Window	U-value 0.52 to 1.03; SHGC 0.04 to 0.11; VT 0.02 to 0.1
Foundation	Mass floor 4-in. slab
HVAC	
Type	Packaged single zone, constant air volume system
Heating	Gas furnace (78% to 80% efficiency)
Cooling	Unitary DX (3.23 to 3.7 COP)
Ventilation	0.3 cfm/ft^2 in cashier and two sales zones; 0.15 cfm/ft^2 in storage zone.
System schedule	7 am-10 pm (weekdays) 7 am-11 pm (Sat.) 9 am-10 pm (Sun.)
Cooling set point and setback	75˚F / 86 ˚F
Heating set point and setback	70 ˚F /60 ˚F
Internal Load	
Occupancy density	300 ft^2/per person in storage zone (total 323 persons in the building) 67 ft^2/per person in four other zones
Lighting	1.2 W/ft^2 in storage zone 3.4 W/ft^2 in four other zones
Plug equipment	0.3 W/ft^2 in two Sales zones; 0.7 W/ft^2 in storage zone; 2.0 W/ft^2 in cashier zone.

Table A-3: Key Geometric, Envelope, HVAC, Water Heating, and Internal Load Characteristics for the Strip Mall Building Prototype

Geometry	
Floor area	22,500 ft^2
Aspect ratio	4
Number of floor	1
Window-to-wall ratio	10.5%
Floor-to-ceiling height	17 ft
Envelope	
Exterior wall	Steel-frame wall (R-value: 1.8 to 22)
Roof	IEAD (R-value: 10 to 33)
Window	U-value 0.52 to 1.03; SHGC 0.04 to 0.11; VT 0.02 to 0.1
Foundation	Mass Floor 4-in slab (R-value: 1.8)
HVAC	
Type	Packaged single zone, constant air volume system
Heating	Gas furnace (78% to 80% efficiency)
Cooling	Unitary DX (3.2 to 3.7 COP)
Ventilation	0.3 cfm/ft^2 in all zones
System schedule	7 am-10 pm (weekdays) 7 am-11 pm (Sat.) 9 am-8 pm (Sun.)
Cooling set point and setback	75˚F / 86 ˚F
Heating set point and setback	70 ˚F /60 ˚F
Internal Load	
Occupancy density	67 ft^2/per person
Lighting	5.6 W/ft^2 in one large-store zone, and one small-store zone; 3.3 W/ft^2 in three small-store zones; 2.7 W/ft2 in one large-store zone, and four small-store zones.
Plug equipment	0.4 W/ft^2 in all the zones

Table A-4: Key Geometric, Envelope, HVAC, Water Heating, and Internal Load Characteristics for the Supermarket Building Prototype

Geometry	
Floor area	45,000 ft^2
Aspect ratio	1.5
Number of floor	1
Window-to-wall ratio	11%
Floor-to-ceiling height	20 ft
Envelope	
Exterior wall	Steel-frame wall (R-value: 2.4 to 21.3)
Roof	IEAD (R-value: 10 to 33)
Window	U-value 0.52 to 1.03; SHGC 0.04 to 0.11; VT 0.02 to 0.1
Foundation	Mass floor 4-in slab (R-value: 1.8)
HVAC	
Type	Packaged single zone, constant air volume system
Heating	Gas furnace (78% - 80% efficiency)
Cooling	Unitary DX (3.1 – 3.7 COP)
Ventilation	20 cfm/person in office 0.3 cfm/ft^2 in sales, deli, produce and bakery zones 0.15 cfm/ft^2 in dry storage zones
System schedule	7 am-11 pm
Cooling set point and setback	75˚F / 86 ˚F
Heating set point and setback	70 ˚F /60 ˚F
Internal Load	
Occupancy density	125 ft^2/per person in sales, deli, produce and bakery zones 200 ft^2/per person in office 300 ft^2/per person in dry storage zone
Lighting	2.8 W/ft^2 in sales, deli, produce and bakery zones 2.0 W/ft^2 in office 1.1 W/ft^2 in dry storage zone
Plug equipment	0.4 W/ft^2 in all the zones

B. APPENDIX B
Tables of HVAC Energy Uses

Table B-1: HVAC Energy Uses for the Small Office Building in Climate Zones 1A and 2A

Units: [10^6 Btus]

Case No	Case Name	Miami-1A				Houston-2A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	49	113	1	162	47	78	30	155
2	NIEcon.DB.SSFan.CS1.DCV0	52	105	1	157	48	71	30	149
3	NIEcon.EH.SSFan.CS1.DCV0	49	108	1	158	47	73	30	150
4	IEcon.DB.SSFan.CS1.DCV0	52	105	1	158	48	71	30	149
5	IEcon.EH.SSFan.CS1.DCV0	49	108	1	158	47	73	30	150
6	NoEcon.MSFan.CS1.DCV0	21	110	1	132	17	75	39	131
7	NIEcon.DB.MSFan.CS1.DCV0	25	103	1	130	19	69	39	128
8	NIEcon.EH.MSFan.CS1.DCV0	22	107	1	130	18	72	39	128
9	IEcon.DB.MSFan.CS1.DCV0	25	104	1	130	19	70	39	128
10	IEcon.EH.MSFan.CS1.DCV0	22	107	1	130	18	71	39	128
11	NoEcon.MSFan.CS2.DCV0	18	96	1	115	14	66	39	119
12	IEcon.DB.MSFan.CS2.DCV0	22	92	1	115	17	62	39	119
13	IEcon.EH.MSFan.CS2.DCV0	19	93	1	113	16	63	39	117
14	NoEcon.SSFan.CS1.DCV1	49	100	1	149	47	70	22	138
15	IEcon.DB.SSFan.CS1.DCV1	51	93	1	146	48	62	22	132
16	IEcon.EH.SSFan.CS1.DCV1	49	95	1	145	47	64	22	133
17	NoEcon.MSFan.CS1.DCV1	20	97	1	117	15	66	29	110
18	IEcon.DB.MSFan.CS1.DCV1	23	92	1	116	18	61	29	108
19	IEcon.EH.MSFan.CS1.DCV1	20	93	1	115	16	62	29	107
20	NoEcon.MSFan.CS2.DCV1	16	85	1	102	13	58	29	100
21	IEcon.DB.MSFan.CS2.DCV1	20	82	1	103	16	55	29	100
22	IEcon.EH.MSFan.CS2.DCV1	18	82	1	100	14	55	29	98

Table B-2: HVAC Energy Uses for the Small Office Building in Climate Zones 2B and 3A

Units: [10^6 Btus]

Case No	Case Name	Phoenix-2B				Atlanta-3A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	49	95	17	161	46	46	63	155
2	NIEcon.DB.SSFan.CS1.DCV0	50	89	17	156	47	37	63	146
3	NIEcon.EH.SSFan.CS1.DCV0	49	89	17	155	46	39	63	148
4	IEcon.DB.SSFan.CS1.DCV0	50	89	17	156	47	37	63	146
5	IEcon.EH.SSFan.CS1.DCV0	49	89	17	155	46	39	63	148
6	NoEcon.MSFan.CS1.DCV0	18	92	25	135	14	42	81	137
7	NIEcon.DB.MSFan.CS1.DCV0	19	88	25	133	16	36	81	133
8	NIEcon.EH.MSFan.CS1.DCV0	19	88	25	132	15	38	81	133
9	IEcon.DB.MSFan.CS1.DCV0	19	88	25	132	16	36	81	133
10	IEcon.EH.MSFan.CS1.DCV0	19	88	25	132	15	38	81	133
11	NoEcon.MSFan.CS2.DCV0	15	80	25	120	12	36	81	129
12	IEcon.DB.MSFan.CS2.DCV0	17	76	25	118	14	32	81	127
13	IEcon.EH.MSFan.CS2.DCV0	17	76	25	118	14	32	81	127
14	NoEcon.SSFan.CS1.DCV1	49	89	12	150	46	43	46	135
15	IEcon.DB.SSFan.CS1.DCV1	50	82	12	143	47	33	46	126
16	IEcon.EH.SSFan.CS1.DCV1	49	82	12	143	46	35	47	127
17	NoEcon.MSFan.CS1.DCV1	17	86	18	120	13	39	60	112
18	IEcon.DB.MSFan.CS1.DCV1	18	80	18	116	15	33	60	107
19	IEcon.EH.MSFan.CS1.DCV1	18	80	18	116	14	34	60	107
20	NoEcon.MSFan.CS2.DCV1	14	74	18	106	11	34	60	105
21	IEcon.DB.MSFan.CS2.DCV1	16	70	18	103	14	29	60	103
22	IEcon.EH.MSFan.CS2.DCV1	16	70	18	103	13	29	60	102

Table B-3: HVAC Energy Uses for the Small Office Building in Climate Zone 3B

Units: [10^6 Btus]

Case No	Case Name	Los Angeles-3B				Las Vegas-3B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	46	36	12	94	45	65	33	143
2	NIEcon.DB.SSFan.CS1.DCV0	47	15	12	74	45	59	33	137
3	NIEcon.EH.SSFan.CS1.DCV0	47	19	12	78	45	59	33	137
4	IEcon.DB.SSFan.CS1.DCV0	47	15	12	74	45	59	33	137
5	IEcon.EH.SSFan.CS1.DCV0	47	19	12	78	45	59	33	137
6	NoEcon.MSFan.CS1.DCV0	11	31	20	62	14	62	46	122
7	NIEcon.DB.MSFan.CS1.DCV0	14	16	20	49	15	59	46	120
8	NIEcon.EH.MSFan.CS1.DCV0	13	20	20	52	15	59	46	120
9	IEcon.DB.MSFan.CS1.DCV0	14	16	20	49	15	59	46	119
10	IEcon.EH.MSFan.CS1.DCV0	13	19	20	52	15	59	46	119
11	NoEcon.MSFan.CS2.DCV0	9	25	20	54	12	55	46	113
12	IEcon.DB.MSFan.CS2.DCV0	13	14	20	47	14	52	46	111
13	IEcon.EH.MSFan.CS2.DCV0	12	15	20	47	14	52	46	111
14	NoEcon.SSFan.CS1.DCV1	46	38	9	93	45	62	24	130
15	IEcon.DB.SSFan.CS1.DCV1	47	15	10	71	45	55	24	123
16	IEcon.EH.SSFan.CS1.DCV1	47	19	10	75	45	55	24	123
17	NoEcon.MSFan.CS1.DCV1	11	32	14	58	13	58	33	105
18	IEcon.DB.MSFan.CS1.DCV1	14	15	14	43	14	54	33	101
19	IEcon.EH.MSFan.CS1.DCV1	13	19	14	46	15	54	33	101
20	NoEcon.MSFan.CS2.DCV1	10	27	14	50	11	51	33	96
21	IEcon.DB.MSFan.CS2.DCV1	13	14	14	41	13	47	33	93
22	IEcon.EH.MSFan.CS2.DCV1	12	15	14	41	13	47	33	94

Table B-4: HVAC Energy Uses for the Small Office Building in Climate Zones 3C and 4A

Units: [10^6 Btus]

Case No	Case Name	San Francisco-3C				Baltimore-4A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	37	13	42	91	42	33	93	167
2	NIEcon.DB.SSFan.CS1.DCV0	37	4	41	82	42	27	93	161
3	NIEcon.EH.SSFan.CS1.DCV0	37	4	41	82	42	28	93	162
4	IEcon.DB.SSFan.CS1.DCV0	37	3	41	82	42	27	93	161
5	IEcon.EH.SSFan.CS1.DCV0	37	4	41	82	42	28	93	162
6	NoEcon.MSFan.CS1.DCV0	8	10	60	77	12	30	115	157
7	NIEcon.DB.MSFan.CS1.DCV0	8	4	59	72	14	26	115	154
8	NIEcon.EH.MSFan.CS1.DCV0	8	4	59	72	13	27	115	154
9	IEcon.DB.MSFan.CS1.DCV0	8	4	59	71	14	26	115	154
10	IEcon.EH.MSFan.CS1.DCV0	8	4	59	72	13	27	115	154
11	NoEcon.MSFan.CS2.DCV0	7	8	59	74	11	26	115	152
12	IEcon.DB.MSFan.CS2.DCV0	8	3	59	70	13	23	115	151
13	IEcon.EH.MSFan.CS2.DCV0	8	3	59	70	12	23	115	150
14	NoEcon.SSFan.CS1.DCV1	37	15	28	81	42	31	64	137
15	IEcon.DB.SSFan.CS1.DCV1	37	3	28	69	42	24	64	129
16	IEcon.EH.SSFan.CS1.DCV1	37	4	28	69	42	24	64	130
17	NoEcon.MSFan.CS1.DCV1	8	12	41	61	11	27	81	119
18	IEcon.DB.MSFan.CS1.DCV1	8	4	41	53	12	23	80	116
19	IEcon.EH.MSFan.CS1.DCV1	8	4	41	53	12	23	80	116
20	NoEcon.MSFan.CS2.DCV1	7	10	41	57	10	24	80	115
21	IEcon.DB.MSFan.CS2.DCV1	8	3	41	52	12	21	80	113
22	IEcon.EH.MSFan.CS2.DCV1	8	3	41	52	11	21	80	112

Table B-5: HVAC Energy Uses for the Small Office Building in Climate Zones 4B and 4C

Units: [10^6 Btus]

Case No	Case Name	Albuquerque-4B				Seattle-4C			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	44	34	67	145	40	11	77	128
2	NIEcon.DB.SSFan.CS1.DCV0	44	27	67	138	40	5	77	121
3	NIEcon.EH.SSFan.CS1.DCV0	44	28	67	139	40	5	77	121
4	IEcon.DB.SSFan.CS1.DCV0	44	27	67	138	40	4	77	121
5	IEcon.EH.SSFan.CS1.DCV0	44	27	67	139	40	5	77	121
6	NoEcon.MSFan.CS1.DCV0	12	31	86	129	9	9	103	121
7	NIEcon.DB.MSFan.CS1.DCV0	14	26	85	125	10	5	103	117
8	NIEcon.EH.MSFan.CS1.DCV0	13	27	85	125	10	5	103	118
9	IEcon.DB.MSFan.CS1.DCV0	14	26	85	125	10	4	103	117
10	IEcon.EH.MSFan.CS1.DCV0	13	27	85	125	10	5	103	117
11	NoEcon.MSFan.CS2.DCV0	11	25	85	121	8	7	103	118
12	IEcon.DB.MSFan.CS2.DCV0	13	22	85	119	9	4	103	116
13	IEcon.EH.MSFan.CS2.DCV0	13	22	85	119	9	4	103	116
14	NoEcon.SSFan.CS1.DCV1	44	33	50	128	40	13	50	103
15	IEcon.DB.SSFan.CS1.DCV1	44	25	50	120	40	4	49	93
16	IEcon.EH.SSFan.CS1.DCV1	44	26	50	120	40	5	49	94
17	NoEcon.MSFan.CS1.DCV1	12	30	64	105	8	10	69	87
18	IEcon.DB.MSFan.CS1.DCV1	13	24	63	100	9	4	68	82
19	IEcon.EH.MSFan.CS1.DCV1	13	25	63	101	9	5	68	82
20	NoEcon.MSFan.CS2.DCV1	10	25	63	98	8	8	68	84
21	IEcon.DB.MSFan.CS2.DCV1	12	20	63	95	9	3	68	81
22	IEcon.EH.MSFan.CS2.DCV1	12	20	63	95	9	3	68	81

Table B-6: HVAC Energy Uses for the Small Office Building in Climate Zones 5A and 5B

Units: [10^6 Btus]

Case No	Case Name	Chicago-5A				Denver-5B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	45	26	137	208	47	22	99	168
2	NIEcon.DB.SSFan.CS1.DCV0	46	20	136	202	47	16	98	161
3	NIEcon.EH.SSFan.CS1.DCV0	45	21	136	203	47	17	98	162
4	IEcon.DB.SSFan.CS1.DCV0	46	20	136	201	47	16	98	161
5	IEcon.EH.SSFan.CS1.DCV0	45	21	136	203	47	17	98	162
6	NoEcon.MSFan.CS1.DCV0	13	23	166	201	12	18	124	155
7	NIEcon.DB.MSFan.CS1.DCV0	14	19	165	199	13	15	124	152
8	NIEcon.EH.MSFan.CS1.DCV0	14	20	165	199	13	15	124	152
9	IEcon.DB.MSFan.CS1.DCV0	14	19	165	199	13	15	124	152
10	IEcon.EH.MSFan.CS1.DCV0	14	20	165	199	13	15	124	152
11	NoEcon.MSFan.CS2.DCV0	12	19	165	197	11	14	124	150
12	IEcon.DB.MSFan.CS2.DCV0	14	16	165	195	13	12	124	148
13	IEcon.EH.MSFan.CS2.DCV0	13	17	165	195	13	12	124	148
14	NoEcon.SSFan.CS1.DCV1	46	25	97	167	47	23	73	143
15	IEcon.DB.SSFan.CS1.DCV1	46	18	96	160	47	15	72	134
16	IEcon.EH.SSFan.CS1.DCV1	46	19	96	161	47	16	72	135
17	NoEcon.MSFan.CS1.DCV1	12	22	119	153	11	19	92	122
18	IEcon.DB.MSFan.CS1.DCV1	13	17	119	149	12	14	91	118
19	IEcon.EH.MSFan.CS1.DCV1	12	18	119	150	12	15	91	118
20	NoEcon.MSFan.CS2.DCV1	11	18	119	148	10	15	92	117
21	IEcon.DB.MSFan.CS2.DCV1	12	15	119	146	12	11	91	114
22	IEcon.EH.MSFan.CS2.DCV1	12	15	119	146	12	11	91	114

Table B-7: HVAC Energy Uses for the Small Office Building in Climate Zones 6A and 6B

Units: [10^6 Btus]

Case No	Case Name	Minneapolis-6A				Helena-6B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	47	22	175	245	49	15	142	206
2	NIEcon.DB.SSFan.CS1.DCV0	47	16	175	238	49	9	142	200
3	NIEcon.EH.SSFan.CS1.DCV0	47	17	175	239	49	10	142	201
4	IEcon.DB.SSFan.CS1.DCV0	47	16	175	238	49	9	142	200
5	IEcon.EH.SSFan.CS1.DCV0	47	17	175	239	49	10	142	201
6	NoEcon.MSFan.CS1.DCV0	14	19	206	240	13	12	176	201
7	NIEcon.DB.MSFan.CS1.DCV0	15	15	206	236	14	9	175	198
8	NIEcon.EH.MSFan.CS1.DCV0	15	16	206	237	14	9	175	198
9	IEcon.DB.MSFan.CS1.DCV0	15	15	206	236	14	9	176	198
10	IEcon.EH.MSFan.CS1.DCV0	15	16	206	237	14	9	176	198
11	NoEcon.MSFan.CS2.DCV0	13	16	206	235	12	9	176	197
12	IEcon.DB.MSFan.CS2.DCV0	15	13	206	234	13	7	175	195
13	IEcon.EH.MSFan.CS2.DCV0	14	13	206	233	13	7	175	195
14	NoEcon.SSFan.CS1.DCV1	47	22	124	193	49	17	103	169
15	IEcon.DB.SSFan.CS1.DCV1	47	14	124	185	49	9	102	160
16	IEcon.EH.SSFan.CS1.DCV1	47	15	124	186	49	9	102	161
17	NoEcon.MSFan.CS1.DCV1	12	19	149	180	12	13	128	153
18	IEcon.DB.MSFan.CS1.DCV1	14	14	149	176	12	8	128	148
19	IEcon.EH.MSFan.CS1.DCV1	13	15	149	176	12	9	128	149
20	NoEcon.MSFan.CS2.DCV1	11	16	149	176	11	10	128	149
21	IEcon.DB.MSFan.CS2.DCV1	13	12	149	174	12	6	128	146
22	IEcon.EH.MSFan.CS2.DCV1	13	12	149	173	12	6	128	146

Table B-8: HVAC Energy Uses for the Small Office Building in Climate Zones 7 and 8

Units: [10^6 Btus]

Case No	Case Name	Duluth-7				Fairbanks-8			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	48	11	213	272	58	9	383	450
2	NIEcon.DB.SSFan.CS1.DCV0	48	5	212	266	58	3	384	444
3	NIEcon.EH.SSFan.CS1.DCV0	48	6	212	267	58	3	384	444
4	IEcon.DB.SSFan.CS1.DCV0	48	5	212	266	58	2	384	444
5	IEcon.EH.SSFan.CS1.DCV0	48	6	212	267	58	3	384	444
6	NoEcon.MSFan.CS1.DCV0	14	9	251	273	19	6	432	458
7	NIEcon.DB.MSFan.CS1.DCV0	15	5	250	270	20	3	431	453
8	NIEcon.EH.MSFan.CS1.DCV0	14	6	250	271	20	3	431	453
9	IEcon.DB.MSFan.CS1.DCV0	15	5	250	270	20	2	431	453
10	IEcon.EH.MSFan.CS1.DCV0	14	6	250	271	20	3	431	453
11	NoEcon.MSFan.CS2.DCV0	13	7	250	271	19	5	431	455
12	IEcon.DB.MSFan.CS2.DCV0	14	4	250	269	20	2	431	452
13	IEcon.EH.MSFan.CS2.DCV0	14	4	250	269	20	2	431	452
14	NoEcon.SSFan.CS1.DCV1	48	13	154	215	58	10	294	362
15	IEcon.DB.SSFan.CS1.DCV1	48	5	153	207	58	2	297	357
16	IEcon.EH.SSFan.CS1.DCV1	48	6	153	208	58	3	297	358
17	NoEcon.MSFan.CS1.DCV1	12	10	183	205	17	8	335	360
18	IEcon.DB.MSFan.CS1.DCV1	13	5	182	200	18	2	334	354
19	IEcon.EH.MSFan.CS1.DCV1	13	6	182	201	17	3	334	354
20	NoEcon.MSFan.CS2.DCV1	12	8	183	202	16	6	334	356
21	IEcon.DB.MSFan.CS2.DCV1	13	4	182	199	17	2	334	353
22	IEcon.EH.MSFan.CS2.DCV1	13	4	182	199	17	2	334	353

Table B-9: HVAC Energy Uses for the Stand-alone Retail Building in Climate Zones 1A and 2A

Units: [10^6 Btus]

Case No	Case Name	Miami-1A				Houston-2A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	247	678	24	948	240	478	409	1127
2	NIEcon.DB.SSFan.CS1.DCV0	247	651	23	921	240	456	408	1105
3	NIEcon.EH.SSFan.CS1.DCV0	247	662	23	932	240	464	408	1112
4	IEcon.DB.SSFan.CS1.DCV0	247	651	23	921	240	456	408	1105
5	IEcon.EH.SSFan.CS1.DCV0	247	661	23	931	240	463	408	1112
6	NoEcon.MSFan.CS1.DCV0	121	650	34	804	101	455	476	1032
7	NIEcon.DB.MSFan.CS1.DCV0	128	633	34	794	106	444	475	1025
8	NIEcon.EH.MSFan.CS1.DCV0	125	641	34	799	104	448	476	1028
9	IEcon.DB.MSFan.CS1.DCV0	128	633	34	794	106	444	475	1025
10	IEcon.EH.MSFan.CS1.DCV0	125	640	34	798	104	448	476	1027
11	NoEcon.MSFan.CS2.DCV0	104	585	34	722	90	413	476	979
12	IEcon.DB.MSFan.CS2.DCV0	110	571	34	714	95	404	475	974
13	IEcon.EH.MSFan.CS2.DCV0	108	575	34	716	94	406	475	975
14	NoEcon.SSFan.CS1.DCV1	247	558	10	815	240	386	256	882
15	IEcon.DB.SSFan.CS1.DCV1	247	539	10	796	240	370	255	866
16	IEcon.EH.SSFan.CS1.DCV1	247	547	10	804	240	375	255	871
17	NoEcon.MSFan.CS1.DCV1	105	536	16	656	85	370	300	755
18	IEcon.DB.MSFan.CS1.DCV1	111	519	15	646	90	357	300	746
19	IEcon.EH.MSFan.CS1.DCV1	108	526	15	649	88	361	300	748
20	NoEcon.MSFan.CS2.DCV1	87	481	15	584	74	332	300	706
21	IEcon.DB.MSFan.CS2.DCV1	94	469	15	578	79	322	300	701
22	IEcon.EH.MSFan.CS2.DCV1	92	471	15	579	78	324	300	701

Table B-10: HVAC Energy Uses for the Stand-alone Retail Building in Climate Zones 2B and 3A

Units: [10^6 Btus]

Case No	Case Name	Phoenix-2B				Atlanta-3A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	244	497	311	1053	252	259	854	1365
2	NIEcon.DB.SSFan.CS1.DCV0	244	484	311	1039	252	236	854	1342
3	NIEcon.EH.SSFan.CS1.DCV0	244	482	311	1037	252	241	854	1347
4	IEcon.DB.SSFan.CS1.DCV0	244	483	311	1038	252	236	854	1341
5	IEcon.EH.SSFan.CS1.DCV0	244	482	311	1037	252	241	854	1346
6	NoEcon.MSFan.CS1.DCV0	93	480	380	953	86	239	977	1302
7	NIEcon.DB.MSFan.CS1.DCV0	96	472	380	948	91	228	977	1295
8	NIEcon.EH.MSFan.CS1.DCV0	97	471	380	947	90	231	977	1298
9	IEcon.DB.MSFan.CS1.DCV0	96	472	380	948	91	227	977	1295
10	IEcon.EH.MSFan.CS1.DCV0	97	471	380	947	89	230	977	1297
11	NoEcon.MSFan.CS2.DCV0	81	430	380	891	78	208	977	1263
12	IEcon.DB.MSFan.CS2.DCV0	85	424	380	889	83	199	977	1259
13	IEcon.EH.MSFan.CS2.DCV0	86	423	379	888	82	200	977	1259
14	NoEcon.SSFan.CS1.DCV1	244	408	192	844	252	217	559	1028
15	IEcon.DB.SSFan.CS1.DCV1	244	396	191	832	252	201	559	1012
16	IEcon.EH.SSFan.CS1.DCV1	244	395	191	830	252	205	559	1016
17	NoEcon.MSFan.CS1.DCV1	79	391	236	705	73	206	644	923
18	IEcon.DB.MSFan.CS1.DCV1	82	382	235	699	78	193	644	915
19	IEcon.EH.MSFan.CS1.DCV1	83	380	235	698	77	196	644	916
20	NoEcon.MSFan.CS2.DCV1	67	343	235	645	66	181	644	890
21	IEcon.DB.MSFan.CS2.DCV1	71	337	235	642	71	171	644	885
22	IEcon.EH.MSFan.CS2.DCV1	72	335	235	642	70	172	644	886

Table B-11: HVAC Energy Uses for the Stand-alone Retail Building in Climate Zone 3B

Units: [10^6 Btus]

Case No	Case Name	Los Angeles-3B				Las Vegas-3B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	224	131	281	637	223	332	551	1106
2	NIEcon.DB.SSFan.CS1.DCV0	224	77	281	581	223	322	550	1095
3	NIEcon.EH.SSFan.CS1.DCV0	224	85	281	590	223	321	550	1094
4	IEcon.DB.SSFan.CS1.DCV0	224	74	281	579	223	322	550	1095
5	IEcon.EH.SSFan.CS1.DCV0	224	83	281	588	223	321	550	1094
6	NoEcon.MSFan.CS1.DCV0	53	112	365	530	79	318	642	1039
7	NIEcon.DB.MSFan.CS1.DCV0	62	77	365	504	81	313	641	1035
8	NIEcon.EH.MSFan.CS1.DCV0	61	84	365	510	81	312	641	1035
9	IEcon.DB.MSFan.CS1.DCV0	61	75	365	501	81	313	642	1035
10	IEcon.EH.MSFan.CS1.DCV0	61	82	365	507	81	312	641	1035
11	NoEcon.MSFan.CS2.DCV0	47	95	365	507	71	291	642	1004
12	IEcon.DB.MSFan.CS2.DCV0	57	67	364	488	74	287	641	1002
13	IEcon.EH.MSFan.CS2.DCV0	57	69	364	490	75	286	641	1002
14	NoEcon.SSFan.CS1.DCV1	224	113	165	503	223	272	356	851
15	IEcon.DB.SSFan.CS1.DCV1	224	71	165	460	223	262	356	840
16	IEcon.EH.SSFan.CS1.DCV1	224	79	165	467	223	261	356	840
17	NoEcon.MSFan.CS1.DCV1	50	117	216	382	66	258	418	742
18	IEcon.DB.MSFan.CS1.DCV1	58	74	215	347	68	250	417	736
19	IEcon.EH.MSFan.CS1.DCV1	57	81	215	353	69	250	417	736
20	NoEcon.MSFan.CS2.DCV1	44	98	215	357	59	233	417	709
21	IEcon.DB.MSFan.CS2.DCV1	54	65	215	334	62	227	417	706
22	IEcon.EH.MSFan.CS2.DCV1	53	68	215	336	63	226	417	706

Table B-12: HVAC Energy Uses for the Stand-alone Retail Building in Climate Zones 3C and 4A

Units: [10^6 Btus]

Case No	Case Name	San Francisco-3C				Baltimore-4A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	187	33	781	1002	236	184	1385	1804
2	NIEcon.DB.SSFan.CS1.DCV0	187	18	781	985	236	169	1384	1789
3	NIEcon.EH.SSFan.CS1.DCV0	187	18	781	985	236	172	1384	1792
4	IEcon.DB.SSFan.CS1.DCV0	187	17	781	985	236	169	1384	1789
5	IEcon.EH.SSFan.CS1.DCV0	187	17	781	985	236	172	1384	1792
6	NoEcon.MSFan.CS1.DCV0	46	27	874	947	84	169	1532	1785
7	NIEcon.DB.MSFan.CS1.DCV0	49	18	873	941	87	161	1532	1781
8	NIEcon.EH.MSFan.CS1.DCV0	49	18	873	941	87	163	1532	1782
9	IEcon.DB.MSFan.CS1.DCV0	49	17	873	940	87	161	1532	1781
10	IEcon.EH.MSFan.CS1.DCV0	49	17	873	940	86	163	1532	1782
11	NoEcon.MSFan.CS2.DCV0	45	22	874	940	79	149	1532	1760
12	IEcon.DB.MSFan.CS2.DCV0	48	14	873	936	82	143	1532	1757
13	IEcon.EH.MSFan.CS2.DCV0	48	14	873	936	82	143	1532	1757
14	NoEcon.SSFan.CS1.DCV1	187	31	466	684	235	152	896	1284
15	IEcon.DB.SSFan.CS1.DCV1	187	16	465	668	235	141	896	1273
16	IEcon.EH.SSFan.CS1.DCV1	187	16	465	668	235	143	896	1275
17	NoEcon.MSFan.CS1.DCV1	39	31	553	624	69	142	1000	1211
18	IEcon.DB.MSFan.CS1.DCV1	42	17	553	612	72	134	1000	1206
19	IEcon.EH.MSFan.CS1.DCV1	42	17	553	612	71	135	1000	1207
20	NoEcon.MSFan.CS2.DCV1	37	26	553	616	64	125	1000	1189
21	IEcon.DB.MSFan.CS2.DCV1	41	14	553	608	67	119	1000	1186
22	IEcon.EH.MSFan.CS2.DCV1	42	14	553	608	67	119	1000	1186

Table B-13: HVAC Energy Uses for the Stand-alone Retail Building in Climate Zones 4B and 4C

Units: [10^6 Btus]

Case No	Case Name	Albuquerque-4B				Seattle-4C			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	242	165	1020	1426	196	36	1274	1506
2	NIEcon.DB.SSFan.CS1.DCV0	242	151	1019	1412	196	25	1274	1495
3	NIEcon.EH.SSFan.CS1.DCV0	242	152	1019	1412	196	25	1274	1495
4	IEcon.DB.SSFan.CS1.DCV0	242	151	1019	1411	196	25	1274	1495
5	IEcon.EH.SSFan.CS1.DCV0	242	151	1019	1412	196	25	1274	1495
6	NoEcon.MSFan.CS1.DCV0	79	149	1153	1382	58	30	1393	1481
7	NIEcon.DB.MSFan.CS1.DCV0	82	142	1152	1377	60	24	1393	1477
8	NIEcon.EH.MSFan.CS1.DCV0	82	143	1152	1377	60	24	1393	1477
9	IEcon.DB.MSFan.CS1.DCV0	82	142	1152	1376	60	23	1393	1477
10	IEcon.EH.MSFan.CS1.DCV0	82	142	1152	1377	60	24	1393	1477
11	NoEcon.MSFan.CS2.DCV0	73	125	1152	1350	56	24	1393	1473
12	IEcon.DB.MSFan.CS2.DCV0	77	119	1152	1348	59	19	1393	1471
13	IEcon.EH.MSFan.CS2.DCV0	77	118	1152	1347	59	19	1393	1471
14	NoEcon.SSFan.CS1.DCV1	241	146	677	1064	196	33	739	968
15	IEcon.DB.SSFan.CS1.DCV1	241	134	676	1051	196	23	739	958
16	IEcon.EH.SSFan.CS1.DCV1	241	135	676	1052	196	23	739	958
17	NoEcon.MSFan.CS1.DCV1	67	134	771	972	46	31	859	936
18	IEcon.DB.MSFan.CS1.DCV1	70	125	770	965	49	22	858	929
19	IEcon.EH.MSFan.CS1.DCV1	70	125	770	965	49	23	858	930
20	NoEcon.MSFan.CS2.DCV1	61	112	770	943	45	26	858	929
21	IEcon.DB.MSFan.CS2.DCV1	65	105	770	940	48	18	858	924
22	IEcon.EH.MSFan.CS2.DCV1	66	104	769	939	48	18	858	924

Table B-14: HVAC Energy Uses for the Stand-alone Retail Building in Climate Zones 5A and 5B

Units: [10^6 Btus]

Case No	Case Name	Chicago-5A				Denver-5B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	278	136	1913	2327	279	106	1466	1851
2	NIEcon.DB.SSFan.CS1.DCV0	278	118	1911	2308	279	92	1464	1836
3	NIEcon.EH.SSFan.CS1.DCV0	278	122	1911	2312	279	93	1464	1836
4	IEcon.DB.SSFan.CS1.DCV0	278	118	1911	2308	279	92	1464	1835
5	IEcon.EH.SSFan.CS1.DCV0	278	122	1911	2312	279	93	1464	1836
6	NoEcon.MSFan.CS1.DCV0	94	119	2118	2331	87	90	1663	1839
7	NIEcon.DB.MSFan.CS1.DCV0	98	111	2117	2326	90	84	1662	1836
8	NIEcon.EH.MSFan.CS1.DCV0	97	113	2117	2327	90	84	1662	1836
9	IEcon.DB.MSFan.CS1.DCV0	98	110	2117	2325	90	83	1662	1835
10	IEcon.EH.MSFan.CS1.DCV0	97	113	2117	2326	90	83	1662	1836
11	NoEcon.MSFan.CS2.DCV0	89	99	2117	2305	83	73	1662	1818
12	IEcon.DB.MSFan.CS2.DCV0	93	93	2117	2303	87	68	1661	1816
13	IEcon.EH.MSFan.CS2.DCV0	93	93	2117	2303	87	67	1661	1816
14	NoEcon.SSFan.CS1.DCV1	278	115	1297	1690	279	94	998	1371
15	IEcon.DB.SSFan.CS1.DCV1	278	102	1299	1679	279	82	996	1357
16	IEcon.EH.SSFan.CS1.DCV1	278	105	1299	1682	279	83	996	1358
17	NoEcon.MSFan.CS1.DCV1	78	104	1439	1621	73	81	1140	1294
18	IEcon.DB.MSFan.CS1.DCV1	81	94	1434	1610	76	73	1138	1287
19	IEcon.EH.MSFan.CS1.DCV1	80	96	1434	1611	76	73	1138	1288
20	NoEcon.MSFan.CS2.DCV1	73	87	1436	1597	69	65	1138	1272
21	IEcon.DB.MSFan.CS2.DCV1	77	80	1434	1591	73	59	1138	1269
22	IEcon.EH.MSFan.CS2.DCV1	77	80	1434	1591	74	58	1138	1270

Table B-15: HVAC Energy Uses for the Stand-alone Retail Building in Climate Zones 6A and 6B

Units: [10^6 Btus]

Case No	Case Name	Minneapolis-6A				Helena-6B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	316	117	2424	2857	336	71	2099	2506
2	NIEcon.DB.SSFan.CS1.DCV0	316	98	2421	2834	336	56	2096	2488
3	NIEcon.EH.SSFan.CS1.DCV0	316	101	2421	2837	336	56	2096	2488
4	IEcon.DB.SSFan.CS1.DCV0	316	97	2421	2834	336	55	2096	2487
5	IEcon.EH.SSFan.CS1.DCV0	316	100	2421	2837	336	56	2096	2487
6	NoEcon.MSFan.CS1.DCV0	108	99	2672	2879	105	57	2395	2556
7	NIEcon.DB.MSFan.CS1.DCV0	111	89	2664	2865	107	50	2387	2543
8	NIEcon.EH.MSFan.CS1.DCV0	111	91	2664	2866	107	49	2387	2543
9	IEcon.DB.MSFan.CS1.DCV0	111	89	2664	2864	107	49	2387	2543
10	IEcon.EH.MSFan.CS1.DCV0	111	91	2664	2866	107	49	2387	2543
11	NoEcon.MSFan.CS2.DCV0	103	81	2667	2851	101	43	2392	2537
12	IEcon.DB.MSFan.CS2.DCV0	107	74	2664	2845	105	39	2386	2529
13	IEcon.EH.MSFan.CS2.DCV0	107	74	2664	2845	105	38	2386	2529
14	NoEcon.SSFan.CS1.DCV1	316	98	1697	2111	336	62	1448	1845
15	IEcon.DB.SSFan.CS1.DCV1	316	84	1697	2096	336	50	1452	1837
16	IEcon.EH.SSFan.CS1.DCV1	316	86	1697	2099	336	50	1452	1838
17	NoEcon.MSFan.CS1.DCV1	89	87	1857	2033	87	52	1661	1800
18	IEcon.DB.MSFan.CS1.DCV1	92	76	1846	2014	88	43	1647	1778
19	IEcon.EH.MSFan.CS1.DCV1	92	77	1846	2015	88	43	1647	1778
20	NoEcon.MSFan.CS2.DCV1	85	71	1848	2004	83	39	1652	1775
21	IEcon.DB.MSFan.CS2.DCV1	89	63	1846	1998	86	33	1646	1766
22	IEcon.EH.MSFan.CS2.DCV1	89	63	1846	1998	87	33	1646	1766

Table B-16: HVAC Energy Uses for the Stand-alone Retail Building in Climate Zones 7 and 8

Units: [10^6 Btus]

Case No	Case Name	Duluth-7				Fairbanks-8			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	341	44	3033	3418	465	49	5095	5609
2	NIEcon.DB.SSFan.CS1.DCV0	341	29	3031	3401	465	10	5017	5492
3	NIEcon.EH.SSFan.CS1.DCV0	341	30	3031	3402	465	11	5017	5492
4	IEcon.DB.SSFan.CS1.DCV0	341	28	3031	3401	465	10	5017	5492
5	IEcon.EH.SSFan.CS1.DCV0	341	30	3031	3402	465	11	5017	5492
6	NoEcon.MSFan.CS1.DCV0	118	33	3368	3519	184	40	5606	5830
7	NIEcon.DB.MSFan.CS1.DCV0	120	25	3353	3498	179	8	5485	5672
8	NIEcon.EH.MSFan.CS1.DCV0	120	25	3353	3498	179	8	5485	5672
9	IEcon.DB.MSFan.CS1.DCV0	120	25	3353	3498	179	8	5485	5672
10	IEcon.EH.MSFan.CS1.DCV0	120	25	3353	3498	179	8	5485	5672
11	NoEcon.MSFan.CS2.DCV0	116	25	3360	3501	176	20	5500	5696
12	IEcon.DB.MSFan.CS2.DCV0	119	20	3353	3491	179	5	5484	5668
13	IEcon.EH.MSFan.CS2.DCV0	119	19	3353	3491	179	5	5484	5668
14	NoEcon.SSFan.CS1.DCV1	341	38	2124	2502	465	30	3756	4251
15	IEcon.DB.SSFan.CS1.DCV1	341	25	2121	2487	465	10	3754	4228
16	IEcon.EH.SSFan.CS1.DCV1	341	26	2121	2488	465	10	3754	4228
17	NoEcon.MSFan.CS1.DCV1	96	31	2345	2473	156	39	4228	4422
18	IEcon.DB.MSFan.CS1.DCV1	97	21	2326	2445	149	7	4068	4224
19	IEcon.EH.MSFan.CS1.DCV1	97	22	2326	2446	149	7	4068	4224
20	NoEcon.MSFan.CS2.DCV1	94	24	2329	2447	146	19	4074	4240
21	IEcon.DB.MSFan.CS2.DCV1	97	17	2326	2440	149	5	4066	4220
22	IEcon.EH.MSFan.CS2.DCV1	97	17	2326	2440	149	5	4066	4220

Table B-17: HVAC Energy Uses for the Strip Mall Building in Climate Zones 1A and 2A

Units: [10^6 Btus]

Case No	Case Name	Miami-1A				Houston-2A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	297	730	40	1068	251	468	399	1118
2	NIEcon.DB.SSFan.CS1.DCV0	297	693	38	1029	251	442	398	1091
3	NIEcon.EH.SSFan.CS1.DCV0	297	709	38	1045	251	450	398	1099
4	IEcon.DB.SSFan.CS1.DCV0	297	692	38	1027	251	441	398	1091
5	IEcon.EH.SSFan.CS1.DCV0	297	709	38	1044	251	449	398	1099
6	NoEcon.MSFan.CS1.DCV0	143	706	55	904	105	447	469	1022
7	NIEcon.DB.MSFan.CS1.DCV0	151	681	53	885	111	432	469	1012
8	NIEcon.EH.MSFan.CS1.DCV0	147	693	54	894	109	438	469	1015
9	IEcon.DB.MSFan.CS1.DCV0	150	680	53	884	111	432	469	1011
10	IEcon.EH.MSFan.CS1.DCV0	146	693	54	893	109	437	469	1015
11	NoEcon.MSFan.CS2.DCV0	121	629	54	804	93	403	469	965
12	IEcon.DB.MSFan.CS2.DCV0	129	611	53	794	99	391	468	959
13	IEcon.EH.MSFan.CS2.DCV0	127	616	53	796	98	393	469	960
14	NoEcon.SSFan.CS1.DCV1	297	603	24	924	251	371	253	875
15	IEcon.DB.SSFan.CS1.DCV1	297	577	24	898	251	358	252	861
16	IEcon.EH.SSFan.CS1.DCV1	297	593	24	914	251	364	252	867
17	NoEcon.MSFan.CS1.DCV1	124	589	33	746	88	362	294	744
18	IEcon.DB.MSFan.CS1.DCV1	132	564	32	728	94	347	293	734
19	IEcon.EH.MSFan.CS1.DCV1	128	578	32	738	92	353	293	738
20	NoEcon.MSFan.CS2.DCV1	103	521	32	656	76	323	294	693
21	IEcon.DB.MSFan.CS2.DCV1	111	506	32	649	82	313	293	688
22	IEcon.EH.MSFan.CS2.DCV1	109	511	32	652	81	316	293	689

Table B-18: HVAC Energy Uses for the Strip Mall Building in Climate Zones 2B and 3A

Units: [10^6 Btus]

Case No	Case Name	Phoenix-2B				Atlanta-3A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	254	485	333	1073	254	259	810	1322
2	NIEcon.DB.SSFan.CS1.DCV0	254	469	332	1055	254	231	808	1293
3	NIEcon.EH.SSFan.CS1.DCV0	254	466	332	1052	254	236	808	1299
4	IEcon.DB.SSFan.CS1.DCV0	254	468	332	1054	254	230	808	1292
5	IEcon.EH.SSFan.CS1.DCV0	254	466	332	1052	254	236	808	1298
6	NoEcon.MSFan.CS1.DCV0	98	471	404	972	88	242	929	1259
7	NIEcon.DB.MSFan.CS1.DCV0	102	461	403	966	94	225	928	1248
8	NIEcon.EH.MSFan.CS1.DCV0	103	459	402	964	93	229	929	1251
9	IEcon.DB.MSFan.CS1.DCV0	102	461	403	965	94	225	928	1247
10	IEcon.EH.MSFan.CS1.DCV0	103	458	402	963	93	229	929	1250
11	NoEcon.MSFan.CS2.DCV0	85	420	402	908	79	208	929	1216
12	IEcon.DB.MSFan.CS2.DCV0	90	413	402	905	85	197	928	1210
13	IEcon.EH.MSFan.CS2.DCV0	91	411	402	904	85	197	928	1210
14	NoEcon.SSFan.CS1.DCV1	254	391	220	866	254	207	528	989
15	IEcon.DB.SSFan.CS1.DCV1	254	386	220	860	254	196	528	978
16	IEcon.EH.SSFan.CS1.DCV1	254	383	220	857	254	200	528	982
17	NoEcon.MSFan.CS1.DCV1	83	382	264	729	74	205	601	880
18	IEcon.DB.MSFan.CS1.DCV1	86	375	263	725	79	190	601	870
19	IEcon.EH.MSFan.CS1.DCV1	88	373	263	723	78	194	601	873
20	NoEcon.MSFan.CS2.DCV1	71	336	263	669	66	179	601	845
21	IEcon.DB.MSFan.CS2.DCV1	75	331	262	669	72	169	601	842
22	IEcon.EH.MSFan.CS2.DCV1	77	329	262	668	71	170	601	842

Table B-19: HVAC Energy Uses for the Strip Mall Building in Climate Zone 3B

Units: [10^6 Btus]

Case No	Case Name	Los Angeles-3B				Las Vegas-3B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	250	159	297	706	236	328	546	1110
2	NIEcon.DB.SSFan.CS1.DCV0	250	87	296	632	236	313	545	1093
3	NIEcon.EH.SSFan.CS1.DCV0	250	96	296	642	236	312	545	1092
4	IEcon.DB.SSFan.CS1.DCV0	250	83	296	629	236	313	545	1093
5	IEcon.EH.SSFan.CS1.DCV0	250	93	296	639	236	311	545	1092
6	NoEcon.MSFan.CS1.DCV0	63	138	392	593	83	315	636	1033
7	NIEcon.DB.MSFan.CS1.DCV0	75	89	390	554	86	307	635	1028
8	NIEcon.EH.MSFan.CS1.DCV0	74	97	390	561	87	305	635	1026
9	IEcon.DB.MSFan.CS1.DCV0	74	86	390	550	86	306	635	1027
10	IEcon.EH.MSFan.CS1.DCV0	73	94	390	558	87	305	635	1026
11	NoEcon.MSFan.CS2.DCV0	56	116	391	562	74	285	635	994
12	IEcon.DB.MSFan.CS2.DCV0	69	79	390	538	79	278	635	992
13	IEcon.EH.MSFan.CS2.DCV0	68	81	390	539	79	277	634	991
14	NoEcon.SSFan.CS1.DCV1	250	109	188	548	236	260	366	862
15	IEcon.DB.SSFan.CS1.DCV1	250	79	188	517	236	256	366	857
16	IEcon.EH.SSFan.CS1.DCV1	250	86	188	524	236	254	365	855
17	NoEcon.MSFan.CS1.DCV1	57	131	242	431	69	253	421	743
18	IEcon.DB.MSFan.CS1.DCV1	68	84	241	392	72	247	420	739
19	IEcon.EH.MSFan.CS1.DCV1	67	92	241	400	73	245	420	738
20	NoEcon.MSFan.CS2.DCV1	50	106	241	397	61	227	420	708
21	IEcon.DB.MSFan.CS2.DCV1	62	77	241	380	65	222	420	707
22	IEcon.EH.MSFan.CS2.DCV1	62	79	241	382	66	221	420	706

Table B-20: HVAC Energy Uses for the Strip Mall Building in Climate Zones 3C and 4A

Units: [10^6 Btus]

Case No	Case Name	San Francisco-3C				Baltimore-4A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	194	45	700	939	232	187	1356	1776
2	NIEcon.DB.SSFan.CS1.DCV0	194	21	699	914	232	169	1356	1757
3	NIEcon.EH.SSFan.CS1.DCV0	194	21	699	914	232	172	1356	1761
4	IEcon.DB.SSFan.CS1.DCV0	194	20	699	913	232	168	1356	1756
5	IEcon.EH.SSFan.CS1.DCV0	194	20	699	913	232	172	1356	1760
6	NoEcon.MSFan.CS1.DCV0	48	37	822	907	86	175	1504	1765
7	NIEcon.DB.MSFan.CS1.DCV0	53	22	822	897	90	164	1504	1757
8	NIEcon.EH.MSFan.CS1.DCV0	53	22	822	897	89	166	1504	1759
9	IEcon.DB.MSFan.CS1.DCV0	53	21	822	896	90	164	1504	1757
10	IEcon.EH.MSFan.CS1.DCV0	53	21	822	896	89	166	1504	1759
11	NoEcon.MSFan.CS2.DCV0	46	30	822	898	80	153	1504	1737
12	IEcon.DB.MSFan.CS2.DCV0	51	18	822	891	84	145	1504	1733
13	IEcon.EH.MSFan.CS2.DCV0	51	18	822	891	84	145	1504	1733
14	NoEcon.SSFan.CS1.DCV1	193	25	419	637	232	149	883	1265
15	IEcon.DB.SSFan.CS1.DCV1	193	19	419	631	232	141	883	1256
16	IEcon.EH.SSFan.CS1.DCV1	193	19	419	631	232	143	883	1259
17	NoEcon.MSFan.CS1.DCV1	39	35	488	562	69	146	974	1189
18	IEcon.DB.MSFan.CS1.DCV1	44	21	487	552	73	136	974	1183
19	IEcon.EH.MSFan.CS1.DCV1	44	21	487	552	72	138	974	1185
20	NoEcon.MSFan.CS2.DCV1	37	27	487	552	64	128	974	1166
21	IEcon.DB.MSFan.CS2.DCV1	42	18	487	547	68	121	974	1163
22	IEcon.EH.MSFan.CS2.DCV1	42	17	487	547	68	122	974	1163

Table B-21: HVAC Energy Uses for the Strip Mall Building in Climate Zones 4B and 4C

Units: [10^6 Btus]

Case No	Case Name	Albuquerque-4B				Seattle-4C			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	233	166	982	1381	203	43	1252	1499
2	NIEcon.DB.SSFan.CS1.DCV0	233	150	981	1363	203	28	1252	1483
3	NIEcon.EH.SSFan.CS1.DCV0	233	150	981	1364	203	28	1252	1483
4	IEcon.DB.SSFan.CS1.DCV0	233	149	981	1362	203	27	1252	1482
5	IEcon.EH.SSFan.CS1.DCV0	233	150	981	1363	203	28	1252	1483
6	NoEcon.MSFan.CS1.DCV0	79	154	1106	1339	62	37	1416	1514
7	NIEcon.DB.MSFan.CS1.DCV0	83	144	1105	1332	65	28	1416	1508
8	NIEcon.EH.MSFan.CS1.DCV0	83	144	1105	1332	65	28	1416	1509
9	IEcon.DB.MSFan.CS1.DCV0	83	144	1105	1332	65	27	1416	1508
10	IEcon.EH.MSFan.CS1.DCV0	83	144	1105	1332	65	27	1416	1508
11	NoEcon.MSFan.CS2.DCV0	73	129	1105	1306	60	30	1416	1505
12	IEcon.DB.MSFan.CS2.DCV0	77	122	1104	1303	64	22	1416	1501
13	IEcon.EH.MSFan.CS2.DCV0	78	120	1104	1302	64	22	1416	1501
14	NoEcon.SSFan.CS1.DCV1	233	140	654	1026	203	31	740	974
15	IEcon.DB.SSFan.CS1.DCV1	233	133	653	1019	203	25	740	968
16	IEcon.EH.SSFan.CS1.DCV1	233	133	653	1019	203	26	740	969
17	NoEcon.MSFan.CS1.DCV1	66	136	733	935	47	35	847	929
18	IEcon.DB.MSFan.CS1.DCV1	69	127	733	929	51	25	846	922
19	IEcon.EH.MSFan.CS1.DCV1	70	127	733	929	51	26	846	923
20	NoEcon.MSFan.CS2.DCV1	60	114	733	906	45	28	846	919
21	IEcon.DB.MSFan.CS2.DCV1	64	108	732	905	49	21	846	917
22	IEcon.EH.MSFan.CS2.DCV1	66	106	732	904	50	21	846	917

Table B-22: HVAC Energy Uses for the Strip Mall Building in Climate Zones 5A and 5B

Units: [10^6 Btus]

Case No	Case Name	Chicago-5A				Denver-5B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	279	140	1887	2306	270	111	1416	1797
2	NIEcon.DB.SSFan.CS1.DCV0	279	119	1885	2283	270	94	1413	1778
3	NIEcon.EH.SSFan.CS1.DCV0	279	123	1885	2287	270	95	1413	1778
4	IEcon.DB.SSFan.CS1.DCV0	279	118	1885	2282	270	94	1413	1777
5	IEcon.EH.SSFan.CS1.DCV0	279	123	1885	2287	270	94	1413	1778
6	NoEcon.MSFan.CS1.DCV0	97	126	2099	2322	88	98	1606	1791
7	NIEcon.DB.MSFan.CS1.DCV0	102	114	2098	2314	91	89	1605	1785
8	NIEcon.EH.MSFan.CS1.DCV0	101	117	2098	2316	92	89	1605	1785
9	IEcon.DB.MSFan.CS1.DCV0	102	113	2098	2313	91	89	1605	1785
10	IEcon.EH.MSFan.CS1.DCV0	101	116	2098	2315	92	88	1605	1785
11	NoEcon.MSFan.CS2.DCV0	92	105	2098	2294	83	79	1604	1766
12	IEcon.DB.MSFan.CS2.DCV0	97	96	2098	2291	87	72	1604	1764
13	IEcon.EH.MSFan.CS2.DCV0	97	96	2098	2291	88	71	1604	1763
14	NoEcon.SSFan.CS1.DCV1	279	111	1289	1679	270	91	966	1326
15	IEcon.DB.SSFan.CS1.DCV1	279	102	1289	1670	270	84	965	1319
16	IEcon.EH.SSFan.CS1.DCV1	279	105	1289	1673	270	84	965	1319
17	NoEcon.MSFan.CS1.DCV1	79	107	1415	1601	71	86	1085	1242
18	IEcon.DB.MSFan.CS1.DCV1	83	97	1414	1594	75	78	1085	1238
19	IEcon.EH.MSFan.CS1.DCV1	82	99	1415	1596	75	78	1084	1238
20	NoEcon.MSFan.CS2.DCV1	74	90	1414	1578	67	68	1084	1219
21	IEcon.DB.MSFan.CS2.DCV1	79	83	1414	1576	71	63	1084	1218
22	IEcon.EH.MSFan.CS2.DCV1	79	83	1414	1576	73	62	1083	1218

Table B-23: HVAC Energy Uses for the Strip Mall Building in Climate Zones 6A and 6B

Units: [10^6 Btus]

Case No	Case Name	Minneapolis-6A				Helena-6B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	316	122	2409	2848	335	78	2091	2504
2	NIEcon.DB.SSFan.CS1.DCV0	316	98	2398	2812	334	58	2082	2475
3	NIEcon.EH.SSFan.CS1.DCV0	316	101	2398	2816	334	58	2082	2475
4	IEcon.DB.SSFan.CS1.DCV0	316	97	2398	2812	334	58	2082	2474
5	IEcon.EH.SSFan.CS1.DCV0	316	101	2398	2816	334	58	2082	2475
6	NoEcon.MSFan.CS1.DCV0	112	106	2659	2877	108	65	2387	2559
7	NIEcon.DB.MSFan.CS1.DCV0	116	93	2649	2858	111	55	2376	2542
8	NIEcon.EH.MSFan.CS1.DCV0	115	95	2649	2859	111	54	2376	2542
9	IEcon.DB.MSFan.CS1.DCV0	116	92	2649	2857	111	55	2376	2542
10	IEcon.EH.MSFan.CS1.DCV0	115	95	2649	2859	111	54	2376	2541
11	NoEcon.MSFan.CS2.DCV0	106	86	2652	2844	104	48	2382	2534
12	IEcon.DB.MSFan.CS2.DCV0	112	77	2649	2837	108	41	2375	2524
13	IEcon.EH.MSFan.CS2.DCV0	112	77	2648	2837	109	40	2375	2524
14	NoEcon.SSFan.CS1.DCV1	316	91	1698	2106	334	57	1448	1839
15	IEcon.DB.SSFan.CS1.DCV1	316	84	1698	2098	334	52	1447	1834
16	IEcon.EH.SSFan.CS1.DCV1	316	87	1698	2101	334	52	1447	1834
17	NoEcon.MSFan.CS1.DCV1	90	89	1848	2027	86	55	1645	1786
18	IEcon.DB.MSFan.CS1.DCV1	94	78	1840	2012	89	48	1637	1774
19	IEcon.EH.MSFan.CS1.DCV1	93	81	1840	2014	89	48	1637	1774
20	NoEcon.MSFan.CS2.DCV1	86	72	1844	2001	83	40	1642	1765
21	IEcon.DB.MSFan.CS2.DCV1	90	66	1840	1996	87	36	1636	1758
22	IEcon.EH.MSFan.CS2.DCV1	90	66	1840	1996	88	35	1636	1758

Table B-24: HVAC Energy Uses for the Strip Mall Building in Climate Zones 7 and 8

Units: [10^6 Btus]

Case No	Case Name	Duluth-7				Fairbanks-8			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	341	51	3015	3407	464	57	5070	5591
2	NIEcon.DB.SSFan.CS1.DCV0	341	30	2994	3365	463	12	4951	5426
3	NIEcon.EH.SSFan.CS1.DCV0	341	32	2994	3367	463	12	4951	5426
4	IEcon.DB.SSFan.CS1.DCV0	341	30	2994	3365	463	12	4951	5426
5	IEcon.EH.SSFan.CS1.DCV0	341	32	2994	3367	463	12	4951	5427
6	NoEcon.MSFan.CS1.DCV0	122	39	3349	3510	188	43	5571	5802
7	NIEcon.DB.MSFan.CS1.DCV0	124	28	3327	3479	183	10	5425	5618
8	NIEcon.EH.MSFan.CS1.DCV0	124	28	3327	3479	183	10	5425	5618
9	IEcon.DB.MSFan.CS1.DCV0	124	27	3327	3478	183	10	5425	5618
10	IEcon.EH.MSFan.CS1.DCV0	123	28	3327	3479	183	10	5425	5618
11	NoEcon.MSFan.CS2.DCV0	119	28	3334	3481	179	21	5448	5648
12	IEcon.DB.MSFan.CS2.DCV0	122	21	3327	3471	182	7	5425	5614
13	IEcon.EH.MSFan.CS2.DCV0	123	21	3327	3471	183	6	5425	5614
14	NoEcon.SSFan.CS1.DCV1	341	30	2113	2485	463	14	3707	4185
15	IEcon.DB.SSFan.CS1.DCV1	341	26	2113	2480	463	11	3717	4191
16	IEcon.EH.SSFan.CS1.DCV1	341	28	2113	2482	463	11	3717	4191
17	NoEcon.MSFan.CS1.DCV1	96	32	2331	2460	161	46	4330	4537
18	IEcon.DB.MSFan.CS1.DCV1	98	24	2315	2437	151	9	4101	4261
19	IEcon.EH.MSFan.CS1.DCV1	98	25	2315	2438	151	9	4101	4261
20	NoEcon.MSFan.CS2.DCV1	94	24	2323	2440	147	18	4093	4258
21	IEcon.DB.MSFan.CS2.DCV1	97	19	2315	2431	150	6	4101	4257
22	IEcon.EH.MSFan.CS2.DCV1	97	19	2315	2431	151	6	4101	4257

Table B-25: HVAC Energy Uses for the Supermarket Building in Climate Zones 1A and 2A

Units: [10^6 Btus]

Case No	Case Name	Miami-1A				Houston-2A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	498	674	143	1315	710	529	1290	2529
2	NIEcon.DB.SSFan.CS1.DCV0	498	647	141	1286	710	498	1281	2489
3	NIEcon.EH.SSFan.CS1.DCV0	498	661	141	1299	710	509	1281	2500
4	IEcon.DB.SSFan.CS1.DCV0	498	648	141	1286	710	498	1281	2488
5	IEcon.EH.SSFan.CS1.DCV0	498	660	141	1299	710	509	1281	2500
6	NoEcon.MSFan.CS1.DCV0	171	598	185	955	214	458	1570	2242
7	NIEcon.DB.MSFan.CS1.DCV0	177	579	183	938	218	437	1556	2211
8	NIEcon.EH.MSFan.CS1.DCV0	173	589	183	945	215	444	1557	2217
9	IEcon.DB.MSFan.CS1.DCV0	177	579	183	938	218	437	1556	2211
10	IEcon.EH.MSFan.CS1.DCV0	173	589	183	945	215	444	1557	2217
11	NoEcon.MSFan.CS2.DCV0	146	527	183	856	191	391	1560	2141
12	IEcon.DB.MSFan.CS2.DCV0	152	512	183	846	197	376	1556	2128
13	IEcon.EH.MSFan.CS2.DCV0	149	519	183	851	194	380	1557	2131
14	NoEcon.SSFan.CS1.DCV1	498	554	96	1147	709	428	941	2078
15	IEcon.DB.SSFan.CS1.DCV1	498	527	93	1118	709	396	931	2037
16	IEcon.EH.SSFan.CS1.DCV1	498	540	93	1131	709	408	931	2049
17	NoEcon.MSFan.CS1.DCV1	145	488	145	779	179	354	1229	1762
18	IEcon.DB.MSFan.CS1.DCV1	151	469	143	764	184	333	1216	1733
19	IEcon.EH.MSFan.CS1.DCV1	147	479	143	770	180	341	1216	1738
20	NoEcon.MSFan.CS2.DCV1	125	429	144	697	162	306	1219	1687
21	IEcon.DB.MSFan.CS2.DCV1	131	414	143	688	169	291	1215	1675
22	IEcon.EH.MSFan.CS2.DCV1	128	421	143	692	166	295	1216	1677

Table B-26: HVAC Energy Uses for the Supermarket Building in Climate Zones 2B and 3A

Units: [10^6 Btus]

Case No	Case Name	Phoenix-2B				Atlanta-3A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	644	570	1217	2431	821	296	2475	3592
2	NIEcon.DB.SSFan.CS1.DCV0	644	548	1203	2396	821	256	2455	3532
3	NIEcon.EH.SSFan.CS1.DCV0	644	548	1203	2396	821	266	2456	3543
4	IEcon.DB.SSFan.CS1.DCV0	644	547	1204	2395	821	256	2455	3532
5	IEcon.EH.SSFan.CS1.DCV0	644	548	1203	2395	821	266	2456	3543
6	NoEcon.MSFan.CS1.DCV0	205	521	1471	2197	237	237	2990	3465
7	NIEcon.DB.MSFan.CS1.DCV0	207	506	1453	2166	242	211	2964	3416
8	NIEcon.EH.MSFan.CS1.DCV0	207	506	1453	2166	239	218	2964	3421
9	IEcon.DB.MSFan.CS1.DCV0	207	505	1453	2166	242	210	2964	3416
10	IEcon.EH.MSFan.CS1.DCV0	207	505	1453	2165	239	217	2964	3421
11	NoEcon.MSFan.CS2.DCV0	184	455	1455	2094	223	194	2970	3387
12	IEcon.DB.MSFan.CS2.DCV0	188	444	1451	2084	230	176	2963	3369
13	IEcon.EH.MSFan.CS2.DCV0	188	444	1451	2084	228	180	2963	3371
14	NoEcon.SSFan.CS1.DCV1	644	442	932	2018	821	257	1839	2917
15	IEcon.DB.SSFan.CS1.DCV1	644	419	918	1982	821	216	1820	2856
16	IEcon.EH.SSFan.CS1.DCV1	644	420	918	1982	821	227	1820	2868
17	NoEcon.MSFan.CS1.DCV1	170	389	1209	1768	205	197	2367	2769
18	IEcon.DB.MSFan.CS1.DCV1	173	373	1193	1738	210	170	2342	2723
19	IEcon.EH.MSFan.CS1.DCV1	173	373	1193	1738	207	178	2343	2728
20	NoEcon.MSFan.CS2.DCV1	155	336	1195	1686	194	161	2348	2703
21	IEcon.DB.MSFan.CS2.DCV1	159	325	1191	1676	201	144	2341	2687
22	IEcon.EH.MSFan.CS2.DCV1	159	325	1191	1675	199	147	2342	2688

Table B-27: HVAC Energy Uses for the Supermarket Building in Climate Zone 3B

Units: [10^6 Btus]

Case No	Case Name	Los Angeles-3B				Las Vegas-3B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	575	120	1335	2031	740	392	1994	3126
2	NIEcon.DB.SSFan.CS1.DCV0	575	57	1327	1960	740	369	1975	3083
3	NIEcon.EH.SSFan.CS1.DCV0	575	68	1327	1971	740	369	1975	3083
4	IEcon.DB.SSFan.CS1.DCV0	575	56	1327	1958	740	369	1975	3083
5	IEcon.EH.SSFan.CS1.DCV0	575	67	1327	1970	740	369	1975	3083
6	NoEcon.MSFan.CS1.DCV0	145	97	1684	1926	224	344	2393	2961
7	NIEcon.DB.MSFan.CS1.DCV0	152	53	1676	1881	226	327	2373	2927
8	NIEcon.EH.MSFan.CS1.DCV0	150	60	1676	1886	226	327	2373	2927
9	IEcon.DB.MSFan.CS1.DCV0	152	51	1676	1879	226	327	2373	2926
10	IEcon.EH.MSFan.CS1.DCV0	149	59	1676	1885	226	327	2373	2926
11	NoEcon.MSFan.CS2.DCV0	137	77	1678	1892	210	299	2377	2885
12	IEcon.DB.MSFan.CS2.DCV0	148	45	1676	1869	214	287	2372	2873
13	IEcon.EH.MSFan.CS2.DCV0	147	47	1676	1870	214	287	2372	2873
14	NoEcon.SSFan.CS1.DCV1	575	121	947	1643	740	306	1548	2593
15	IEcon.DB.SSFan.CS1.DCV1	575	53	937	1566	740	282	1529	2551
16	IEcon.EH.SSFan.CS1.DCV1	575	69	937	1582	740	282	1529	2551
17	NoEcon.MSFan.CS1.DCV1	129	97	1280	1506	192	255	1984	2431
18	IEcon.DB.MSFan.CS1.DCV1	138	49	1272	1459	194	239	1965	2397
19	IEcon.EH.MSFan.CS1.DCV1	134	59	1272	1465	194	239	1965	2397
20	NoEcon.MSFan.CS2.DCV1	122	76	1273	1471	181	216	1968	2365
21	IEcon.DB.MSFan.CS2.DCV1	134	43	1271	1449	185	205	1963	2352
22	IEcon.EH.MSFan.CS2.DCV1	131	47	1271	1449	185	205	1963	2352

Table B-28: HVAC Energy Uses for the Supermarket Building in Climate Zones 3C and 4A

Units: [10^6 Btus]

Case No	Case Name	San Francisco-3C				Baltimore-4A			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	622	47	2778	3447	844	211	3749	4804
2	NIEcon.DB.SSFan.CS1.DCV0	622	15	2772	3410	844	181	3727	4751
3	NIEcon.EH.SSFan.CS1.DCV0	622	16	2772	3410	844	188	3727	4758
4	IEcon.DB.SSFan.CS1.DCV0	622	15	2772	3409	844	181	3727	4751
5	IEcon.EH.SSFan.CS1.DCV0	622	15	2773	3410	844	187	3727	4758
6	NoEcon.MSFan.CS1.DCV0	194	37	3314	3546	266	167	4369	4802
7	NIEcon.DB.MSFan.CS1.DCV0	197	15	3309	3521	269	147	4332	4747
8	NIEcon.EH.MSFan.CS1.DCV0	197	15	3309	3521	267	151	4332	4750
9	IEcon.DB.MSFan.CS1.DCV0	196	15	3309	3520	268	146	4332	4747
10	IEcon.EH.MSFan.CS1.DCV0	196	15	3309	3520	267	151	4333	4750
11	NoEcon.MSFan.CS2.DCV0	191	28	3310	3529	256	136	4339	4731
12	IEcon.DB.MSFan.CS2.DCV0	195	12	3309	3516	261	122	4332	4715
13	IEcon.EH.MSFan.CS2.DCV0	195	12	3309	3516	259	124	4332	4715
14	NoEcon.SSFan.CS1.DCV1	622	45	2001	2668	843	178	2804	3825
15	IEcon.DB.SSFan.CS1.DCV1	622	13	1995	2630	843	147	2782	3773
16	IEcon.EH.SSFan.CS1.DCV1	622	14	1995	2631	843	155	2782	3781
17	NoEcon.MSFan.CS1.DCV1	166	36	2553	2754	227	134	3446	3807
18	IEcon.DB.MSFan.CS1.DCV1	168	13	2549	2730	230	113	3411	3754
19	IEcon.EH.MSFan.CS1.DCV1	168	14	2549	2730	228	118	3411	3757
20	NoEcon.MSFan.CS2.DCV1	163	27	2550	2739	219	109	3419	3747
21	IEcon.DB.MSFan.CS2.DCV1	167	10	2548	2726	224	96	3410	3730
22	IEcon.EH.MSFan.CS2.DCV1	167	11	2548	2726	222	98	3411	3731

Table B-29: HVAC Energy Uses for the Supermarket Building in Climate Zones 4B and 4C

Units: [10^6 Btus]

Case No	Case Name	Albuquerque-4B				Seattle-4C			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	907	196	3078	4180	721	48	3822	4591
2	NIEcon.DB.SSFan.CS1.DCV0	907	166	3050	4123	721	21	3802	4545
3	NIEcon.EH.SSFan.CS1.DCV0	907	169	3050	4126	721	23	3803	4546
4	IEcon.DB.SSFan.CS1.DCV0	907	165	3050	4122	721	21	3802	4545
5	IEcon.EH.SSFan.CS1.DCV0	907	169	3050	4126	721	22	3802	4546
6	NoEcon.MSFan.CS1.DCV0	279	148	3704	4130	240	37	4460	4737
7	NIEcon.DB.MSFan.CS1.DCV0	281	128	3675	4084	241	18	4435	4694
8	NIEcon.EH.MSFan.CS1.DCV0	281	130	3676	4086	241	19	4435	4695
9	IEcon.DB.MSFan.CS1.DCV0	281	127	3675	4084	241	18	4435	4694
10	IEcon.EH.MSFan.CS1.DCV0	280	130	3676	4086	241	19	4435	4695
11	NoEcon.MSFan.CS2.DCV0	268	111	3681	4060	237	27	4441	4704
12	IEcon.DB.MSFan.CS2.DCV0	273	97	3673	4043	240	14	4434	4688
13	IEcon.EH.MSFan.CS2.DCV0	273	97	3674	4044	240	14	4434	4689
14	NoEcon.SSFan.CS1.DCV1	907	168	2359	3434	721	45	2787	3552
15	IEcon.DB.SSFan.CS1.DCV1	907	137	2333	3377	721	18	2767	3506
16	IEcon.EH.SSFan.CS1.DCV1	907	142	2333	3382	721	20	2767	3508
17	NoEcon.MSFan.CS1.DCV1	244	123	3025	3392	203	35	3451	3689
18	IEcon.DB.MSFan.CS1.DCV1	247	102	3000	3349	205	16	3428	3649
19	IEcon.EH.MSFan.CS1.DCV1	246	106	3000	3352	205	17	3428	3650
20	NoEcon.MSFan.CS2.DCV1	236	93	3006	3334	200	25	3434	3659
21	IEcon.DB.MSFan.CS2.DCV1	241	79	2999	3318	204	12	3427	3644
22	IEcon.EH.MSFan.CS2.DCV1	241	79	2999	3319	204	13	3427	3644

Table B-30: HVAC Energy Uses for the Supermarket Building in Climate Zones 5A and 5B

Units: [10^6 Btus]

Case No	Case Name	Chicago-5A				Denver-5B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	1014	162	4857	6033	1059	128	4087	5275
2	NIEcon.DB.SSFan.CS1.DCV0	1014	129	4823	5966	1059	99	4050	5208
3	NIEcon.EH.SSFan.CS1.DCV0	1014	137	4823	5974	1059	101	4049	5210
4	IEcon.DB.SSFan.CS1.DCV0	1014	129	4823	5965	1059	98	4050	5207
5	IEcon.EH.SSFan.CS1.DCV0	1014	137	4823	5974	1059	101	4050	5210
6	NoEcon.MSFan.CS1.DCV0	318	117	5726	6162	332	89	4987	5408
7	NIEcon.DB.MSFan.CS1.DCV0	320	94	5672	6086	333	70	4950	5353
8	NIEcon.EH.MSFan.CS1.DCV0	318	99	5672	6090	333	71	4950	5354
9	IEcon.DB.MSFan.CS1.DCV0	319	94	5672	6085	333	69	4950	5352
10	IEcon.EH.MSFan.CS1.DCV0	318	99	5672	6089	333	71	4950	5354
11	NoEcon.MSFan.CS2.DCV0	309	89	5678	6076	325	66	4960	5351
12	IEcon.DB.MSFan.CS2.DCV0	314	75	5671	6059	329	53	4948	5329
13	IEcon.EH.MSFan.CS2.DCV0	313	77	5671	6061	329	53	4947	5329
14	NoEcon.SSFan.CS1.DCV1	1014	147	3692	4853	1059	114	3144	4316
15	IEcon.DB.SSFan.CS1.DCV1	1014	107	3635	4756	1059	81	3099	4239
16	IEcon.EH.SSFan.CS1.DCV1	1014	118	3639	4770	1059	85	3100	4244
17	NoEcon.MSFan.CS1.DCV1	277	105	4589	4971	293	80	4100	4474
18	IEcon.DB.MSFan.CS1.DCV1	276	75	4503	4854	294	59	4054	4407
19	IEcon.EH.MSFan.CS1.DCV1	275	83	4512	4869	293	61	4056	4410
20	NoEcon.MSFan.CS2.DCV1	267	77	4521	4865	286	59	4067	4411
21	IEcon.DB.MSFan.CS2.DCV1	272	60	4499	4830	290	45	4048	4383
22	IEcon.EH.MSFan.CS2.DCV1	270	63	4501	4834	290	45	4048	4383

Table B-31: HVAC Energy Uses for the Supermarket Building in Climate Zones 6A and 6B

Units: [10^6 Btus]

Case No	Case Name	Minneapolis-6A				Helena-6B			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	1104	152	5889	7144	1184	101	5513	6798
2	NIEcon.DB.SSFan.CS1.DCV0	1103	109	5817	7030	1183	62	5439	6684
3	NIEcon.EH.SSFan.CS1.DCV0	1103	115	5818	7036	1183	63	5439	6685
4	IEcon.DB.SSFan.CS1.DCV0	1103	109	5817	7029	1183	61	5439	6684
5	IEcon.EH.SSFan.CS1.DCV0	1103	115	5818	7036	1183	63	5439	6686
6	NoEcon.MSFan.CS1.DCV0	365	110	6912	7387	392	73	6685	7150
7	NIEcon.DB.MSFan.CS1.DCV0	362	75	6794	7231	388	41	6572	7001
8	NIEcon.EH.MSFan.CS1.DCV0	361	79	6798	7238	388	43	6577	7008
9	IEcon.DB.MSFan.CS1.DCV0	362	74	6794	7231	388	41	6573	7001
10	IEcon.EH.MSFan.CS1.DCV0	361	79	6798	7238	388	43	6578	7008
11	NoEcon.MSFan.CS2.DCV0	353	79	6820	7251	383	50	6619	7051
12	IEcon.DB.MSFan.CS2.DCV0	357	59	6792	7209	385	30	6570	6985
13	IEcon.EH.MSFan.CS2.DCV0	356	61	6793	7210	385	31	6571	6986
14	NoEcon.SSFan.CS1.DCV1	1104	147	4572	5823	1184	106	4315	5605
15	IEcon.DB.SSFan.CS1.DCV1	1103	91	4451	5645	1183	50	4242	5475
16	IEcon.EH.SSFan.CS1.DCV1	1103	98	4455	5657	1183	52	4242	5477
17	NoEcon.MSFan.CS1.DCV1	322	111	5604	6037	352	88	5530	5969
18	IEcon.DB.MSFan.CS1.DCV1	314	60	5416	5789	341	36	5331	5708
19	IEcon.EH.MSFan.CS1.DCV1	314	69	5436	5819	342	40	5349	5731
20	NoEcon.MSFan.CS2.DCV1	306	74	5469	5849	338	55	5413	5806
21	IEcon.DB.MSFan.CS2.DCV1	310	48	5411	5769	338	26	5319	5683
22	IEcon.EH.MSFan.CS2.DCV1	309	51	5418	5778	338	27	5322	5687

Table B-32: HVAC Energy Uses for the Supermarket Building in Climate Zones 7 and 8

Units: [10^6 Btus]

Case No	Case Name	Duluth-7				Fairbanks-8			
		Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy	Fan Energy	Cooling Energy	Heating Energy	Total HVAC Energy
1	NoEcon.SSFan.CS1.DCV0 (Baseline)	1162	74	7343	8579	1453	110	11369	12933
2	NIEcon.DB.SSFan.CS1.DCV0	1162	30	7250	8442	1452	11	11217	12681
3	NIEcon.EH.SSFan.CS1.DCV0	1162	33	7251	8446	1452	12	11218	12682
4	IEcon.DB.SSFan.CS1.DCV0	1162	30	7249	8441	1452	11	11218	12681
5	IEcon.EH.SSFan.CS1.DCV0	1162	33	7251	8446	1452	12	11219	12683
6	NoEcon.MSFan.CS1.DCV0	422	56	8564	9042	587	92	12930	13609
7	NIEcon.DB.MSFan.CS1.DCV0	416	20	8430	8866	566	7	12646	13220
8	NIEcon.EH.MSFan.CS1.DCV0	416	23	8436	8875	567	8	12651	13226
9	IEcon.DB.MSFan.CS1.DCV0	416	20	8430	8865	566	7	12647	13220
10	IEcon.EH.MSFan.CS1.DCV0	416	23	8436	8875	566	8	12651	13226
11	NoEcon.MSFan.CS2.DCV0	413	36	8478	8927	563	46	12689	13298
12	IEcon.DB.MSFan.CS2.DCV0	414	15	8430	8860	566	4	12643	13213
13	IEcon.EH.MSFan.CS2.DCV0	414	16	8431	8862	566	5	12645	13215
14	NoEcon.SSFan.CS1.DCV1	1162	88	5737	6987	1454	133	9214	10802
15	IEcon.DB.SSFan.CS1.DCV1	1162	25	5612	6800	1453	10	9033	10496
16	IEcon.EH.SSFan.CS1.DCV1	1162	29	5616	6807	1453	11	9035	10499
17	NoEcon.MSFan.CS1.DCV1	372	74	6949	7395	529	127	10760	11417
18	IEcon.DB.MSFan.CS1.DCV1	359	17	6736	7113	501	7	10402	10910
19	IEcon.EH.MSFan.CS1.DCV1	360	25	6761	7146	502	11	10420	10933
20	NoEcon.MSFan.CS2.DCV1	357	44	6816	7217	491	61	10367	10919
21	IEcon.DB.MSFan.CS2.DCV1	358	14	6734	7106	500	4	10396	10900
22	IEcon.EH.MSFan.CS2.DCV1	357	16	6741	7114	500	5	10399	10904

C. APPENDIX C
Tables of Energy Savings

Table C-1: HVAC Energy Savings Compared to Case 1 for the Small Office Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	5	2.8	6	3.8	5	3.4	8	5.5
3	NIEcon.EH.SSFan.CS1.DCV0	4	2.5	5	3.2	6	3.6	7	4.5
4	IEcon.DB.SSFan.CS1.DCV0	5	2.8	6	3.8	6	3.5	8	5.5
5	IEcon.EH.SSFan.CS1.DCV0	4	2.5	5	3.3	6	3.7	7	4.6
6	NoEcon.MSFan.CS1.DCV0	30	18.5	24	15.4	26	16.0	18	11.5
7	NIEcon.DB.MSFan.CS1.DCV0	32	20.0	27	17.3	29	17.8	22	14.1
8	NIEcon.EH.MSFan.CS1.DCV0	32	19.8	26	17.1	29	17.9	21	13.8
9	IEcon.DB.MSFan.CS1.DCV0	32	19.9	26	17.1	29	18.0	22	14.2
10	IEcon.EH.MSFan.CS1.DCV0	32	19.9	26	17.1	29	18.0	21	13.8
11	NoEcon.MSFan.CS2.DCV0	47	29.0	35	22.9	41	25.7	26	16.6
12	IEcon.DB.MSFan.CS2.DCV0	47	29.0	36	23.3	43	26.7	27	17.7
13	IEcon.EH.MSFan.CS2.DCV0	49	30.0	37	24.0	43	26.8	28	18.1
14	NoEcon.SSFan.CS1.DCV1	13	7.9	16	10.7	11	7.0	19	12.5
15	IEcon.DB.SSFan.CS1.DCV1	16	10.2	22	14.4	18	11.2	28	18.3
16	IEcon.EH.SSFan.CS1.DCV1	17	10.5	22	14.1	18	11.4	27	17.7
17	NoEcon.MSFan.CS1.DCV1	45	27.7	44	28.6	41	25.4	43	27.5
18	IEcon.DB.MSFan.CS1.DCV1	46	28.6	47	30.4	45	27.9	47	30.6
19	IEcon.EH.MSFan.CS1.DCV1	48	29.3	48	30.7	45	28.0	47	30.6
20	NoEcon.MSFan.CS2.DCV1	60	36.9	54	35.2	55	34.3	50	32.3
21	IEcon.DB.MSFan.CS2.DCV1	59	36.6	55	35.6	58	35.9	52	33.6
22	IEcon.EH.MSFan.CS2.DCV1	62	38.1	57	36.7	58	35.9	53	34.3

Table C-2: HVAC Energy Savings Compared to Case 1 for the Small Office Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	20	21.0	6	3.9	9	10.2	6	3.8
3	NIEcon.EH.SSFan.CS1.DCV0	16	16.9	6	4.0	9	10.0	5	3.1
4	IEcon.DB.SSFan.CS1.DCV0	21	21.8	6	4.0	9	10.4	6	3.7
5	IEcon.EH.SSFan.CS1.DCV0	16	17.2	6	4.1	9	10.1	5	3.1
6	NoEcon.MSFan.CS1.DCV0	32	34.2	21	14.4	15	15.9	10	6.2
7	NIEcon.DB.MSFan.CS1.DCV0	45	47.4	23	16.2	20	21.6	13	7.8
8	NIEcon.EH.MSFan.CS1.DCV0	42	44.7	23	16.2	20	21.5	13	7.6
9	IEcon.DB.MSFan.CS1.DCV0	45	48.2	23	16.3	20	21.9	13	7.7
10	IEcon.EH.MSFan.CS1.DCV0	43	45.2	23	16.3	20	21.7	13	7.7
11	NoEcon.MSFan.CS2.DCV0	40	42.6	30	21.1	18	19.2	16	9.3
12	IEcon.DB.MSFan.CS2.DCV0	48	50.5	32	22.1	21	22.9	17	9.9
13	IEcon.EH.MSFan.CS2.DCV0	47	50.3	32	22.1	21	22.9	17	10.2
14	NoEcon.SSFan.CS1.DCV1	1	1.3	12	8.7	10	11.5	31	18.4
15	IEcon.DB.SSFan.CS1.DCV1	23	24.8	19	13.6	23	25.0	38	22.6
16	IEcon.EH.SSFan.CS1.DCV1	19	20.1	19	13.6	23	24.7	37	22.2
17	NoEcon.MSFan.CS1.DCV1	36	38.3	38	26.4	31	33.4	48	28.7
18	IEcon.DB.MSFan.CS1.DCV1	51	54.4	41	29.0	39	42.2	51	30.7
19	IEcon.EH.MSFan.CS1.DCV1	48	51.2	41	29.0	38	41.9	52	30.9
20	NoEcon.MSFan.CS2.DCV1	44	46.7	47	33.0	34	37.3	53	31.5
21	IEcon.DB.MSFan.CS2.DCV1	53	56.7	49	34.5	39	43.2	54	32.5
22	IEcon.EH.MSFan.CS2.DCV1	53	56.4	49	34.4	39	43.2	55	33.0

Table C-3: HVAC Energy Savings Compared to Case 1 for the Small Office Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	7	4.9	7	5.4	6	3.0	7	4.0
3	NIEcon.EH.SSFan.CS1.DCV0	6	4.4	7	5.1	5	2.2	6	3.6
4	IEcon.DB.SSFan.CS1.DCV0	7	5.0	7	5.5	6	3.1	7	4.1
5	IEcon.EH.SSFan.CS1.DCV0	6	4.4	7	5.2	5	2.3	6	3.6
6	NoEcon.MSFan.CS1.DCV0	16	11.3	7	5.4	6	3.1	13	7.6
7	NIEcon.DB.MSFan.CS1.DCV0	20	13.8	10	8.1	9	4.4	16	9.3
8	NIEcon.EH.MSFan.CS1.DCV0	20	13.6	10	8.0	8	4.1	15	9.2
9	IEcon.DB.MSFan.CS1.DCV0	20	14.0	11	8.3	9	4.4	16	9.4
10	IEcon.EH.MSFan.CS1.DCV0	20	13.7	10	8.1	9	4.1	15	9.2
11	NoEcon.MSFan.CS2.DCV0	24	16.4	10	7.4	11	5.4	18	10.8
12	IEcon.DB.MSFan.CS2.DCV0	26	17.8	12	9.2	13	6.0	20	11.7
13	IEcon.EH.MSFan.CS2.DCV0	26	17.8	12	9.2	13	6.1	20	11.7
14	NoEcon.SSFan.CS1.DCV1	17	11.8	25	19.7	41	19.6	25	14.8
15	IEcon.DB.SSFan.CS1.DCV1	25	17.6	35	27.0	48	23.2	33	19.9
16	IEcon.EH.SSFan.CS1.DCV1	25	17.0	34	26.6	46	22.3	32	19.2
17	NoEcon.MSFan.CS1.DCV1	40	27.5	41	31.8	55	26.6	46	27.2
18	IEcon.DB.MSFan.CS1.DCV1	45	30.9	46	36.2	59	28.3	50	29.8
19	IEcon.EH.MSFan.CS1.DCV1	44	30.6	46	36.0	58	28.0	50	29.6
20	NoEcon.MSFan.CS2.DCV1	47	32.2	44	34.1	60	28.7	51	30.5
21	IEcon.DB.MSFan.CS2.DCV1	50	34.2	47	37.0	62	29.7	54	31.9
22	IEcon.EH.MSFan.CS2.DCV1	50	34.2	47	37.0	62	29.8	53	31.9

Table C-4: HVAC Energy Savings Compared to Case 1 for the Small Office Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	7	2.8	6	3.0	6	2.2	6	1.3
3	NIEcon.EH.SSFan.CS1.DCV0	6	2.4	6	2.8	5	1.9	6	1.3
4	IEcon.DB.SSFan.CS1.DCV0	7	2.9	6	3.1	6	2.2	6	1.3
5	IEcon.EH.SSFan.CS1.DCV0	6	2.4	6	2.8	5	1.9	6	1.3
6	NoEcon.MSFan.CS1.DCV0	5	2.0	5	2.7	-1	-0.4	-8	-1.7
7	NIEcon.DB.MSFan.CS1.DCV0	8	3.3	8	4.0	2	0.7	-3	-0.8
8	NIEcon.EH.MSFan.CS1.DCV0	8	3.1	8	3.9	2	0.6	-4	-0.8
9	IEcon.DB.MSFan.CS1.DCV0	8	3.4	8	4.0	2	0.7	-3	-0.7
10	IEcon.EH.MSFan.CS1.DCV0	8	3.2	8	4.0	2	0.6	-3	-0.8
11	NoEcon.MSFan.CS2.DCV0	9	3.8	9	4.5	1	0.5	-5	-1.0
12	IEcon.DB.MSFan.CS2.DCV0	11	4.4	11	5.3	3	1.1	-3	-0.6
13	IEcon.EH.MSFan.CS2.DCV0	11	4.5	11	5.3	3	1.1	-3	-0.6
14	NoEcon.SSFan.CS1.DCV1	51	20.9	38	18.3	57	21.1	88	19.5
15	IEcon.DB.SSFan.CS1.DCV1	59	24.3	46	22.3	65	24.0	93	20.6
16	IEcon.EH.SSFan.CS1.DCV1	58	23.8	45	22.0	64	23.6	92	20.5
17	NoEcon.MSFan.CS1.DCV1	64	26.2	54	26.0	67	24.8	90	20.0
18	IEcon.DB.MSFan.CS1.DCV1	69	28.0	58	28.1	72	26.5	96	21.4
19	IEcon.EH.MSFan.CS1.DCV1	68	27.9	58	28.0	72	26.3	96	21.4
20	NoEcon.MSFan.CS2.DCV1	69	28.0	58	27.9	70	25.8	94	20.8
21	IEcon.DB.MSFan.CS2.DCV1	71	29.0	60	29.2	73	26.8	97	21.6
22	IEcon.EH.MSFan.CS2.DCV1	71	29.2	60	29.2	73	26.9	97	21.6

Table C-5: HVAC Energy Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	27	2.9	22	2.0	14	1.3	24	1.7
3	NIEcon.EH.SSFan.CS1.DCV0	16	1.7	15	1.3	16	1.5	18	1.3
4	IEcon.DB.SSFan.CS1.DCV0	27	2.8	22	2.0	14	1.4	24	1.7
5	IEcon.EH.SSFan.CS1.DCV0	17	1.8	15	1.4	16	1.5	19	1.4
6	NoEcon.MSFan.CS1.DCV0	143	15.1	95	8.4	100	9.5	63	4.6
7	NIEcon.DB.MSFan.CS1.DCV0	154	16.2	102	9.1	104	9.9	70	5.1
8	NIEcon.EH.MSFan.CS1.DCV0	149	15.7	99	8.8	106	10.0	68	4.9
9	IEcon.DB.MSFan.CS1.DCV0	154	16.2	102	9.1	105	10.0	70	5.1
10	IEcon.EH.MSFan.CS1.DCV0	150	15.8	100	8.8	106	10.1	68	5.0
11	NoEcon.MSFan.CS2.DCV0	226	23.9	148	13.1	162	15.4	102	7.5
12	IEcon.DB.MSFan.CS2.DCV0	234	24.7	153	13.5	164	15.6	106	7.8
13	IEcon.EH.MSFan.CS2.DCV0	232	24.4	152	13.5	164	15.6	106	7.8
14	NoEcon.SSFan.CS1.DCV1	133	14.1	245	21.7	209	19.8	337	24.7
15	IEcon.DB.SSFan.CS1.DCV1	152	16.0	261	23.2	221	21.0	353	25.9
16	IEcon.EH.SSFan.CS1.DCV1	144	15.2	256	22.7	223	21.1	349	25.6
17	NoEcon.MSFan.CS1.DCV1	292	30.8	372	33.0	348	33.0	442	32.4
18	IEcon.DB.MSFan.CS1.DCV1	302	31.8	381	33.8	354	33.6	450	33.0
19	IEcon.EH.MSFan.CS1.DCV1	298	31.5	378	33.6	354	33.7	449	32.9
20	NoEcon.MSFan.CS2.DCV1	364	38.4	421	37.4	407	38.7	475	34.8
21	IEcon.DB.MSFan.CS2.DCV1	370	39.0	426	37.8	410	39.0	480	35.1
22	IEcon.EH.MSFan.CS2.DCV1	369	39.0	426	37.8	410	39.0	480	35.1

Table C-6: HVAC Energy Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	55	8.7	11	1.0	16	1.6	15	0.9
3	NIEcon.EH.SSFan.CS1.DCV0	47	7.4	12	1.1	16	1.6	12	0.7
4	IEcon.DB.SSFan.CS1.DCV0	58	9.0	11	1.0	17	1.7	16	0.9
5	IEcon.EH.SSFan.CS1.DCV0	49	7.7	12	1.1	17	1.7	12	0.7
6	NoEcon.MSFan.CS1.DCV0	107	16.8	67	6.0	55	5.5	19	1.0
7	NIEcon.DB.MSFan.CS1.DCV0	133	20.9	71	6.4	61	6.1	23	1.3
8	NIEcon.EH.MSFan.CS1.DCV0	127	20.0	71	6.4	61	6.1	22	1.2
9	IEcon.DB.MSFan.CS1.DCV0	136	21.3	71	6.4	62	6.2	24	1.3
10	IEcon.EH.MSFan.CS1.DCV0	130	20.4	71	6.4	62	6.2	23	1.2
11	NoEcon.MSFan.CS2.DCV0	130	20.3	102	9.2	62	6.2	44	2.5
12	IEcon.DB.MSFan.CS2.DCV0	148	23.3	103	9.4	66	6.5	47	2.6
13	IEcon.EH.MSFan.CS2.DCV0	147	23.0	104	9.4	66	6.6	47	2.6
14	NoEcon.SSFan.CS1.DCV1	134	21.1	255	23.0	318	31.7	520	28.8
15	IEcon.DB.SSFan.CS1.DCV1	177	27.7	265	24.0	333	33.3	532	29.5
16	IEcon.EH.SSFan.CS1.DCV1	169	26.6	266	24.1	333	33.3	529	29.3
17	NoEcon.MSFan.CS1.DCV1	254	40.0	364	32.9	378	37.7	593	32.9
18	IEcon.DB.MSFan.CS1.DCV1	290	45.5	370	33.4	389	38.9	598	33.2
19	IEcon.EH.MSFan.CS1.DCV1	283	44.5	370	33.5	389	38.9	598	33.1
20	NoEcon.MSFan.CS2.DCV1	279	43.8	397	35.9	385	38.5	615	34.1
21	IEcon.DB.MSFan.CS2.DCV1	302	47.5	400	36.2	393	39.3	618	34.3
22	IEcon.EH.MSFan.CS2.DCV1	300	47.2	400	36.2	394	39.3	619	34.3

Table C-7: HVAC Energy Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	15	1.0	11	0.7	19	0.8	16	0.8
3	NIEcon.EH.SSFan.CS1.DCV0	14	1.0	11	0.7	15	0.6	15	0.8
4	IEcon.DB.SSFan.CS1.DCV0	15	1.1	11	0.8	19	0.8	16	0.9
5	IEcon.EH.SSFan.CS1.DCV0	14	1.0	11	0.7	15	0.7	15	0.8
6	NoEcon.MSFan.CS1.DCV0	45	3.1	25	1.7	-4	-0.2	12	0.6
7	NIEcon.DB.MSFan.CS1.DCV0	49	3.5	29	1.9	1	0.0	15	0.8
8	NIEcon.EH.MSFan.CS1.DCV0	49	3.4	29	1.9	0	0.0	15	0.8
9	IEcon.DB.MSFan.CS1.DCV0	50	3.5	29	1.9	2	0.1	16	0.9
10	IEcon.EH.MSFan.CS1.DCV0	50	3.5	29	1.9	0	0.0	16	0.8
11	NoEcon.MSFan.CS2.DCV0	76	5.3	33	2.2	22	0.9	33	1.8
12	IEcon.DB.MSFan.CS2.DCV0	79	5.5	35	2.3	24	1.0	35	1.9
13	IEcon.EH.MSFan.CS2.DCV0	79	5.6	35	2.3	24	1.0	35	1.9
14	NoEcon.SSFan.CS1.DCV1	362	25.4	538	35.7	637	27.4	480	26.0
15	IEcon.DB.SSFan.CS1.DCV1	375	26.3	548	36.4	648	27.8	494	26.7
16	IEcon.EH.SSFan.CS1.DCV1	375	26.3	548	36.4	645	27.7	493	26.7
17	NoEcon.MSFan.CS1.DCV1	454	31.9	570	37.8	706	30.3	557	30.1
18	IEcon.DB.MSFan.CS1.DCV1	462	32.4	576	38.3	717	30.8	564	30.5
19	IEcon.EH.MSFan.CS1.DCV1	461	32.3	576	38.3	716	30.8	564	30.4
20	NoEcon.MSFan.CS2.DCV1	483	33.9	577	38.3	730	31.4	579	31.3
21	IEcon.DB.MSFan.CS2.DCV1	486	34.1	581	38.6	735	31.6	582	31.4
22	IEcon.EH.MSFan.CS2.DCV1	487	34.1	582	38.6	736	31.6	581	31.4

Table C-8: HVAC Energy Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	23	0.8	18	0.7	17	0.5	117	2.1
3	NIEcon.EH.SSFan.CS1.DCV0	20	0.7	18	0.7	16	0.5	116	2.1
4	IEcon.DB.SSFan.CS1.DCV0	24	0.8	19	0.7	17	0.5	117	2.1
5	IEcon.EH.SSFan.CS1.DCV0	20	0.7	19	0.7	16	0.5	116	2.1
6	NoEcon.MSFan.CS1.DCV0	-22	-0.8	-50	-2.0	-101	-3.0	-222	-4.0
7	NIEcon.DB.MSFan.CS1.DCV0	-7	-0.3	-37	-1.5	-80	-2.3	-64	-1.1
8	NIEcon.EH.MSFan.CS1.DCV0	-9	-0.3	-37	-1.5	-80	-2.3	-63	-1.1
9	IEcon.DB.MSFan.CS1.DCV0	-7	-0.2	-37	-1.5	-80	-2.3	-64	-1.1
10	IEcon.EH.MSFan.CS1.DCV0	-8	-0.3	-37	-1.5	-80	-2.3	-64	-1.1
11	NoEcon.MSFan.CS2.DCV0	7	0.2	-31	-1.2	-82	-2.4	-88	-1.6
12	IEcon.DB.MSFan.CS2.DCV0	12	0.4	-23	-0.9	-73	-2.1	-59	-1.1
13	IEcon.EH.MSFan.CS2.DCV0	12	0.4	-23	-0.9	-73	-2.1	-59	-1.1
14	NoEcon.SSFan.CS1.DCV1	747	26.1	661	26.4	916	26.8	1358	24.2
15	IEcon.DB.SSFan.CS1.DCV1	761	26.6	669	26.7	932	27.3	1380	24.6
16	IEcon.EH.SSFan.CS1.DCV1	759	26.6	668	26.7	930	27.2	1380	24.6
17	NoEcon.MSFan.CS1.DCV1	824	28.8	706	28.2	945	27.7	1186	21.2
18	IEcon.DB.MSFan.CS1.DCV1	844	29.5	728	29.1	973	28.5	1384	24.7
19	IEcon.EH.MSFan.CS1.DCV1	842	29.5	728	29.1	972	28.4	1384	24.7
20	NoEcon.MSFan.CS2.DCV1	853	29.9	731	29.2	971	28.4	1369	24.4
21	IEcon.DB.MSFan.CS2.DCV1	859	30.1	741	29.6	978	28.6	1389	24.8
22	IEcon.EH.MSFan.CS2.DCV1	859	30.1	740	29.5	978	28.6	1388	24.8

Table C-9: HVAC Energy Savings Compared to Case 1 for the Strip Mall Retail Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	39	3.7	27	2.4	18	1.7	29	2.2
3	NIEcon.EH.SSFan.CS1.DCV0	23	2.1	19	1.7	21	1.9	23	1.8
4	IEcon.DB.SSFan.CS1.DCV0	41	3.8	27	2.4	18	1.7	30	2.3
5	IEcon.EH.SSFan.CS1.DCV0	23	2.2	19	1.7	21	2.0	24	1.8
6	NoEcon.MSFan.CS1.DCV0	164	15.3	96	8.6	101	9.4	63	4.8
7	NIEcon.DB.MSFan.CS1.DCV0	182	17.1	106	9.5	107	10.0	74	5.6
8	NIEcon.EH.MSFan.CS1.DCV0	174	16.3	103	9.2	109	10.2	72	5.4
9	IEcon.DB.MSFan.CS1.DCV0	184	17.2	107	9.5	107	10.0	75	5.7
10	IEcon.EH.MSFan.CS1.DCV0	175	16.4	103	9.2	110	10.2	72	5.5
11	NoEcon.MSFan.CS2.DCV0	264	24.7	153	13.7	165	15.4	106	8.0
12	IEcon.DB.MSFan.CS2.DCV0	274	25.7	159	14.2	168	15.6	112	8.5
13	IEcon.EH.MSFan.CS2.DCV0	272	25.4	158	14.1	169	15.7	112	8.5
14	NoEcon.SSFan.CS1.DCV1	144	13.5	243	21.7	207	19.3	333	25.2
15	IEcon.DB.SSFan.CS1.DCV1	169	15.9	257	23.0	213	19.8	345	26.1
16	IEcon.EH.SSFan.CS1.DCV1	154	14.4	251	22.4	216	20.1	340	25.7
17	NoEcon.MSFan.CS1.DCV1	322	30.1	374	33.4	344	32.0	442	33.5
18	IEcon.DB.MSFan.CS1.DCV1	340	31.8	384	34.3	348	32.4	452	34.2
19	IEcon.EH.MSFan.CS1.DCV1	330	30.9	380	34.0	349	32.6	449	34.0
20	NoEcon.MSFan.CS2.DCV1	412	38.6	425	38.0	403	37.6	477	36.1
21	IEcon.DB.MSFan.CS2.DCV1	418	39.2	429	38.4	404	37.7	481	36.4
22	IEcon.EH.MSFan.CS2.DCV1	416	39.0	428	38.3	405	37.7	480	36.3

Table C-10: HVAC Energy Savings Compared to Case 1 for the Strip Mall Retail Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	74	10.5	16	1.5	25	2.6	19	1.1
3	NIEcon.EH.SSFan.CS1.DCV0	64	9.1	18	1.6	25	2.6	15	0.8
4	IEcon.DB.SSFan.CS1.DCV0	77	10.9	17	1.5	26	2.7	19	1.1
5	IEcon.EH.SSFan.CS1.DCV0	67	9.4	18	1.6	26	2.7	15	0.9
6	NoEcon.MSFan.CS1.DCV0	113	16.1	77	6.9	31	3.3	11	0.6
7	NIEcon.DB.MSFan.CS1.DCV0	152	21.5	82	7.4	42	4.4	18	1.0
8	NIEcon.EH.MSFan.CS1.DCV0	145	20.5	83	7.5	42	4.4	16	0.9
9	IEcon.DB.MSFan.CS1.DCV0	156	22.1	83	7.4	43	4.6	19	1.0
10	IEcon.EH.MSFan.CS1.DCV0	148	21.0	84	7.5	43	4.6	17	1.0
11	NoEcon.MSFan.CS2.DCV0	144	20.4	116	10.4	41	4.3	39	2.2
12	IEcon.DB.MSFan.CS2.DCV0	168	23.8	118	10.6	47	5.0	43	2.4
13	IEcon.EH.MSFan.CS2.DCV0	167	23.7	119	10.7	47	5.1	43	2.4
14	NoEcon.SSFan.CS1.DCV1	158	22.4	248	22.4	301	32.1	511	28.8
15	IEcon.DB.SSFan.CS1.DCV1	189	26.8	253	22.8	307	32.8	520	29.3
16	IEcon.EH.SSFan.CS1.DCV1	182	25.8	254	22.9	307	32.7	517	29.1
17	NoEcon.MSFan.CS1.DCV1	275	39.0	367	33.1	377	40.1	586	33.0
18	IEcon.DB.MSFan.CS1.DCV1	314	44.4	371	33.4	387	41.2	593	33.4
19	IEcon.EH.MSFan.CS1.DCV1	306	43.3	372	33.5	387	41.2	591	33.3
20	NoEcon.MSFan.CS2.DCV1	309	43.8	402	36.2	387	41.2	610	34.4
21	IEcon.DB.MSFan.CS2.DCV1	326	46.1	403	36.3	392	41.7	612	34.5
22	IEcon.EH.MSFan.CS2.DCV1	324	45.9	403	36.3	392	41.7	612	34.5

Table C-11: HVAC Energy Savings Compared to Case 1 for the Strip Mall Retail Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	19	1.3	16	1.1	23	1.0	19	1.1
3	NIEcon.EH.SSFan.CS1.DCV0	18	1.3	16	1.0	19	0.8	19	1.0
4	IEcon.DB.SSFan.CS1.DCV0	19	1.4	17	1.1	24	1.0	19	1.1
5	IEcon.EH.SSFan.CS1.DCV0	18	1.3	16	1.1	19	0.8	19	1.1
6	NoEcon.MSFan.CS1.DCV0	42	3.1	-16	-1.0	-16	-0.7	6	0.3
7	NIEcon.DB.MSFan.CS1.DCV0	49	3.6	-9	-0.6	-8	-0.4	11	0.6
8	NIEcon.EH.MSFan.CS1.DCV0	49	3.6	-10	-0.6	-10	-0.4	12	0.6
9	IEcon.DB.MSFan.CS1.DCV0	50	3.6	-9	-0.6	-7	-0.3	12	0.7
10	IEcon.EH.MSFan.CS1.DCV0	50	3.6	-9	-0.6	-9	-0.4	12	0.7
11	NoEcon.MSFan.CS2.DCV0	75	5.5	-6	-0.4	11	0.5	31	1.7
12	IEcon.DB.MSFan.CS2.DCV0	78	5.7	-2	-0.2	15	0.7	33	1.9
13	IEcon.EH.MSFan.CS2.DCV0	79	5.7	-2	-0.1	15	0.7	34	1.9
14	NoEcon.SSFan.CS1.DCV1	355	25.7	525	35.0	627	27.2	471	26.2
15	IEcon.DB.SSFan.CS1.DCV1	363	26.3	531	35.4	636	27.6	477	26.6
16	IEcon.EH.SSFan.CS1.DCV1	363	26.3	530	35.4	633	27.4	478	26.6
17	NoEcon.MSFan.CS1.DCV1	447	32.3	570	38.1	705	30.6	555	30.9
18	IEcon.DB.MSFan.CS1.DCV1	452	32.7	577	38.5	712	30.9	559	31.1
19	IEcon.EH.MSFan.CS1.DCV1	452	32.7	576	38.4	710	30.8	559	31.1
20	NoEcon.MSFan.CS2.DCV1	475	34.4	580	38.7	728	31.6	578	32.2
21	IEcon.DB.MSFan.CS2.DCV1	477	34.5	582	38.8	730	31.7	579	32.2
22	IEcon.EH.MSFan.CS2.DCV1	478	34.6	582	38.8	730	31.6	579	32.2

Table C-12: HVAC Energy Savings Compared to Case 1 for the Strip Mall Retail Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	36	1.3	29	1.2	41	1.2	164	2.9
3	NIEcon.EH.SSFan.CS1.DCV0	32	1.1	29	1.2	40	1.2	164	2.9
4	IEcon.DB.SSFan.CS1.DCV0	36	1.3	30	1.2	42	1.2	164	2.9
5	IEcon.EH.SSFan.CS1.DCV0	32	1.1	29	1.2	40	1.2	164	2.9
6	NoEcon.MSFan.CS1.DCV0	-29	-1.0	-55	-2.2	-103	-3.0	-212	-3.8
7	NIEcon.DB.MSFan.CS1.DCV0	-10	-0.3	-38	-1.5	-72	-2.1	-28	-0.5
8	NIEcon.EH.MSFan.CS1.DCV0	-11	-0.4	-38	-1.5	-73	-2.1	-27	-0.5
9	IEcon.DB.MSFan.CS1.DCV0	-9	-0.3	-38	-1.5	-72	-2.1	-27	-0.5
10	IEcon.EH.MSFan.CS1.DCV0	-11	-0.4	-38	-1.5	-72	-2.1	-27	-0.5
11	NoEcon.MSFan.CS2.DCV0	4	0.1	-30	-1.2	-74	-2.2	-58	-1.0
12	IEcon.DB.MSFan.CS2.DCV0	11	0.4	-20	-0.8	-64	-1.9	-23	-0.4
13	IEcon.EH.MSFan.CS2.DCV0	11	0.4	-20	-0.8	-64	-1.9	-23	-0.4
14	NoEcon.SSFan.CS1.DCV1	742	26.1	665	26.6	922	27.1	1406	25.2
15	IEcon.DB.SSFan.CS1.DCV1	750	26.3	670	26.8	926	27.2	1399	25.0
16	IEcon.EH.SSFan.CS1.DCV1	747	26.2	670	26.8	925	27.2	1400	25.0
17	NoEcon.MSFan.CS1.DCV1	821	28.8	718	28.7	947	27.8	1054	18.8
18	IEcon.DB.MSFan.CS1.DCV1	836	29.3	730	29.1	969	28.5	1329	23.8
19	IEcon.EH.MSFan.CS1.DCV1	834	29.3	730	29.2	969	28.4	1329	23.8
20	NoEcon.MSFan.CS2.DCV1	847	29.7	739	29.5	967	28.4	1333	23.8
21	IEcon.DB.MSFan.CS2.DCV1	852	29.9	746	29.8	976	28.7	1333	23.8
22	IEcon.EH.MSFan.CS2.DCV1	851	29.9	746	29.8	976	28.6	1333	23.8

Table C-13: HVAC Energy Savings Compared to Case 1 for the Supermarket Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	29	2.2	40	1.6	36	1.5	59	1.7
3	NIEcon.EH.SSFan.CS1.DCV0	16	1.2	29	1.2	36	1.5	49	1.4
4	IEcon.DB.SSFan.CS1.DCV0	29	2.2	40	1.6	36	1.5	60	1.7
5	IEcon.EH.SSFan.CS1.DCV0	16	1.2	29	1.2	36	1.5	49	1.4
6	NoEcon.MSFan.CS1.DCV0	360	27.4	287	11.3	235	9.7	127	3.5
7	NIEcon.DB.MSFan.CS1.DCV0	377	28.7	317	12.5	266	10.9	176	4.9
8	NIEcon.EH.MSFan.CS1.DCV0	369	28.1	312	12.3	266	10.9	171	4.7
9	IEcon.DB.MSFan.CS1.DCV0	376	28.6	317	12.5	266	10.9	176	4.9
10	IEcon.EH.MSFan.CS1.DCV0	370	28.1	312	12.3	266	11.0	171	4.8
11	NoEcon.MSFan.CS2.DCV0	459	34.9	388	15.3	337	13.9	205	5.7
12	IEcon.DB.MSFan.CS2.DCV0	469	35.6	400	15.8	348	14.3	222	6.2
13	IEcon.EH.MSFan.CS2.DCV0	464	35.3	398	15.7	348	14.3	221	6.1
14	NoEcon.SSFan.CS1.DCV1	168	12.8	451	17.8	413	17.0	675	18.8
15	IEcon.DB.SSFan.CS1.DCV1	197	15.0	492	19.5	450	18.5	735	20.5
16	IEcon.EH.SSFan.CS1.DCV1	184	14.0	480	19.0	449	18.5	724	20.1
17	NoEcon.MSFan.CS1.DCV1	536	40.8	766	30.3	663	27.3	822	22.9
18	IEcon.DB.MSFan.CS1.DCV1	551	41.9	796	31.5	693	28.5	869	24.2
19	IEcon.EH.MSFan.CS1.DCV1	545	41.5	791	31.3	693	28.5	864	24.0
20	NoEcon.MSFan.CS2.DCV1	618	47.0	842	33.3	746	30.7	889	24.7
21	IEcon.DB.MSFan.CS2.DCV1	627	47.7	854	33.8	756	31.1	905	25.2
22	IEcon.EH.MSFan.CS2.DCV1	623	47.4	852	33.7	756	31.1	903	25.2

Table C-14: HVAC Energy Savings Compared to Case 1 for the Supermarket Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	71	3.5	42	1.4	37	1.1	53	1.1
3	NIEcon.EH.SSFan.CS1.DCV0	60	3.0	42	1.4	36	1.1	46	1.0
4	IEcon.DB.SSFan.CS1.DCV0	73	3.6	43	1.4	37	1.1	53	1.1
5	IEcon.EH.SSFan.CS1.DCV0	61	3.0	43	1.4	37	1.1	46	1.0
6	NoEcon.MSFan.CS1.DCV0	105	5.2	165	5.3	-99	-2.9	1	0.0
7	NIEcon.DB.MSFan.CS1.DCV0	150	7.4	199	6.4	-74	-2.1	57	1.2
8	NIEcon.EH.MSFan.CS1.DCV0	144	7.1	199	6.4	-74	-2.2	53	1.1
9	IEcon.DB.MSFan.CS1.DCV0	152	7.5	199	6.4	-73	-2.1	57	1.2
10	IEcon.EH.MSFan.CS1.DCV0	146	7.2	199	6.4	-74	-2.1	54	1.1
11	NoEcon.MSFan.CS2.DCV0	139	6.8	240	7.7	-82	-2.4	73	1.5
12	IEcon.DB.MSFan.CS2.DCV0	162	8.0	253	8.1	-69	-2.0	89	1.9
13	IEcon.EH.MSFan.CS2.DCV0	161	7.9	253	8.1	-69	-2.0	88	1.8
14	NoEcon.SSFan.CS1.DCV1	388	19.1	532	17.0	778	22.6	979	20.4
15	IEcon.DB.SSFan.CS1.DCV1	465	22.9	575	18.4	816	23.7	1031	21.5
16	IEcon.EH.SSFan.CS1.DCV1	449	22.1	575	18.4	816	23.7	1023	21.3
17	NoEcon.MSFan.CS1.DCV1	525	25.9	695	22.2	692	20.1	997	20.8
18	IEcon.DB.MSFan.CS1.DCV1	572	28.2	729	23.3	717	20.8	1050	21.9
19	IEcon.EH.MSFan.CS1.DCV1	566	27.9	729	23.3	716	20.8	1047	21.8
20	NoEcon.MSFan.CS2.DCV1	560	27.6	761	24.3	708	20.5	1057	22.0
21	IEcon.DB.MSFan.CS2.DCV1	582	28.7	773	24.7	721	20.9	1074	22.4
22	IEcon.EH.MSFan.CS2.DCV1	582	28.6	774	24.7	721	20.9	1073	22.3

Table C-15: HVAC Energy Savings Compared to Case 1 for the Supermarket Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	58	1.4	46	1.0	68	1.1	67	1.3
3	NIEcon.EH.SSFan.CS1.DCV0	54	1.3	45	1.0	59	1.0	65	1.2
4	IEcon.DB.SSFan.CS1.DCV0	58	1.4	47	1.0	68	1.1	67	1.3
5	IEcon.EH.SSFan.CS1.DCV0	55	1.3	45	1.0	59	1.0	65	1.2
6	NoEcon.MSFan.CS1.DCV0	50	1.2	-146	-3.2	-129	-2.1	-133	-2.5
7	NIEcon.DB.MSFan.CS1.DCV0	96	2.3	-103	-2.2	-52	-0.9	-78	-1.5
8	NIEcon.EH.MSFan.CS1.DCV0	94	2.2	-104	-2.3	-56	-0.9	-80	-1.5
9	IEcon.DB.MSFan.CS1.DCV0	97	2.3	-103	-2.2	-52	-0.9	-78	-1.5
10	IEcon.EH.MSFan.CS1.DCV0	94	2.3	-103	-2.3	-56	-0.9	-80	-1.5
11	NoEcon.MSFan.CS2.DCV0	120	2.9	-113	-2.5	-42	-0.7	-77	-1.5
12	IEcon.DB.MSFan.CS2.DCV0	137	3.3	-97	-2.1	-26	-0.4	-55	-1.0
13	IEcon.EH.MSFan.CS2.DCV0	136	3.3	-97	-2.1	-27	-0.4	-55	-1.0
14	NoEcon.SSFan.CS1.DCV1	746	17.9	1039	22.6	1181	19.6	958	18.2
15	IEcon.DB.SSFan.CS1.DCV1	803	19.2	1085	23.6	1278	21.2	1036	19.6
16	IEcon.EH.SSFan.CS1.DCV1	799	19.1	1083	23.6	1263	20.9	1031	19.5
17	NoEcon.MSFan.CS1.DCV1	789	18.9	902	19.6	1062	17.6	801	15.2
18	IEcon.DB.MSFan.CS1.DCV1	831	19.9	943	20.5	1179	19.5	868	16.5
19	IEcon.EH.MSFan.CS1.DCV1	829	19.8	941	20.5	1164	19.3	865	16.4
20	NoEcon.MSFan.CS2.DCV1	846	20.2	932	20.3	1168	19.4	863	16.4
21	IEcon.DB.MSFan.CS2.DCV1	862	20.6	947	20.6	1203	19.9	891	16.9
22	IEcon.EH.MSFan.CS2.DCV1	862	20.6	947	20.6	1199	19.9	891	16.9

Table C-16: HVAC Energy Savings Compared to Case 1 for the Supermarket Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	114	1.6	115	1.7	137	1.6	252	1.9
3	NIEcon.EH.SSFan.CS1.DCV0	108	1.5	113	1.7	133	1.6	251	1.9
4	IEcon.DB.SSFan.CS1.DCV0	115	1.6	114	1.7	138	1.6	252	1.9
5	IEcon.EH.SSFan.CS1.DCV0	108	1.5	113	1.7	133	1.6	250	1.9
6	NoEcon.MSFan.CS1.DCV0	-244	-3.4	-351	-5.2	-463	-5.4	-677	-5.2
7	NIEcon.DB.MSFan.CS1.DCV0	-87	-1.2	-203	-3.0	-287	-3.3	-287	-2.2
8	NIEcon.EH.MSFan.CS1.DCV0	-94	-1.3	-209	-3.1	-296	-3.5	-293	-2.3
9	IEcon.DB.MSFan.CS1.DCV0	-87	-1.2	-203	-3.0	-286	-3.3	-287	-2.2
10	IEcon.EH.MSFan.CS1.DCV0	-94	-1.3	-210	-3.1	-296	-3.5	-293	-2.3
11	NoEcon.MSFan.CS2.DCV0	-107	-1.5	-253	-3.7	-348	-4.1	-365	-2.8
12	IEcon.DB.MSFan.CS2.DCV0	-65	-0.9	-187	-2.8	-281	-3.3	-280	-2.2
13	IEcon.EH.MSFan.CS2.DCV0	-66	-0.9	-188	-2.8	-283	-3.3	-282	-2.2
14	NoEcon.SSFan.CS1.DCV1	1321	18.5	1193	17.6	1592	18.6	2131	16.5
15	IEcon.DB.SSFan.CS1.DCV1	1499	21.0	1324	19.5	1779	20.7	2436	18.8
16	IEcon.EH.SSFan.CS1.DCV1	1487	20.8	1321	19.4	1772	20.7	2434	18.8
17	NoEcon.MSFan.CS1.DCV1	1106	15.5	829	12.2	1184	13.8	1516	11.7
18	IEcon.DB.MSFan.CS1.DCV1	1355	19.0	1091	16.0	1466	17.1	2023	15.6
19	IEcon.EH.MSFan.CS1.DCV1	1325	18.5	1067	15.7	1433	16.7	2000	15.5
20	NoEcon.MSFan.CS2.DCV1	1295	18.1	992	14.6	1362	15.9	2014	15.6
21	IEcon.DB.MSFan.CS2.DCV1	1375	19.3	1115	16.4	1473	17.2	2033	15.7
22	IEcon.EH.MSFan.CS2.DCV1	1366	19.1	1111	16.3	1465	17.1	2029	15.7

Table C-17: Electricity Savings Compared to Case 1 for the Small Office Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	5	3.0	6	4.7	5	3.7	8	9.0
3	NIEcon.EH.SSFan.CS1.DCV0	4	2.6	5	4.0	6	3.9	7	7.5
4	IEcon.DB.SSFan.CS1.DCV0	5	3.0	6	4.6	6	3.8	8	9.0
5	IEcon.EH.SSFan.CS1.DCV0	4	2.7	5	4.0	6	4.0	7	7.5
6	NoEcon.MSFan.CS1.DCV0	30	18.8	33	26.7	34	23.7	36	39.0
7	NIEcon.DB.MSFan.CS1.DCV0	33	20.3	36	28.8	37	25.6	39	43.1
8	NIEcon.EH.MSFan.CS1.DCV0	32	20.1	36	28.5	37	25.6	39	42.5
9	IEcon.DB.MSFan.CS1.DCV0	33	20.2	36	28.6	37	25.7	39	43.1
10	IEcon.EH.MSFan.CS1.DCV0	33	20.2	36	28.6	37	25.8	39	42.6
11	NoEcon.MSFan.CS2.DCV0	47	29.3	45	35.8	49	34.3	43	47.4
12	IEcon.DB.MSFan.CS2.DCV0	47	29.4	45	36.2	51	35.5	45	49.0
13	IEcon.EH.MSFan.CS2.DCV0	49	30.3	46	37.1	51	35.5	46	49.8
14	NoEcon.SSFan.CS1.DCV1	13	7.8	9	6.8	6	4.3	3	2.9
15	IEcon.DB.SSFan.CS1.DCV1	17	10.3	15	11.7	13	8.9	12	12.8
16	IEcon.EH.SSFan.CS1.DCV1	17	10.7	14	11.4	13	9.2	11	11.7
17	NoEcon.MSFan.CS1.DCV1	45	27.8	43	34.8	42	29.1	40	43.1
18	IEcon.DB.MSFan.CS1.DCV1	46	28.7	46	36.9	46	31.7	44	47.9
19	IEcon.EH.MSFan.CS1.DCV1	47	29.4	47	37.3	46	31.8	44	48.0
20	NoEcon.MSFan.CS2.DCV1	60	37.0	53	42.8	56	38.9	47	50.9
21	IEcon.DB.MSFan.CS2.DCV1	59	36.8	54	43.2	59	40.6	49	53.0
22	IEcon.EH.MSFan.CS2.DCV1	62	38.3	56	44.6	59	40.6	50	54.3

Table C-18: Electricity Savings Compared to Case 1 for the Small Office Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	20	24.4	5	4.7	9	17.9	6	8.1
3	NIEcon.EH.SSFan.CS1.DCV0	16	19.7	5	4.8	9	17.5	5	6.5
4	IEcon.DB.SSFan.CS1.DCV0	21	25.3	5	4.9	9	18.2	6	8.0
5	IEcon.EH.SSFan.CS1.DCV0	16	20.0	5	5.0	9	17.8	5	6.7
6	NoEcon.MSFan.CS1.DCV0	40	49.1	34	30.6	33	65.4	32	43.6
7	NIEcon.DB.MSFan.CS1.DCV0	52	63.6	36	32.6	37	75.2	35	46.9
8	NIEcon.EH.MSFan.CS1.DCV0	50	60.4	36	32.6	37	74.9	35	46.6
9	IEcon.DB.MSFan.CS1.DCV0	53	64.5	36	32.7	38	75.7	35	46.7
10	IEcon.EH.MSFan.CS1.DCV0	50	61.0	36	32.7	38	75.4	35	46.8
11	NoEcon.MSFan.CS2.DCV0	48	58.1	43	39.0	35	71.0	37	50.3
12	IEcon.DB.MSFan.CS2.DCV0	55	67.1	44	40.2	39	77.5	39	51.7
13	IEcon.EH.MSFan.CS2.DCV0	55	66.8	44	40.2	39	77.5	39	52.3
14	NoEcon.SSFan.CS1.DCV1	-2	-2.2	3	3.0	-3	-5.8	2	2.6
15	IEcon.DB.SSFan.CS1.DCV1	21	25.5	10	9.1	9	18.3	9	11.9
16	IEcon.EH.SSFan.CS1.DCV1	17	20.2	10	9.1	9	17.7	8	11.0
17	NoEcon.MSFan.CS1.DCV1	38	46.6	38	34.7	30	60.6	36	48.2
18	IEcon.DB.MSFan.CS1.DCV1	53	64.3	41	37.8	38	75.9	39	52.4
19	IEcon.EH.MSFan.CS1.DCV1	50	60.6	41	37.8	38	75.5	39	52.7
20	NoEcon.MSFan.CS2.DCV1	46	55.5	47	43.0	33	67.0	40	54.3
21	IEcon.DB.MSFan.CS2.DCV1	55	66.9	49	44.9	39	77.6	42	56.4
22	IEcon.EH.MSFan.CS2.DCV1	55	66.7	49	44.8	39	77.7	43	57.5

Table C-19: Electricity Savings Compared to Case 1 for the Small Office Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	7	8.7	7	13.1	6	8.6	6	8.9
3	NIEcon.EH.SSFan.CS1.DCV0	6	7.7	6	12.4	4	6.3	5	7.8
4	IEcon.DB.SSFan.CS1.DCV0	7	9.0	7	13.4	6	8.7	6	9.1
5	IEcon.EH.SSFan.CS1.DCV0	6	7.9	6	12.5	4	6.3	5	7.8
6	NoEcon.MSFan.CS1.DCV0	35	44.9	33	65.5	35	49.5	38	55.7
7	NIEcon.DB.MSFan.CS1.DCV0	38	48.8	37	71.9	38	53.0	41	59.1
8	NIEcon.EH.MSFan.CS1.DCV0	38	48.4	36	71.5	37	52.1	41	58.7
9	IEcon.DB.MSFan.CS1.DCV0	38	49.2	37	72.2	38	53.2	41	59.3
10	IEcon.EH.MSFan.CS1.DCV0	38	48.6	37	71.8	37	52.2	41	58.9
11	NoEcon.MSFan.CS2.DCV0	42	53.7	36	70.2	40	56.0	43	62.8
12	IEcon.DB.MSFan.CS2.DCV0	44	56.1	38	74.4	41	57.8	45	64.8
13	IEcon.EH.MSFan.CS2.DCV0	44	56.1	38	74.4	41	58.0	45	64.7
14	NoEcon.SSFan.CS1.DCV1	0	0.3	-2	-4.2	1	1.0	-1	-1.1
15	IEcon.DB.SSFan.CS1.DCV1	9	11.0	7	13.6	8	11.2	7	10.3
16	IEcon.EH.SSFan.CS1.DCV1	8	9.9	6	12.5	6	8.8	6	8.7
17	NoEcon.MSFan.CS1.DCV1	36	46.7	32	63.5	38	52.9	39	56.7
18	IEcon.DB.MSFan.CS1.DCV1	41	52.3	38	73.8	41	57.6	43	62.1
19	IEcon.EH.MSFan.CS1.DCV1	40	51.7	37	73.3	40	56.8	42	61.4
20	NoEcon.MSFan.CS2.DCV1	43	54.9	35	68.7	42	59.0	44	63.7
21	IEcon.DB.MSFan.CS2.DCV1	46	58.4	39	75.9	44	61.6	46	67.0
22	IEcon.EH.MSFan.CS2.DCV1	46	58.4	39	75.9	44	62.0	46	66.8

Table C-20: Electricity Savings Compared to Case 1 for the Small Office Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	7	9.6	6	9.1	6	9.3	6	9.2
3	NIEcon.EH.SSFan.CS1.DCV0	6	8.0	5	8.5	5	8.1	6	8.9
4	IEcon.DB.SSFan.CS1.DCV0	7	9.7	6	9.2	6	9.4	6	9.3
5	IEcon.EH.SSFan.CS1.DCV0	6	8.0	5	8.5	5	8.1	6	9.0
6	NoEcon.MSFan.CS1.DCV0	36	51.9	39	61.1	37	61.9	41	61.9
7	NIEcon.DB.MSFan.CS1.DCV0	39	56.2	42	64.8	40	66.4	44	66.4
8	NIEcon.EH.MSFan.CS1.DCV0	39	55.6	42	64.6	39	65.9	44	66.3
9	IEcon.DB.MSFan.CS1.DCV0	39	56.4	42	65.0	40	66.6	44	66.5
10	IEcon.EH.MSFan.CS1.DCV0	39	55.8	42	64.7	39	66.0	44	66.4
11	NoEcon.MSFan.CS2.DCV0	40	58.0	43	66.7	39	65.8	43	64.8
12	IEcon.DB.MSFan.CS2.DCV0	42	60.1	44	68.9	41	68.5	45	67.7
13	IEcon.EH.MSFan.CS2.DCV0	42	60.5	44	68.8	41	68.5	45	67.7
14	NoEcon.SSFan.CS1.DCV1	0	0.2	-1	-2.0	-2	-2.6	-2	-2.6
15	IEcon.DB.SSFan.CS1.DCV1	8	11.7	6	10.0	6	10.0	6	9.4
16	IEcon.EH.SSFan.CS1.DCV1	7	10.2	6	9.1	5	8.6	6	9.0
17	NoEcon.MSFan.CS1.DCV1	38	54.8	40	62.0	38	63.2	42	63.0
18	IEcon.DB.MSFan.CS1.DCV1	42	60.7	44	67.9	42	70.1	47	70.1
19	IEcon.EH.MSFan.CS1.DCV1	42	60.2	43	67.6	41	69.5	47	69.9
20	NoEcon.MSFan.CS2.DCV1	42	60.7	43	67.6	40	67.4	44	66.3
21	IEcon.DB.MSFan.CS2.DCV1	45	64.1	46	71.4	43	71.8	47	71.2
22	IEcon.EH.MSFan.CS2.DCV1	45	64.6	46	71.3	43	71.8	47	71.2

Table C-21: Electricity Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	27	2.9	22	3.0	13	1.8	23	4.5
3	NIEcon.EH.SSFan.CS1.DCV0	16	1.7	15	2.0	15	2.0	18	3.5
4	IEcon.DB.SSFan.CS1.DCV0	27	2.9	22	3.1	14	1.9	23	4.6
5	IEcon.EH.SSFan.CS1.DCV0	17	1.8	15	2.1	15	2.1	18	3.6
6	NoEcon.MSFan.CS1.DCV0	154	16.6	162	22.6	169	22.8	186	36.4
7	NIEcon.DB.MSFan.CS1.DCV0	164	17.7	169	23.5	173	23.3	193	37.7
8	NIEcon.EH.MSFan.CS1.DCV0	159	17.2	166	23.1	174	23.4	190	37.3
9	IEcon.DB.MSFan.CS1.DCV0	164	17.7	169	23.5	173	23.4	193	37.8
10	IEcon.EH.MSFan.CS1.DCV0	160	17.3	167	23.2	174	23.5	191	37.4
11	NoEcon.MSFan.CS2.DCV0	236	25.6	215	29.9	230	31.1	225	44.1
12	IEcon.DB.MSFan.CS2.DCV0	244	26.4	219	30.6	232	31.3	229	44.9
13	IEcon.EH.MSFan.CS2.DCV0	242	26.1	219	30.4	232	31.3	229	44.8
14	NoEcon.SSFan.CS1.DCV1	120	13.0	92	12.8	89	12.0	42	8.2
15	IEcon.DB.SSFan.CS1.DCV1	139	15.0	108	15.0	101	13.6	58	11.3
16	IEcon.EH.SSFan.CS1.DCV1	130	14.1	103	14.3	102	13.8	54	10.6
17	NoEcon.MSFan.CS1.DCV1	284	30.7	263	36.7	272	36.7	232	45.3
18	IEcon.DB.MSFan.CS1.DCV1	294	31.8	272	37.8	278	37.5	240	47.0
19	IEcon.EH.MSFan.CS1.DCV1	290	31.4	270	37.5	278	37.5	238	46.7
20	NoEcon.MSFan.CS2.DCV1	356	38.5	312	43.5	331	44.7	265	51.8
21	IEcon.DB.MSFan.CS2.DCV1	362	39.1	317	44.1	334	45.0	269	52.7
22	IEcon.EH.MSFan.CS2.DCV1	361	39.1	317	44.1	334	45.0	269	52.7

Table C-22: Electricity Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	55	15.3	10	1.8	16	7.1	15	3.6
3	NIEcon.EH.SSFan.CS1.DCV0	47	13.1	11	2.0	16	7.1	12	2.8
4	IEcon.DB.SSFan.CS1.DCV0	57	16.0	11	1.9	16	7.4	15	3.7
5	IEcon.EH.SSFan.CS1.DCV0	49	13.7	11	2.0	16	7.4	12	2.9
6	NoEcon.MSFan.CS1.DCV0	191	53.7	158	28.5	147	66.8	167	39.7
7	NIEcon.DB.MSFan.CS1.DCV0	216	60.8	161	29.1	153	69.5	171	40.7
8	NIEcon.EH.MSFan.CS1.DCV0	210	59.2	162	29.1	153	69.5	170	40.4
9	IEcon.DB.MSFan.CS1.DCV0	219	61.6	162	29.1	154	69.9	171	40.8
10	IEcon.EH.MSFan.CS1.DCV0	213	60.0	162	29.2	154	69.9	170	40.5
11	NoEcon.MSFan.CS2.DCV0	213	60.0	193	34.7	154	69.9	192	45.8
12	IEcon.DB.MSFan.CS2.DCV0	231	65.1	194	35.0	158	71.6	195	46.4
13	IEcon.EH.MSFan.CS2.DCV0	230	64.6	194	35.0	158	71.6	195	46.4
14	NoEcon.SSFan.CS1.DCV1	18	5.0	60	10.9	2	1.0	32	7.6
15	IEcon.DB.SSFan.CS1.DCV1	60	16.9	70	12.7	17	7.8	43	10.2
16	IEcon.EH.SSFan.CS1.DCV1	53	14.8	71	12.8	17	7.8	41	9.7
17	NoEcon.MSFan.CS1.DCV1	189	53.2	231	41.6	150	67.9	208	49.7
18	IEcon.DB.MSFan.CS1.DCV1	224	62.9	236	42.6	161	73.0	214	50.9
19	IEcon.EH.MSFan.CS1.DCV1	217	61.1	236	42.6	161	73.0	213	50.7
20	NoEcon.MSFan.CS2.DCV1	213	60.0	263	47.5	157	71.2	231	55.0
21	IEcon.DB.MSFan.CS2.DCV1	236	66.5	266	48.0	165	74.8	234	55.7
22	IEcon.EH.MSFan.CS2.DCV1	234	65.9	266	47.9	165	74.8	234	55.7

Table C-23: Electricity Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	14	3.4	11	4.6	17	4.1	13	3.5
3	NIEcon.EH.SSFan.CS1.DCV0	13	3.2	10	4.5	13	3.2	13	3.4
4	IEcon.DB.SSFan.CS1.DCV0	14	3.5	11	4.8	17	4.2	14	3.6
5	IEcon.EH.SSFan.CS1.DCV0	13	3.3	11	4.6	13	3.3	13	3.4
6	NoEcon.MSFan.CS1.DCV0	178	43.7	144	62.2	201	48.5	208	54.1
7	NIEcon.DB.MSFan.CS1.DCV0	182	44.7	147	63.6	205	49.6	211	54.9
8	NIEcon.EH.MSFan.CS1.DCV0	181	44.6	147	63.6	204	49.3	211	54.9
9	IEcon.DB.MSFan.CS1.DCV0	182	44.8	148	63.8	206	49.7	212	55.0
10	IEcon.EH.MSFan.CS1.DCV0	182	44.8	148	63.8	204	49.4	212	54.9
11	NoEcon.MSFan.CS2.DCV0	208	51.3	151	65.3	226	54.5	229	59.5
12	IEcon.DB.MSFan.CS2.DCV0	211	51.8	153	66.2	228	55.1	230	59.8
13	IEcon.EH.MSFan.CS2.DCV0	211	52.0	154	66.3	228	55.1	230	59.8
14	NoEcon.SSFan.CS1.DCV1	19	4.6	3	1.2	21	5.1	12	3.2
15	IEcon.DB.SSFan.CS1.DCV1	31	7.6	13	5.5	34	8.2	24	6.2
16	IEcon.EH.SSFan.CS1.DCV1	30	7.5	12	5.3	30	7.4	23	6.0
17	NoEcon.MSFan.CS1.DCV1	205	50.5	154	66.6	232	56.1	231	60.0
18	IEcon.DB.MSFan.CS1.DCV1	212	52.1	161	69.3	239	57.7	236	61.4
19	IEcon.EH.MSFan.CS1.DCV1	211	51.9	160	69.2	237	57.3	236	61.2
20	NoEcon.MSFan.CS2.DCV1	233	57.3	161	69.7	253	61.2	251	65.3
21	IEcon.DB.MSFan.CS2.DCV1	236	58.1	166	71.5	257	62.1	253	65.8
22	IEcon.EH.MSFan.CS2.DCV1	236	58.2	166	71.5	257	62.1	253	65.7

Table C-24: Electricity Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	19	4.5	16	3.8	16	4.1	39	7.5
3	NIEcon.EH.SSFan.CS1.DCV0	16	3.8	16	3.8	15	3.8	38	7.5
4	IEcon.DB.SSFan.CS1.DCV0	20	4.6	16	3.9	16	4.1	39	7.5
5	IEcon.EH.SSFan.CS1.DCV0	17	3.9	16	3.8	15	3.8	38	7.5
6	NoEcon.MSFan.CS1.DCV0	226	52.2	246	60.4	234	60.7	290	56.4
7	NIEcon.DB.MSFan.CS1.DCV0	232	53.6	251	61.6	241	62.5	327	63.5
8	NIEcon.EH.MSFan.CS1.DCV0	231	53.4	251	61.6	240	62.4	327	63.6
9	IEcon.DB.MSFan.CS1.DCV0	232	53.7	251	61.6	241	62.5	327	63.6
10	IEcon.EH.MSFan.CS1.DCV0	231	53.4	251	61.7	241	62.4	327	63.6
11	NoEcon.MSFan.CS2.DCV0	249	57.5	262	64.5	244	63.4	318	61.9
12	IEcon.DB.MSFan.CS2.DCV0	251	58.1	264	64.8	247	64.2	330	64.2
13	IEcon.EH.MSFan.CS2.DCV0	251	58.1	264	64.8	247	64.2	330	64.1
14	NoEcon.SSFan.CS1.DCV1	19	4.4	9	2.2	7	1.7	19	3.8
15	IEcon.DB.SSFan.CS1.DCV1	33	7.7	21	5.3	19	5.0	39	7.7
16	IEcon.EH.SSFan.CS1.DCV1	31	7.1	21	5.2	18	4.7	39	7.6
17	NoEcon.MSFan.CS1.DCV1	256	59.2	268	65.8	258	66.8	319	62.1
18	IEcon.DB.MSFan.CS1.DCV1	265	61.2	276	67.7	267	69.2	357	69.5
19	IEcon.EH.MSFan.CS1.DCV1	264	61.0	276	67.7	266	69.1	357	69.5
20	NoEcon.MSFan.CS2.DCV1	277	64.0	285	69.9	268	69.5	348	67.8
21	IEcon.DB.MSFan.CS2.DCV1	280	64.8	287	70.6	272	70.5	360	70.1
22	IEcon.EH.MSFan.CS2.DCV1	280	64.8	287	70.6	272	70.5	360	70.1

Table C-25: Electricity Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	37	10.6	26	54.3	16	48.6	28	77.3
3	NIEcon.EH.SSFan.CS1.DCV0	21	9.1	18	53.8	19	48.8	22	77.0
4	IEcon.DB.SSFan.CS1.DCV0	39	10.7	26	54.3	17	48.6	29	77.3
5	IEcon.EH.SSFan.CS1.DCV0	22	9.2	18	53.8	19	48.8	23	77.0
6	NoEcon.MSFan.CS1.DCV0	179	23.4	166	63.5	171	59.6	183	84.5
7	NIEcon.DB.MSFan.CS1.DCV0	196	24.9	176	64.2	176	59.9	193	85.0
8	NIEcon.EH.MSFan.CS1.DCV0	188	24.2	172	64.0	178	60.1	191	84.9
9	IEcon.DB.MSFan.CS1.DCV0	197	25.0	176	64.2	177	60.0	194	85.1
10	IEcon.EH.MSFan.CS1.DCV0	189	24.3	173	64.0	178	60.1	192	84.9
11	NoEcon.MSFan.CS2.DCV0	278	32.3	223	67.3	234	64.1	225	86.5
12	IEcon.DB.MSFan.CS2.DCV0	287	33.2	229	67.7	236	64.2	231	86.8
13	IEcon.EH.MSFan.CS2.DCV0	285	33.0	228	67.6	237	64.3	231	86.8
14	NoEcon.SSFan.CS1.DCV1	128	18.7	96	58.9	94	54.1	52	78.4
15	IEcon.DB.SSFan.CS1.DCV1	153	21.0	110	59.9	99	54.5	63	78.9
16	IEcon.EH.SSFan.CS1.DCV1	138	19.6	104	59.5	102	54.7	59	78.7
17	NoEcon.MSFan.CS1.DCV1	315	35.6	269	70.3	274	66.9	234	86.9
18	IEcon.DB.MSFan.CS1.DCV1	332	37.2	278	70.9	277	67.1	243	87.4
19	IEcon.EH.MSFan.CS1.DCV1	322	36.3	275	70.7	279	67.3	241	87.2
20	NoEcon.MSFan.CS2.DCV1	404	43.7	320	73.7	332	71.1	268	88.5
21	IEcon.DB.MSFan.CS2.DCV1	411	44.3	324	73.9	333	71.1	272	88.7
22	IEcon.EH.MSFan.CS2.DCV1	408	44.1	323	73.9	333	71.1	271	88.7

Table C-26: Electricity Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	72	66.5	15	66.9	24	86.9	18	87.2
3	NIEcon.EH.SSFan.CS1.DCV0	63	65.5	16	66.9	24	86.9	14	87.1
4	IEcon.DB.SSFan.CS1.DCV0	75	66.8	15	66.9	25	86.9	19	87.2
5	IEcon.EH.SSFan.CS1.DCV0	65	65.8	16	67.0	25	86.9	15	87.1
6	NoEcon.MSFan.CS1.DCV0	208	80.0	166	76.0	154	94.8	159	91.7
7	NIEcon.DB.MSFan.CS1.DCV0	244	83.6	171	76.3	164	95.4	165	91.9
8	NIEcon.EH.MSFan.CS1.DCV0	238	83.0	172	76.3	164	95.4	164	91.8
9	IEcon.DB.MSFan.CS1.DCV0	248	84.0	171	76.3	165	95.5	166	91.9
10	IEcon.EH.MSFan.CS1.DCV0	241	83.3	172	76.4	165	95.5	164	91.9
11	NoEcon.MSFan.CS2.DCV0	237	82.9	204	78.3	163	95.4	186	92.6
12	IEcon.DB.MSFan.CS2.DCV0	261	85.3	206	78.4	169	95.8	190	92.7
13	IEcon.EH.MSFan.CS2.DCV0	260	85.2	207	78.5	170	95.8	190	92.7
14	NoEcon.SSFan.CS1.DCV1	49	64.2	68	70.1	21	86.7	38	87.8
15	IEcon.DB.SSFan.CS1.DCV1	80	67.2	72	70.3	26	87.0	46	88.1
16	IEcon.EH.SSFan.CS1.DCV1	73	66.5	74	70.4	26	87.0	44	88.0
17	NoEcon.MSFan.CS1.DCV1	220	81.2	242	80.6	165	95.5	204	93.1
18	IEcon.DB.MSFan.CS1.DCV1	257	84.9	245	80.7	174	96.1	210	93.3
19	IEcon.EH.MSFan.CS1.DCV1	249	84.1	245	80.8	174	96.1	209	93.3
20	NoEcon.MSFan.CS2.DCV1	253	84.5	276	82.6	174	96.1	227	93.9
21	IEcon.DB.MSFan.CS2.DCV1	269	86.1	276	82.7	179	96.3	230	93.9
22	IEcon.EH.MSFan.CS2.DCV1	267	85.9	277	82.7	179	96.4	230	94.0

Table C-27: Electricity Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	17	83.8	16	91.6	21	90.5	17	88.7
3	NIEcon.EH.SSFan.CS1.DCV0	16	83.8	15	91.6	16	90.4	16	88.6
4	IEcon.DB.SSFan.CS1.DCV0	17	83.8	16	91.6	21	90.5	17	88.7
5	IEcon.EH.SSFan.CS1.DCV0	17	83.8	16	91.6	17	90.4	17	88.7
6	NoEcon.MSFan.CS1.DCV0	166	90.1	148	96.4	195	94.7	196	94.2
7	NIEcon.DB.MSFan.CS1.DCV0	172	90.4	154	96.6	202	94.8	201	94.4
8	NIEcon.EH.MSFan.CS1.DCV0	172	90.4	153	96.6	201	94.8	201	94.4
9	IEcon.DB.MSFan.CS1.DCV0	172	90.4	155	96.7	203	94.9	201	94.4
10	IEcon.EH.MSFan.CS1.DCV0	172	90.4	154	96.7	201	94.8	201	94.4
11	NoEcon.MSFan.CS2.DCV0	198	91.5	157	96.8	222	95.3	220	95.0
12	IEcon.DB.MSFan.CS2.DCV0	201	91.6	161	96.9	225	95.4	222	95.0
13	IEcon.EH.MSFan.CS2.DCV0	201	91.6	161	96.9	225	95.4	222	95.0
14	NoEcon.SSFan.CS1.DCV1	27	84.2	13	91.5	29	90.7	20	88.8
15	IEcon.DB.SSFan.CS1.DCV1	34	84.5	18	91.7	38	90.9	27	89.0
16	IEcon.EH.SSFan.CS1.DCV1	34	84.5	18	91.7	35	90.9	27	89.0
17	NoEcon.MSFan.CS1.DCV1	198	91.5	164	97.0	233	95.6	224	95.1
18	IEcon.DB.MSFan.CS1.DCV1	203	91.7	170	97.2	239	95.7	228	95.2
19	IEcon.EH.MSFan.CS1.DCV1	203	91.7	170	97.2	237	95.7	228	95.2
20	NoEcon.MSFan.CS2.DCV1	225	92.6	173	97.3	255	96.1	246	95.8
21	IEcon.DB.MSFan.CS2.DCV1	227	92.7	176	97.4	257	96.1	247	95.8
22	IEcon.EH.MSFan.CS2.DCV1	227	92.7	176	97.4	257	96.1	247	95.8

Table C-28: Electricity Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	25	92.1	20	91.5	21	94.2	45	95.5
3	NIEcon.EH.SSFan.CS1.DCV0	21	92.1	20	91.4	19	94.2	45	95.5
4	IEcon.DB.SSFan.CS1.DCV0	25	92.1	20	91.5	21	94.2	45	95.5
5	IEcon.EH.SSFan.CS1.DCV0	21	92.1	20	91.5	19	94.2	45	95.5
6	NoEcon.MSFan.CS1.DCV0	221	95.9	240	96.2	231	97.5	289	97.8
7	NIEcon.DB.MSFan.CS1.DCV0	230	96.0	247	96.4	241	97.6	327	98.2
8	NIEcon.EH.MSFan.CS1.DCV0	229	96.0	247	96.4	240	97.6	327	98.2
9	IEcon.DB.MSFan.CS1.DCV0	230	96.0	247	96.4	241	97.6	327	98.2
10	IEcon.EH.MSFan.CS1.DCV0	229	96.0	247	96.4	240	97.6	327	98.2
11	NoEcon.MSFan.CS2.DCV0	247	96.4	261	96.7	245	97.7	320	98.1
12	IEcon.DB.MSFan.CS2.DCV0	250	96.4	264	96.8	248	97.8	331	98.2
13	IEcon.EH.MSFan.CS2.DCV0	250	96.4	263	96.8	248	97.8	331	98.2
14	NoEcon.SSFan.CS1.DCV1	31	92.3	22	91.5	21	94.2	43	95.5
15	IEcon.DB.SSFan.CS1.DCV1	39	92.4	26	91.6	25	94.3	46	95.6
16	IEcon.EH.SSFan.CS1.DCV1	36	92.3	26	91.6	23	94.3	46	95.6
17	NoEcon.MSFan.CS1.DCV1	260	96.6	272	96.9	264	98.0	313	98.1
18	IEcon.DB.MSFan.CS1.DCV1	267	96.7	276	97.0	270	98.1	360	98.5
19	IEcon.EH.MSFan.CS1.DCV1	265	96.7	276	97.0	269	98.1	360	98.5
20	NoEcon.MSFan.CS2.DCV1	281	97.0	290	97.3	275	98.2	355	98.5
21	IEcon.DB.MSFan.CS2.DCV1	283	97.0	291	97.3	276	98.2	364	98.5
22	IEcon.EH.MSFan.CS2.DCV1	282	97.0	290	97.3	276	98.2	363	98.5

Table C-29: Electricity Savings Compared to Case 1 for the Supermarket Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	27	21.4	31	68.4	22	67.3	40	82.2
3	NIEcon.EH.SSFan.CS1.DCV0	14	20.5	20	68.1	22	67.3	30	82.1
4	IEcon.DB.SSFan.CS1.DCV0	27	21.4	31	68.4	22	67.3	40	82.3
5	IEcon.EH.SSFan.CS1.DCV0	14	20.5	20	68.1	22	67.3	30	82.1
6	NoEcon.MSFan.CS1.DCV0	403	47.2	567	82.4	488	80.1	642	92.2
7	NIEcon.DB.MSFan.CS1.DCV0	417	48.2	583	82.8	501	80.5	664	92.5
8	NIEcon.EH.MSFan.CS1.DCV0	410	47.7	579	82.7	502	80.5	660	92.5
9	IEcon.DB.MSFan.CS1.DCV0	417	48.2	583	82.8	502	80.5	665	92.5
10	IEcon.EH.MSFan.CS1.DCV0	410	47.7	579	82.7	502	80.5	660	92.5
11	NoEcon.MSFan.CS2.DCV0	499	53.8	657	84.8	575	82.5	700	93.1
12	IEcon.DB.MSFan.CS2.DCV0	509	54.5	666	85.0	582	82.7	710	93.3
13	IEcon.EH.MSFan.CS2.DCV0	504	54.2	664	85.0	582	82.7	709	93.3
14	NoEcon.SSFan.CS1.DCV1	121	27.8	101	70.2	128	70.2	39	82.2
15	IEcon.DB.SSFan.CS1.DCV1	148	29.7	133	71.1	150	70.8	80	82.9
16	IEcon.EH.SSFan.CS1.DCV1	134	28.8	121	70.7	150	70.8	69	82.7
17	NoEcon.MSFan.CS1.DCV1	538	56.5	705	86.0	655	84.7	714	93.4
18	IEcon.DB.MSFan.CS1.DCV1	552	57.4	722	86.5	669	85.1	736	93.7
19	IEcon.EH.MSFan.CS1.DCV1	546	57.0	717	86.3	669	85.1	732	93.6
20	NoEcon.MSFan.CS2.DCV1	618	62.0	770	87.7	723	86.5	762	94.1
21	IEcon.DB.MSFan.CS2.DCV1	627	62.6	779	88.0	730	86.7	772	94.3
22	IEcon.EH.MSFan.CS2.DCV1	624	62.4	777	87.9	730	86.7	771	94.3

Table C-30: Electricity Savings Compared to Case 1 for the Supermarket Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	63	81.2	23	78.3	31	89.8	30	88.0
3	NIEcon.EH.SSFan.CS1.DCV0	52	80.9	23	78.3	31	89.8	23	87.9
4	IEcon.DB.SSFan.CS1.DCV0	65	81.3	24	78.3	32	89.8	30	88.0
5	IEcon.EH.SSFan.CS1.DCV0	53	80.9	24	78.3	31	89.8	24	87.9
6	NoEcon.MSFan.CS1.DCV0	454	92.8	564	88.9	437	96.3	621	94.9
7	NIEcon.DB.MSFan.CS1.DCV0	491	93.9	578	89.2	457	96.6	640	95.1
8	NIEcon.EH.MSFan.CS1.DCV0	485	93.8	578	89.2	457	96.6	637	95.1
9	IEcon.DB.MSFan.CS1.DCV0	493	94.0	579	89.2	458	96.6	640	95.2
10	IEcon.EH.MSFan.CS1.DCV0	487	93.8	579	89.2	457	96.6	637	95.1
11	NoEcon.MSFan.CS2.DCV0	481	93.6	623	90.1	449	96.5	663	95.4
12	IEcon.DB.MSFan.CS2.DCV0	503	94.3	631	90.2	461	96.7	672	95.5
13	IEcon.EH.MSFan.CS2.DCV0	502	94.2	631	90.2	461	96.7	671	95.5
14	NoEcon.SSFan.CS1.DCV1	-1	79.3	86	79.6	2	89.3	33	88.1
15	IEcon.DB.SSFan.CS1.DCV1	67	81.3	110	80.0	33	89.8	64	88.4
16	IEcon.EH.SSFan.CS1.DCV1	51	80.8	110	80.0	33	89.8	56	88.3
17	NoEcon.MSFan.CS1.DCV1	470	93.3	685	91.3	467	96.8	694	95.8
18	IEcon.DB.MSFan.CS1.DCV1	508	94.4	700	91.6	487	97.1	712	96.0
19	IEcon.EH.MSFan.CS1.DCV1	503	94.3	700	91.6	487	97.1	709	96.0
20	NoEcon.MSFan.CS2.DCV1	498	94.1	735	92.2	479	97.0	727	96.2
21	IEcon.DB.MSFan.CS2.DCV1	518	94.7	743	92.4	491	97.1	735	96.3
22	IEcon.EH.MSFan.CS2.DCV1	518	94.7	743	92.4	491	97.1	735	96.3

Table C-31: Electricity Savings Compared to Case 1 for the Supermarket Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	30	85.2	26	91.2	33	89.5	30	87.6
3	NIEcon.EH.SSFan.CS1.DCV0	26	85.2	25	91.2	25	89.4	27	87.6
4	IEcon.DB.SSFan.CS1.DCV0	31	85.2	27	91.2	34	89.5	30	87.6
5	IEcon.EH.SSFan.CS1.DCV0	27	85.2	25	91.2	25	89.4	27	87.6
6	NoEcon.MSFan.CS1.DCV0	676	94.1	492	96.7	740	96.0	767	95.5
7	NIEcon.DB.MSFan.CS1.DCV0	693	94.4	509	96.9	762	96.2	785	95.7
8	NIEcon.EH.MSFan.CS1.DCV0	692	94.3	508	96.9	759	96.2	784	95.7
9	IEcon.DB.MSFan.CS1.DCV0	694	94.4	510	96.9	763	96.2	785	95.7
10	IEcon.EH.MSFan.CS1.DCV0	692	94.3	509	96.9	759	96.2	784	95.7
11	NoEcon.MSFan.CS2.DCV0	724	94.8	505	96.9	778	96.3	797	95.8
12	IEcon.DB.MSFan.CS2.DCV0	732	94.9	515	97.0	788	96.4	806	95.9
13	IEcon.EH.MSFan.CS2.DCV0	732	94.9	515	97.0	787	96.4	806	95.9
14	NoEcon.SSFan.CS1.DCV1	27	85.2	3	90.9	15	89.3	15	87.5
15	IEcon.DB.SSFan.CS1.DCV1	58	85.6	30	91.2	56	89.7	48	87.8
16	IEcon.EH.SSFan.CS1.DCV1	54	85.6	28	91.2	45	89.6	44	87.8
17	NoEcon.MSFan.CS1.DCV1	735	94.9	530	97.2	794	96.5	814	96.0
18	IEcon.DB.MSFan.CS1.DCV1	753	95.2	548	97.4	825	96.8	835	96.2
19	IEcon.EH.MSFan.CS1.DCV1	751	95.2	547	97.4	818	96.7	834	96.2
20	NoEcon.MSFan.CS2.DCV1	774	95.5	544	97.3	832	96.8	843	96.3
21	IEcon.DB.MSFan.CS2.DCV1	783	95.6	552	97.4	844	97.0	853	96.4
22	IEcon.EH.MSFan.CS2.DCV1	782	95.6	552	97.4	843	96.9	853	96.4

Table C-32: Electricity Savings Compared to Case 1 for the Supermarket Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	43	90.7	40	89.9	44	92.5	100	94.0
3	NIEcon.EH.SSFan.CS1.DCV0	37	90.7	39	89.9	41	92.5	100	94.0
4	IEcon.DB.SSFan.CS1.DCV0	43	90.7	40	89.9	44	92.5	100	94.0
5	IEcon.EH.SSFan.CS1.DCV0	37	90.7	39	89.9	41	92.5	100	94.0
6	NoEcon.MSFan.CS1.DCV0	780	96.4	820	96.2	758	97.0	885	97.2
7	NIEcon.DB.MSFan.CS1.DCV0	818	96.6	856	96.5	800	97.3	990	97.6
8	NIEcon.EH.MSFan.CS1.DCV0	815	96.6	854	96.5	797	97.2	989	97.6
9	IEcon.DB.MSFan.CS1.DCV0	819	96.7	857	96.5	801	97.3	990	97.6
10	IEcon.EH.MSFan.CS1.DCV0	815	96.6	855	96.5	797	97.2	989	97.6
11	NoEcon.MSFan.CS2.DCV0	824	96.7	852	96.5	787	97.2	955	97.5
12	IEcon.DB.MSFan.CS2.DCV0	839	96.8	870	96.6	806	97.3	994	97.7
13	IEcon.EH.MSFan.CS2.DCV0	838	96.8	869	96.6	806	97.3	993	97.7
14	NoEcon.SSFan.CS1.DCV1	5	90.4	-5	89.5	-14	92.1	-24	93.5
15	IEcon.DB.SSFan.CS1.DCV1	61	90.8	52	90.0	49	92.5	100	94.0
16	IEcon.EH.SSFan.CS1.DCV1	53	90.8	50	90.0	45	92.5	99	94.0
17	NoEcon.MSFan.CS1.DCV1	822	96.7	845	96.4	790	97.2	907	97.3
18	IEcon.DB.MSFan.CS1.DCV1	882	97.1	908	96.9	860	97.6	1056	97.9
19	IEcon.EH.MSFan.CS1.DCV1	873	97.1	902	96.9	851	97.6	1051	97.9
20	NoEcon.MSFan.CS2.DCV1	875	97.1	892	96.8	835	97.5	1011	97.7
21	IEcon.DB.MSFan.CS2.DCV1	898	97.3	921	97.0	865	97.7	1059	97.9
22	IEcon.EH.MSFan.CS2.DCV1	896	97.2	920	97.0	863	97.7	1059	97.9

Table C-33: Gas Savings Compared to Case 1 for the Small Office Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	0	-35.7	0	0.1	0	0.5	0	0.3
3	NIEcon.EH.SSFan.CS1.DCV0	0	-35.4	0	0.0	0	0.6	0	0.3
4	IEcon.DB.SSFan.CS1.DCV0	0	-35.3	0	0.1	0	0.6	0	0.3
5	IEcon.EH.SSFan.CS1.DCV0	0	-35.4	0	0.0	0	0.8	0	0.3
6	NoEcon.MSFan.CS1.DCV0	0	-60.5	-9	-31.8	-8	-49.4	-18	-28.3
7	NIEcon.DB.MSFan.CS1.DCV0	0	-52.6	-9	-31.0	-8	-47.9	-18	-27.9
8	NIEcon.EH.MSFan.CS1.DCV0	0	-54.0	-9	-31.2	-8	-47.8	-18	-27.9
9	IEcon.DB.MSFan.CS1.DCV0	0	-53.4	-9	-31.0	-8	-47.9	-18	-27.9
10	IEcon.EH.MSFan.CS1.DCV0	0	-54.5	-9	-31.2	-8	-47.8	-18	-27.9
11	NoEcon.MSFan.CS2.DCV0	0	-54.5	-9	-31.1	-8	-47.6	-18	-28.0
12	IEcon.DB.MSFan.CS2.DCV0	0	-53.0	-9	-31.0	-8	-47.5	-18	-27.9
13	IEcon.EH.MSFan.CS2.DCV0	0	-53.3	-9	-31.0	-8	-47.4	-18	-27.9
14	NoEcon.SSFan.CS1.DCV1	0	23.2	8	26.8	5	29.9	17	26.5
15	IEcon.DB.SSFan.CS1.DCV1	0	-21.7	8	25.7	5	30.0	17	26.3
16	IEcon.EH.SSFan.CS1.DCV1	0	-21.4	8	25.6	5	30.0	17	26.3
17	NoEcon.MSFan.CS1.DCV1	0	-0.7	1	2.6	-1	-6.3	3	4.9
18	IEcon.DB.MSFan.CS1.DCV1	0	7.7	1	3.4	-1	-4.6	3	5.3
19	IEcon.EH.MSFan.CS1.DCV1	0	6.3	1	3.3	-1	-4.6	3	5.3
20	NoEcon.MSFan.CS2.DCV1	0	6.5	1	3.3	-1	-4.8	3	5.3
21	IEcon.DB.MSFan.CS2.DCV1	0	8.1	1	3.5	-1	-4.3	3	5.4
22	IEcon.EH.MSFan.CS2.DCV1	0	7.7	1	3.5	-1	-4.3	3	5.4

Table C-34: Gas Savings Compared to Case 1 for the Small Office Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	0	-2.1	0	1.1	0	1.0	0	0.3
3	NIEcon.EH.SSFan.CS1.DCV0	0	-2.1	0	1.1	0	1.0	0	0.3
4	IEcon.DB.SSFan.CS1.DCV0	0	-2.1	0	1.2	0	1.0	0	0.3
5	IEcon.EH.SSFan.CS1.DCV0	0	-2.1	0	1.1	0	0.9	0	0.3
6	NoEcon.MSFan.CS1.DCV0	-8	-67.3	-13	-39.3	-18	-43.5	-22	-23.9
7	NIEcon.DB.MSFan.CS1.DCV0	-8	-62.6	-13	-38.1	-18	-42.5	-22	-23.6
8	NIEcon.EH.MSFan.CS1.DCV0	-8	-62.5	-13	-38.1	-18	-42.5	-22	-23.6
9	IEcon.DB.MSFan.CS1.DCV0	-8	-62.6	-13	-38.2	-18	-42.5	-22	-23.6
10	IEcon.EH.MSFan.CS1.DCV0	-8	-62.6	-13	-38.1	-18	-42.5	-22	-23.6
11	NoEcon.MSFan.CS2.DCV0	-8	-63.0	-13	-38.3	-18	-42.8	-22	-23.6
12	IEcon.DB.MSFan.CS2.DCV0	-8	-62.4	-13	-37.9	-18	-42.5	-22	-23.6
13	IEcon.EH.MSFan.CS2.DCV0	-8	-62.4	-13	-37.9	-18	-42.5	-22	-23.6
14	NoEcon.SSFan.CS1.DCV1	3	24.8	9	27.6	13	32.2	29	31.0
15	IEcon.DB.SSFan.CS1.DCV1	2	19.7	9	28.6	14	33.0	29	31.2
16	IEcon.EH.SSFan.CS1.DCV1	2	19.7	9	28.6	14	33.0	29	31.2
17	NoEcon.MSFan.CS1.DCV1	-2	-18.4	0	-1.3	0	0.8	12	13.0
18	IEcon.DB.MSFan.CS1.DCV1	-2	-13.2	0	-0.1	1	1.8	12	13.3
19	IEcon.EH.MSFan.CS1.DCV1	-2	-13.3	0	-0.1	1	1.8	12	13.3
20	NoEcon.MSFan.CS2.DCV1	-2	-13.3	0	-0.3	1	1.6	12	13.3
21	IEcon.DB.MSFan.CS2.DCV1	-2	-13.0	0	0.0	1	1.9	12	13.3
22	IEcon.EH.MSFan.CS2.DCV1	-2	-13.0	0	0.0	1	1.9	12	13.3

Table C-35: Gas Savings Compared to Case 1 for the Small Office Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	0	0.4	0	0.3	0	0.2	1	0.7
3	NIEcon.EH.SSFan.CS1.DCV0	0	0.4	0	0.3	0	0.1	1	0.7
4	IEcon.DB.SSFan.CS1.DCV0	0	0.4	0	0.3	0	0.2	1	0.6
5	IEcon.EH.SSFan.CS1.DCV0	0	0.4	0	0.3	0	0.1	1	0.6
6	NoEcon.MSFan.CS1.DCV0	-19	-27.8	-26	-34.4	-29	-21.1	-26	-26.0
7	NIEcon.DB.MSFan.CS1.DCV0	-18	-27.0	-26	-34.1	-29	-21.0	-25	-25.5
8	NIEcon.EH.MSFan.CS1.DCV0	-18	-27.0	-26	-34.1	-29	-21.0	-25	-25.5
9	IEcon.DB.MSFan.CS1.DCV0	-18	-27.0	-26	-34.1	-29	-21.0	-25	-25.5
10	IEcon.EH.MSFan.CS1.DCV0	-18	-27.0	-26	-34.1	-29	-21.0	-25	-25.5
11	NoEcon.MSFan.CS2.DCV0	-18	-27.1	-26	-34.1	-29	-21.0	-25	-25.6
12	IEcon.DB.MSFan.CS2.DCV0	-18	-26.9	-26	-34.0	-29	-20.9	-25	-25.4
13	IEcon.EH.MSFan.CS2.DCV0	-18	-26.9	-26	-34.0	-29	-20.9	-25	-25.3
14	NoEcon.SSFan.CS1.DCV1	17	25.3	27	35.6	40	29.3	26	26.0
15	IEcon.DB.SSFan.CS1.DCV1	17	25.2	28	35.9	40	29.4	26	26.6
16	IEcon.EH.SSFan.CS1.DCV1	17	25.2	28	35.9	40	29.4	26	26.6
17	NoEcon.MSFan.CS1.DCV1	3	5.1	8	10.8	18	12.8	7	6.6
18	IEcon.DB.MSFan.CS1.DCV1	4	6.0	9	11.3	18	13.0	7	7.3
19	IEcon.EH.MSFan.CS1.DCV1	4	6.0	9	11.3	18	13.0	7	7.3
20	NoEcon.MSFan.CS2.DCV1	4	5.8	9	11.2	18	13.0	7	7.2
21	IEcon.DB.MSFan.CS2.DCV1	4	6.0	9	11.3	18	13.0	7	7.4
22	IEcon.EH.MSFan.CS2.DCV1	4	6.1	9	11.3	18	13.0	7	7.4

Table C-36: Gas Savings Compared to Case 1 for the Small Office Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7A		Fairbanks-8A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	0	0.2	0	0.3	0	0.2	0	-0.1
3	NIEcon.EH.SSFan.CS1.DCV0	0	0.2	0	0.3	0	0.1	0	-0.1
4	IEcon.DB.SSFan.CS1.DCV0	0	0.2	0	0.3	0	0.2	0	-0.1
5	IEcon.EH.SSFan.CS1.DCV0	0	0.2	0	0.3	0	0.1	0	-0.1
6	NoEcon.MSFan.CS1.DCV0	-31	-17.8	-34	-23.9	-38	-17.8	-49	-12.7
7	NIEcon.DB.MSFan.CS1.DCV0	-31	-17.7	-33	-23.6	-38	-17.7	-48	-12.4
8	NIEcon.EH.MSFan.CS1.DCV0	-31	-17.7	-33	-23.6	-38	-17.7	-48	-12.4
9	IEcon.DB.MSFan.CS1.DCV0	-31	-17.7	-34	-23.6	-38	-17.7	-48	-12.4
10	IEcon.EH.MSFan.CS1.DCV0	-31	-17.7	-34	-23.6	-38	-17.7	-48	-12.4
11	NoEcon.MSFan.CS2.DCV0	-31	-17.7	-34	-23.6	-38	-17.7	-48	-12.4
12	IEcon.DB.MSFan.CS2.DCV0	-31	-17.7	-33	-23.5	-38	-17.7	-48	-12.4
13	IEcon.EH.MSFan.CS2.DCV0	-31	-17.7	-33	-23.5	-38	-17.7	-48	-12.4
14	NoEcon.SSFan.CS1.DCV1	51	29.1	39	27.5	59	27.7	90	23.4
15	IEcon.DB.SSFan.CS1.DCV1	51	29.3	40	27.9	59	27.9	86	22.5
16	IEcon.EH.SSFan.CS1.DCV1	51	29.3	40	27.8	59	27.9	86	22.5
17	NoEcon.MSFan.CS1.DCV1	26	14.9	14	9.7	30	14.0	48	12.6
18	IEcon.DB.MSFan.CS1.DCV1	26	15.1	14	10.0	30	14.3	50	13.0
19	IEcon.EH.MSFan.CS1.DCV1	26	15.1	14	10.0	30	14.3	50	13.0
20	NoEcon.MSFan.CS2.DCV1	26	15.0	14	9.9	30	14.1	49	12.9
21	IEcon.DB.MSFan.CS2.DCV1	26	15.1	14	10.1	30	14.3	50	13.0
22	IEcon.EH.MSFan.CS2.DCV1	26	15.1	14	10.1	30	14.3	50	13.0

Table C-37: Gas Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	0	0.7	0	0.1	0	0.1	0	0.1
3	NIEcon.EH.SSFan.CS1.DCV0	0	0.4	0	0.1	1	0.2	0	0.0
4	IEcon.DB.SSFan.CS1.DCV0	0	0.7	0	0.1	0	0.1	0	0.1
5	IEcon.EH.SSFan.CS1.DCV0	0	0.4	0	0.0	1	0.2	0	0.1
6	NoEcon.MSFan.CS1.DCV0	-10	-43.0	-67	-16.4	-69	-22.2	-123	-14.4
7	NIEcon.DB.MSFan.CS1.DCV0	-10	-42.3	-67	-16.3	-68	-22.0	-123	-14.4
8	NIEcon.EH.MSFan.CS1.DCV0	-10	-42.4	-67	-16.4	-68	-21.9	-123	-14.4
9	IEcon.DB.MSFan.CS1.DCV0	-10	-42.3	-67	-16.3	-68	-22.0	-123	-14.4
10	IEcon.EH.MSFan.CS1.DCV0	-10	-42.4	-67	-16.4	-68	-21.9	-123	-14.4
11	NoEcon.MSFan.CS2.DCV0	-10	-42.5	-67	-16.4	-68	-21.9	-123	-14.4
12	IEcon.DB.MSFan.CS2.DCV0	-10	-42.4	-67	-16.3	-68	-21.9	-123	-14.4
13	IEcon.EH.MSFan.CS2.DCV0	-10	-42.4	-67	-16.3	-68	-21.8	-123	-14.4
14	NoEcon.SSFan.CS1.DCV1	13	55.9	153	37.4	120	38.4	295	34.5
15	IEcon.DB.SSFan.CS1.DCV1	13	56.5	153	37.5	120	38.7	295	34.6
16	IEcon.EH.SSFan.CS1.DCV1	13	56.4	153	37.5	120	38.7	295	34.6
17	NoEcon.MSFan.CS1.DCV1	8	34.0	109	26.6	76	24.4	210	24.6
18	IEcon.DB.MSFan.CS1.DCV1	8	34.6	109	26.7	76	24.5	210	24.6
19	IEcon.EH.MSFan.CS1.DCV1	8	34.5	109	26.7	76	24.5	210	24.6
20	NoEcon.MSFan.CS2.DCV1	8	34.4	109	26.6	76	24.5	210	24.6
21	IEcon.DB.MSFan.CS2.DCV1	8	34.7	109	26.7	77	24.6	210	24.6
22	IEcon.EH.MSFan.CS2.DCV1	8	34.6	109	26.7	77	24.6	210	24.6

Table C-38: Gas Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	1	0.2	1	0.1	1	0.1	0	0.0
3	NIEcon.EH.SSFan.CS1.DCV0	1	0.2	1	0.1	1	0.1	0	0.0
4	IEcon.DB.SSFan.CS1.DCV0	1	0.2	1	0.1	1	0.1	0	0.0
5	IEcon.EH.SSFan.CS1.DCV0	0	0.2	1	0.1	1	0.1	0	0.0
6	NoEcon.MSFan.CS1.DCV0	-84	-29.9	-91	-16.6	-92	-11.8	-148	-10.7
7	NIEcon.DB.MSFan.CS1.DCV0	-83	-29.6	-91	-16.5	-92	-11.8	-147	-10.7
8	NIEcon.EH.MSFan.CS1.DCV0	-83	-29.6	-91	-16.5	-92	-11.8	-148	-10.7
9	IEcon.DB.MSFan.CS1.DCV0	-83	-29.6	-91	-16.5	-92	-11.8	-147	-10.7
10	IEcon.EH.MSFan.CS1.DCV0	-83	-29.6	-91	-16.5	-92	-11.8	-148	-10.7
11	NoEcon.MSFan.CS2.DCV0	-84	-29.7	-91	-16.5	-92	-11.8	-148	-10.7
12	IEcon.DB.MSFan.CS2.DCV0	-83	-29.5	-91	-16.5	-92	-11.8	-147	-10.6
13	IEcon.EH.MSFan.CS2.DCV0	-83	-29.5	-91	-16.5	-92	-11.8	-147	-10.6
14	NoEcon.SSFan.CS1.DCV1	116	41.3	194	35.3	316	40.4	488	35.3
15	IEcon.DB.SSFan.CS1.DCV1	117	41.4	195	35.4	316	40.5	489	35.3
16	IEcon.EH.SSFan.CS1.DCV1	117	41.4	195	35.4	316	40.5	489	35.3
17	NoEcon.MSFan.CS1.DCV1	66	23.3	133	24.1	228	29.2	385	27.8
18	IEcon.DB.MSFan.CS1.DCV1	66	23.5	134	24.2	229	29.3	385	27.8
19	IEcon.EH.MSFan.CS1.DCV1	66	23.5	134	24.2	229	29.3	385	27.8
20	NoEcon.MSFan.CS2.DCV1	66	23.5	133	24.2	229	29.3	385	27.8
21	IEcon.DB.MSFan.CS2.DCV1	66	23.5	134	24.3	229	29.3	385	27.8
22	IEcon.EH.MSFan.CS2.DCV1	66	23.5	134	24.3	229	29.3	385	27.8

Table C-39: Gas Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	1	0.1	0	0.0	2	0.1	2	0.1
3	NIEcon.EH.SSFan.CS1.DCV0	1	0.1	0	0.0	2	0.1	2	0.1
4	IEcon.DB.SSFan.CS1.DCV0	1	0.1	0	0.0	2	0.1	2	0.1
5	IEcon.EH.SSFan.CS1.DCV0	1	0.1	0	0.0	2	0.1	2	0.1
6	NoEcon.MSFan.CS1.DCV0	-133	-13.0	-119	-9.3	-205	-10.7	-197	-13.4
7	NIEcon.DB.MSFan.CS1.DCV0	-132	-13.0	-119	-9.3	-204	-10.7	-196	-13.4
8	NIEcon.EH.MSFan.CS1.DCV0	-132	-13.0	-119	-9.3	-204	-10.7	-196	-13.4
9	IEcon.DB.MSFan.CS1.DCV0	-132	-13.0	-119	-9.3	-204	-10.7	-196	-13.4
10	IEcon.EH.MSFan.CS1.DCV0	-132	-13.0	-119	-9.3	-204	-10.7	-196	-13.4
11	NoEcon.MSFan.CS2.DCV0	-132	-13.0	-119	-9.3	-204	-10.7	-196	-13.3
12	IEcon.DB.MSFan.CS2.DCV0	-132	-12.9	-119	-9.3	-204	-10.7	-195	-13.3
13	IEcon.EH.MSFan.CS2.DCV0	-132	-12.9	-118	-9.3	-204	-10.7	-195	-13.3
14	NoEcon.SSFan.CS1.DCV1	343	33.6	535	42.0	616	32.2	468	31.9
15	IEcon.DB.SSFan.CS1.DCV1	344	33.7	536	42.0	614	32.1	470	32.1
16	IEcon.EH.SSFan.CS1.DCV1	344	33.7	535	42.0	614	32.1	470	32.1
17	NoEcon.MSFan.CS1.DCV1	249	24.4	416	32.6	474	24.8	326	22.2
18	IEcon.DB.MSFan.CS1.DCV1	250	24.5	416	32.6	478	25.0	328	22.4
19	IEcon.EH.MSFan.CS1.DCV1	250	24.5	416	32.6	478	25.0	328	22.4
20	NoEcon.MSFan.CS2.DCV1	250	24.5	416	32.6	477	24.9	328	22.4
21	IEcon.DB.MSFan.CS2.DCV1	250	24.5	416	32.6	479	25.0	328	22.4
22	IEcon.EH.MSFan.CS2.DCV1	251	24.6	416	32.6	479	25.0	328	22.4

Table C-40: Gas Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7A		Fairbanks-8A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	4	0.2	3	0.1	1	0.0	78	1.5
3	NIEcon.EH.SSFan.CS1.DCV0	4	0.1	3	0.1	1	0.0	78	1.5
4	IEcon.DB.SSFan.CS1.DCV0	4	0.2	3	0.1	1	0.0	78	1.5
5	IEcon.EH.SSFan.CS1.DCV0	4	0.1	3	0.1	1	0.0	78	1.5
6	NoEcon.MSFan.CS1.DCV0	-248	-10.2	-296	-14.1	-335	-11.0	-511	-10.0
7	NIEcon.DB.MSFan.CS1.DCV0	-240	-9.9	-288	-13.7	-321	-10.6	-390	-7.7
8	NIEcon.EH.MSFan.CS1.DCV0	-240	-9.9	-288	-13.7	-321	-10.6	-390	-7.7
9	IEcon.DB.MSFan.CS1.DCV0	-240	-9.9	-288	-13.7	-321	-10.6	-390	-7.7
10	IEcon.EH.MSFan.CS1.DCV0	-240	-9.9	-288	-13.7	-321	-10.6	-390	-7.7
11	NoEcon.MSFan.CS2.DCV0	-242	-10.0	-293	-14.0	-327	-10.8	-406	-8.0
12	IEcon.DB.MSFan.CS2.DCV0	-239	-9.9	-287	-13.7	-320	-10.6	-389	-7.6
13	IEcon.EH.MSFan.CS2.DCV0	-239	-9.9	-287	-13.7	-320	-10.6	-389	-7.6
14	NoEcon.SSFan.CS1.DCV1	728	30.0	652	31.0	909	30.0	1338	26.3
15	IEcon.DB.SSFan.CS1.DCV1	728	30.0	647	30.8	912	30.1	1341	26.3
16	IEcon.EH.SSFan.CS1.DCV1	728	30.0	647	30.8	912	30.1	1341	26.3
17	NoEcon.MSFan.CS1.DCV1	568	23.4	439	20.9	688	22.7	867	17.0
18	IEcon.DB.MSFan.CS1.DCV1	579	23.9	453	21.6	706	23.3	1027	20.2
19	IEcon.EH.MSFan.CS1.DCV1	579	23.9	452	21.6	706	23.3	1027	20.2
20	NoEcon.MSFan.CS2.DCV1	576	23.8	447	21.3	703	23.2	1021	20.0
21	IEcon.DB.MSFan.CS2.DCV1	579	23.9	453	21.6	706	23.3	1028	20.2
22	IEcon.EH.MSFan.CS2.DCV1	579	23.9	453	21.6	707	23.3	1028	20.2

Table C-41: Gas Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2	5.0	1	0.3	2	0.5	1	0.2
3	NIEcon.EH.SSFan.CS1.DCV0	2	4.6	1	0.2	2	0.5	1	0.1
4	IEcon.DB.SSFan.CS1.DCV0	2	5.0	1	0.2	2	0.5	1	0.2
5	IEcon.EH.SSFan.CS1.DCV0	2	4.5	1	0.2	2	0.5	1	0.2
6	NoEcon.MSFan.CS1.DCV0	-15	-37.9	-70	-17.6	-70	-21.0	-120	-14.8
7	NIEcon.DB.MSFan.CS1.DCV0	-14	-33.9	-70	-17.5	-69	-20.7	-119	-14.7
8	NIEcon.EH.MSFan.CS1.DCV0	-14	-34.4	-70	-17.5	-69	-20.6	-119	-14.7
9	IEcon.DB.MSFan.CS1.DCV0	-14	-33.9	-70	-17.5	-69	-20.7	-119	-14.7
10	IEcon.EH.MSFan.CS1.DCV0	-14	-34.4	-70	-17.5	-69	-20.7	-119	-14.7
11	NoEcon.MSFan.CS2.DCV0	-14	-35.1	-70	-17.5	-69	-20.7	-119	-14.7
12	IEcon.DB.MSFan.CS2.DCV0	-13	-33.8	-70	-17.5	-68	-20.5	-119	-14.7
13	IEcon.EH.MSFan.CS2.DCV0	-14	-33.9	-70	-17.5	-68	-20.4	-119	-14.7
14	NoEcon.SSFan.CS1.DCV1	16	40.5	146	36.7	113	33.9	281	34.7
15	IEcon.DB.SSFan.CS1.DCV1	16	41.0	147	36.8	114	34.1	282	34.8
16	IEcon.EH.SSFan.CS1.DCV1	16	40.9	146	36.7	114	34.2	281	34.8
17	NoEcon.MSFan.CS1.DCV1	7	17.9	105	26.3	70	20.9	208	25.7
18	IEcon.DB.MSFan.CS1.DCV1	8	19.1	106	26.5	70	21.1	209	25.8
19	IEcon.EH.MSFan.CS1.DCV1	7	18.8	105	26.4	71	21.2	209	25.8
20	NoEcon.MSFan.CS2.DCV1	7	18.6	105	26.4	71	21.3	209	25.8
21	IEcon.DB.MSFan.CS2.DCV1	8	19.2	106	26.5	71	21.3	209	25.8
22	IEcon.EH.MSFan.CS2.DCV1	8	19.0	106	26.5	71	21.4	209	25.8

Table C-42: Gas Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2	0.6	2	0.3	1	0.1	1	0.0
3	NIEcon.EH.SSFan.CS1.DCV0	2	0.5	2	0.3	1	0.1	0	0.0
4	IEcon.DB.SSFan.CS1.DCV0	2	0.6	1	0.3	1	0.1	1	0.0
5	IEcon.EH.SSFan.CS1.DCV0	2	0.5	2	0.3	1	0.1	1	0.0
6	NoEcon.MSFan.CS1.DCV0	-94	-31.7	-90	-16.4	-123	-17.5	-148	-10.9
7	NIEcon.DB.MSFan.CS1.DCV0	-93	-31.1	-89	-16.2	-122	-17.5	-147	-10.9
8	NIEcon.EH.MSFan.CS1.DCV0	-93	-31.2	-88	-16.2	-122	-17.5	-147	-10.9
9	IEcon.DB.MSFan.CS1.DCV0	-93	-31.1	-89	-16.2	-122	-17.5	-147	-10.9
10	IEcon.EH.MSFan.CS1.DCV0	-93	-31.2	-88	-16.2	-122	-17.5	-147	-10.9
11	NoEcon.MSFan.CS2.DCV0	-93	-31.4	-89	-16.2	-122	-17.5	-147	-10.9
12	IEcon.DB.MSFan.CS2.DCV0	-93	-31.2	-88	-16.1	-122	-17.5	-147	-10.9
13	IEcon.EH.MSFan.CS2.DCV0	-93	-31.2	-88	-16.1	-122	-17.5	-147	-10.9
14	NoEcon.SSFan.CS1.DCV1	109	36.7	180	33.0	281	40.1	473	34.9
15	IEcon.DB.SSFan.CS1.DCV1	110	36.8	181	33.1	281	40.2	473	34.9
16	IEcon.EH.SSFan.CS1.DCV1	110	36.8	181	33.1	281	40.2	473	34.9
17	NoEcon.MSFan.CS1.DCV1	55	18.6	126	23.0	212	30.3	382	28.2
18	IEcon.DB.MSFan.CS1.DCV1	56	19.0	126	23.1	213	30.4	383	28.2
19	IEcon.EH.MSFan.CS1.DCV1	56	18.9	126	23.1	213	30.4	383	28.2
20	NoEcon.MSFan.CS2.DCV1	56	18.9	126	23.1	212	30.4	383	28.2
21	IEcon.DB.MSFan.CS2.DCV1	56	19.0	126	23.1	213	30.4	383	28.2
22	IEcon.EH.MSFan.CS2.DCV1	56	19.0	127	23.2	213	30.4	383	28.2

Table C-43: Gas Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2	0.2	1	0.0	2	0.1	2	0.2
3	NIEcon.EH.SSFan.CS1.DCV0	2	0.2	1	0.0	2	0.1	2	0.2
4	IEcon.DB.SSFan.CS1.DCV0	2	0.2	1	0.0	2	0.1	2	0.2
5	IEcon.EH.SSFan.CS1.DCV0	2	0.2	0	0.0	2	0.1	2	0.2
6	NoEcon.MSFan.CS1.DCV0	-124	-12.6	-164	-13.1	-212	-11.2	-190	-13.4
7	NIEcon.DB.MSFan.CS1.DCV0	-122	-12.5	-163	-13.0	-211	-11.2	-189	-13.4
8	NIEcon.EH.MSFan.CS1.DCV0	-122	-12.5	-163	-13.0	-211	-11.2	-189	-13.4
9	IEcon.DB.MSFan.CS1.DCV0	-123	-12.5	-163	-13.0	-211	-11.2	-189	-13.4
10	IEcon.EH.MSFan.CS1.DCV0	-123	-12.5	-163	-13.0	-211	-11.2	-189	-13.4
11	NoEcon.MSFan.CS2.DCV0	-122	-12.5	-163	-13.0	-211	-11.2	-189	-13.3
12	IEcon.DB.MSFan.CS2.DCV0	-122	-12.4	-163	-13.0	-210	-11.1	-188	-13.3
13	IEcon.EH.MSFan.CS2.DCV0	-122	-12.4	-163	-13.0	-210	-11.1	-188	-13.3
14	NoEcon.SSFan.CS1.DCV1	328	33.4	512	40.9	598	31.7	450	31.8
15	IEcon.DB.SSFan.CS1.DCV1	329	33.5	512	40.9	598	31.7	451	31.8
16	IEcon.EH.SSFan.CS1.DCV1	329	33.5	512	40.9	598	31.7	451	31.8
17	NoEcon.MSFan.CS1.DCV1	249	25.3	406	32.4	472	25.0	331	23.4
18	IEcon.DB.MSFan.CS1.DCV1	249	25.4	406	32.4	473	25.1	331	23.4
19	IEcon.EH.MSFan.CS1.DCV1	249	25.4	406	32.4	473	25.1	331	23.4
20	NoEcon.MSFan.CS2.DCV1	250	25.4	406	32.4	473	25.1	332	23.4
21	IEcon.DB.MSFan.CS2.DCV1	250	25.4	406	32.4	473	25.1	332	23.5
22	IEcon.EH.MSFan.CS2.DCV1	250	25.5	406	32.4	473	25.1	332	23.5

Table C-44: Gas Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7A		Fairbanks-8A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	11	0.5	9	0.4	20	0.7	119	2.3
3	NIEcon.EH.SSFan.CS1.DCV0	11	0.5	9	0.5	20	0.7	119	2.4
4	IEcon.DB.SSFan.CS1.DCV0	11	0.5	9	0.4	20	0.7	119	2.3
5	IEcon.EH.SSFan.CS1.DCV0	11	0.5	9	0.4	20	0.7	119	2.3
6	NoEcon.MSFan.CS1.DCV0	-250	-10.4	-296	-14.1	-334	-11.1	-501	-9.9
7	NIEcon.DB.MSFan.CS1.DCV0	-240	-9.9	-285	-13.6	-313	-10.4	-355	-7.0
8	NIEcon.EH.MSFan.CS1.DCV0	-240	-10.0	-285	-13.6	-313	-10.4	-355	-7.0
9	IEcon.DB.MSFan.CS1.DCV0	-240	-9.9	-285	-13.6	-313	-10.4	-355	-7.0
10	IEcon.EH.MSFan.CS1.DCV0	-240	-10.0	-285	-13.6	-313	-10.4	-355	-7.0
11	NoEcon.MSFan.CS2.DCV0	-243	-10.1	-291	-13.9	-319	-10.6	-378	-7.4
12	IEcon.DB.MSFan.CS2.DCV0	-239	-9.9	-284	-13.6	-313	-10.4	-354	-7.0
13	IEcon.EH.MSFan.CS2.DCV0	-239	-9.9	-284	-13.6	-313	-10.4	-354	-7.0
14	NoEcon.SSFan.CS1.DCV1	711	29.5	643	30.8	901	29.9	1363	26.9
15	IEcon.DB.SSFan.CS1.DCV1	711	29.5	644	30.8	902	29.9	1353	26.7
16	IEcon.EH.SSFan.CS1.DCV1	711	29.5	644	30.8	902	29.9	1354	26.7
17	NoEcon.MSFan.CS1.DCV1	561	23.3	446	21.3	683	22.7	740	14.6
18	IEcon.DB.MSFan.CS1.DCV1	569	23.6	454	21.7	699	23.2	969	19.1
19	IEcon.EH.MSFan.CS1.DCV1	569	23.6	454	21.7	699	23.2	969	19.1
20	NoEcon.MSFan.CS2.DCV1	566	23.5	449	21.5	692	23.0	978	19.3
21	IEcon.DB.MSFan.CS2.DCV1	569	23.6	455	21.8	700	23.2	970	19.1
22	IEcon.EH.MSFan.CS2.DCV1	569	23.6	455	21.8	700	23.2	970	19.1

Table C-45: Gas Savings Compared to Case 1 for the Supermarket Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2	1.2	9	0.7	14	1.1	20	0.8
3	NIEcon.EH.SSFan.CS1.DCV0	2	1.2	9	0.7	14	1.1	19	0.8
4	IEcon.DB.SSFan.CS1.DCV0	2	1.2	9	0.7	14	1.1	20	0.8
5	IEcon.EH.SSFan.CS1.DCV0	2	1.2	9	0.7	14	1.1	19	0.8
6	NoEcon.MSFan.CS1.DCV0	-43	-29.8	-280	-21.7	-253	-20.8	-516	-20.8
7	NIEcon.DB.MSFan.CS1.DCV0	-40	-28.1	-266	-20.6	-236	-19.4	-489	-19.8
8	NIEcon.EH.MSFan.CS1.DCV0	-40	-28.3	-266	-20.7	-236	-19.4	-489	-19.8
9	IEcon.DB.MSFan.CS1.DCV0	-40	-28.2	-266	-20.6	-236	-19.4	-489	-19.8
10	IEcon.EH.MSFan.CS1.DCV0	-40	-28.4	-266	-20.7	-236	-19.4	-489	-19.8
11	NoEcon.MSFan.CS2.DCV0	-41	-28.5	-269	-20.9	-238	-19.5	-495	-20.0
12	IEcon.DB.MSFan.CS2.DCV0	-40	-28.1	-266	-20.6	-234	-19.2	-488	-19.7
13	IEcon.EH.MSFan.CS2.DCV0	-40	-28.2	-266	-20.6	-234	-19.2	-488	-19.7
14	NoEcon.SSFan.CS1.DCV1	47	33.0	350	27.1	285	23.4	636	25.7
15	IEcon.DB.SSFan.CS1.DCV1	49	34.5	359	27.8	299	24.6	655	26.5
16	IEcon.EH.SSFan.CS1.DCV1	49	34.5	359	27.8	299	24.6	655	26.5
17	NoEcon.MSFan.CS1.DCV1	-3	-1.8	61	4.7	8	0.7	108	4.4
18	IEcon.DB.MSFan.CS1.DCV1	-1	-0.4	75	5.8	24	2.0	133	5.4
19	IEcon.EH.MSFan.CS1.DCV1	-1	-0.5	74	5.7	25	2.0	132	5.3
20	NoEcon.MSFan.CS2.DCV1	-1	-0.7	71	5.5	22	1.8	127	5.1
21	IEcon.DB.MSFan.CS2.DCV1	0	-0.3	75	5.8	26	2.1	133	5.4
22	IEcon.EH.MSFan.CS2.DCV1	-1	-0.4	75	5.8	26	2.2	133	5.4

Table C-46: Gas Savings Compared to Case 1 for the Supermarket Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	9	0.6	19	1.0	6	0.2	23	0.6
3	NIEcon.EH.SSFan.CS1.DCV0	9	0.6	19	1.0	6	0.2	22	0.6
4	IEcon.DB.SSFan.CS1.DCV0	8	0.6	19	1.0	6	0.2	22	0.6
5	IEcon.EH.SSFan.CS1.DCV0	8	0.6	19	1.0	6	0.2	22	0.6
6	NoEcon.MSFan.CS1.DCV0	-349	-26.1	-399	-20.0	-536	-19.3	-620	-16.5
7	NIEcon.DB.MSFan.CS1.DCV0	-341	-25.5	-380	-19.0	-531	-19.1	-583	-15.6
8	NIEcon.EH.MSFan.CS1.DCV0	-341	-25.5	-380	-19.0	-531	-19.1	-583	-15.6
9	IEcon.DB.MSFan.CS1.DCV0	-341	-25.5	-380	-19.0	-531	-19.1	-583	-15.6
10	IEcon.EH.MSFan.CS1.DCV0	-341	-25.5	-380	-19.0	-531	-19.1	-583	-15.6
11	NoEcon.MSFan.CS2.DCV0	-343	-25.7	-383	-19.2	-532	-19.1	-590	-15.7
12	IEcon.DB.MSFan.CS2.DCV0	-341	-25.5	-378	-19.0	-530	-19.1	-583	-15.5
13	IEcon.EH.MSFan.CS2.DCV0	-341	-25.5	-378	-19.0	-530	-19.1	-583	-15.5
14	NoEcon.SSFan.CS1.DCV1	389	29.1	446	22.4	777	28.0	945	25.2
15	IEcon.DB.SSFan.CS1.DCV1	398	29.8	465	23.3	783	28.2	967	25.8
16	IEcon.EH.SSFan.CS1.DCV1	398	29.8	465	23.3	783	28.2	967	25.8
17	NoEcon.MSFan.CS1.DCV1	55	4.1	9	0.5	225	8.1	303	8.1
18	IEcon.DB.MSFan.CS1.DCV1	64	4.8	29	1.5	229	8.2	338	9.0
19	IEcon.EH.MSFan.CS1.DCV1	63	4.7	29	1.4	229	8.2	338	9.0
20	NoEcon.MSFan.CS2.DCV1	62	4.6	26	1.3	228	8.2	330	8.8
21	IEcon.DB.MSFan.CS2.DCV1	64	4.8	31	1.5	230	8.3	339	9.0
22	IEcon.EH.MSFan.CS2.DCV1	64	4.8	31	1.5	230	8.3	338	9.0

Table C-47: Gas Savings Compared to Case 1 for the Supermarket Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	28	0.9	20	0.5	34	0.7	37	0.9
3	NIEcon.EH.SSFan.CS1.DCV0	28	0.9	20	0.5	34	0.7	38	0.9
4	IEcon.DB.SSFan.CS1.DCV0	28	0.9	20	0.5	34	0.7	37	0.9
5	IEcon.EH.SSFan.CS1.DCV0	28	0.9	20	0.5	34	0.7	37	0.9
6	NoEcon.MSFan.CS1.DCV0	-626	-20.3	-637	-16.7	-869	-17.9	-900	-22.0
7	NIEcon.DB.MSFan.CS1.DCV0	-597	-19.4	-612	-16.0	-814	-16.8	-863	-21.1
8	NIEcon.EH.MSFan.CS1.DCV0	-598	-19.4	-612	-16.0	-815	-16.8	-863	-21.1
9	IEcon.DB.MSFan.CS1.DCV0	-598	-19.4	-612	-16.0	-815	-16.8	-863	-21.1
10	IEcon.EH.MSFan.CS1.DCV0	-598	-19.4	-612	-16.0	-815	-16.8	-864	-21.1
11	NoEcon.MSFan.CS2.DCV0	-603	-19.6	-618	-16.2	-820	-16.9	-874	-21.4
12	IEcon.DB.MSFan.CS2.DCV0	-596	-19.3	-612	-16.0	-814	-16.8	-861	-21.1
13	IEcon.EH.MSFan.CS2.DCV0	-596	-19.4	-612	-16.0	-814	-16.8	-861	-21.1
14	NoEcon.SSFan.CS1.DCV1	719	23.4	1036	27.1	1165	24.0	943	23.1
15	IEcon.DB.SSFan.CS1.DCV1	745	24.2	1055	27.6	1222	25.2	988	24.2
16	IEcon.EH.SSFan.CS1.DCV1	745	24.2	1055	27.6	1218	25.1	987	24.1
17	NoEcon.MSFan.CS1.DCV1	53	1.7	372	9.7	269	5.5	-14	-0.3
18	IEcon.DB.MSFan.CS1.DCV1	78	2.5	395	10.3	355	7.3	32	0.8
19	IEcon.EH.MSFan.CS1.DCV1	78	2.5	394	10.3	346	7.1	31	0.8
20	NoEcon.MSFan.CS2.DCV1	72	2.4	389	10.2	336	6.9	20	0.5
21	IEcon.DB.MSFan.CS2.DCV1	79	2.6	395	10.3	359	7.4	38	0.9
22	IEcon.EH.MSFan.CS2.DCV1	79	2.6	395	10.3	357	7.3	38	0.9

Table C-48: Gas Savings Compared to Case 1 for the Supermarket Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7A		Fairbanks-8A	
		Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)	Abs. (10^6 Btus)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	72	1.2	74	1.4	93	1.3	152	1.3
3	NIEcon.EH.SSFan.CS1.DCV0	71	1.2	74	1.3	92	1.3	151	1.3
4	IEcon.DB.SSFan.CS1.DCV0	72	1.2	74	1.3	93	1.3	151	1.3
5	IEcon.EH.SSFan.CS1.DCV0	71	1.2	74	1.3	92	1.2	150	1.3
6	NoEcon.MSFan.CS1.DCV0	-1023	-17.4	-1171	-21.2	-1221	-16.6	-1561	-13.7
7	NIEcon.DB.MSFan.CS1.DCV0	-906	-15.4	-1059	-19.2	-1087	-14.8	-1277	-11.2
8	NIEcon.EH.MSFan.CS1.DCV0	-909	-15.4	-1064	-19.3	-1094	-14.9	-1282	-11.3
9	IEcon.DB.MSFan.CS1.DCV0	-906	-15.4	-1060	-19.2	-1087	-14.8	-1277	-11.2
10	IEcon.EH.MSFan.CS1.DCV0	-909	-15.4	-1064	-19.3	-1093	-14.9	-1282	-11.3
11	NoEcon.MSFan.CS2.DCV0	-931	-15.8	-1106	-20.1	-1135	-15.5	-1320	-11.6
12	IEcon.DB.MSFan.CS2.DCV0	-904	-15.3	-1057	-19.2	-1087	-14.8	-1274	-11.2
13	IEcon.EH.MSFan.CS2.DCV0	-904	-15.4	-1057	-19.2	-1088	-14.8	-1276	-11.2
14	NoEcon.SSFan.CS1.DCV1	1316	22.4	1198	21.7	1606	21.9	2155	19.0
15	IEcon.DB.SSFan.CS1.DCV1	1438	24.4	1272	23.1	1731	23.6	2336	20.5
16	IEcon.EH.SSFan.CS1.DCV1	1434	24.4	1271	23.1	1726	23.5	2335	20.5
17	NoEcon.MSFan.CS1.DCV1	284	4.8	-16	-0.3	394	5.4	609	5.4
18	IEcon.DB.MSFan.CS1.DCV1	473	8.0	182	3.3	607	8.3	967	8.5
19	IEcon.EH.MSFan.CS1.DCV1	452	7.7	165	3.0	582	7.9	949	8.3
20	NoEcon.MSFan.CS2.DCV1	420	7.1	100	1.8	527	7.2	1002	8.8
21	IEcon.DB.MSFan.CS2.DCV1	478	8.1	194	3.5	609	8.3	973	8.6
22	IEcon.EH.MSFan.CS2.DCV1	471	8.0	191	3.5	602	8.2	970	8.5

D. APPENDIX D
Tables of Energy Cost Savings and Maximum Acceptable Controller Costs

Table D-1: HVAC Energy Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	136	2.9	158	4.4	148	3.6	221	7.0
3	NIEcon.EH.SSFan.CS1.DCV0	119	2.6	133	3.7	156	3.8	183	5.8
4	IEcon.DB.SSFan.CS1.DCV0	135	2.9	156	4.3	152	3.7	222	7.1
5	IEcon.EH.SSFan.CS1.DCV0	121	2.6	136	3.8	160	3.9	184	5.9
6	NoEcon.MSFan.CS1.DCV0	866	18.7	820	22.8	847	20.5	744	23.6
7	NIEcon.DB.MSFan.CS1.DCV0	939	20.2	891	24.8	924	22.3	847	26.9
8	NIEcon.EH.MSFan.CS1.DCV0	927	20.0	883	24.6	925	22.4	832	26.4
9	IEcon.DB.MSFan.CS1.DCV0	930	20.0	886	24.6	930	22.5	847	26.9
10	IEcon.EH.MSFan.CS1.DCV0	932	20.1	887	24.7	930	22.5	835	26.5
11	NoEcon.MSFan.CS2.DCV0	1355	29.2	1126	31.3	1269	30.7	950	30.2
12	IEcon.DB.MSFan.CS2.DCV0	1358	29.3	1140	31.7	1315	31.8	990	31.5
13	IEcon.EH.MSFan.CS2.DCV0	1402	30.2	1171	32.6	1317	31.9	1010	32.1
14	NoEcon.SSFan.CS1.DCV1	365	7.9	293	8.1	225	5.4	259	8.2
15	IEcon.DB.SSFan.CS1.DCV1	475	10.2	453	12.6	408	9.9	499	15.9
16	IEcon.EH.SSFan.CS1.DCV1	493	10.6	443	12.3	418	10.1	473	15.0
17	NoEcon.MSFan.CS1.DCV1	1289	27.8	1175	32.7	1138	27.5	1083	34.4
18	IEcon.DB.MSFan.CS1.DCV1	1332	28.7	1245	34.6	1245	30.1	1203	38.2
19	IEcon.EH.MSFan.CS1.DCV1	1364	29.4	1259	35.0	1248	30.2	1203	38.2
20	NoEcon.MSFan.CS2.DCV1	1717	37.0	1444	40.1	1529	37.0	1274	40.5
21	IEcon.DB.MSFan.CS2.DCV1	1705	36.7	1459	40.6	1597	38.6	1327	42.2
22	IEcon.EH.MSFan.CS2.DCV1	1774	38.2	1506	41.9	1597	38.6	1357	43.1

Table D-2: HVAC Energy Cost Savings Compared to Case 1 for the Small Office Building in Climate Zone 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	811	23.7	154	4.4	363	15.4	208	6.0
3	NIEcon.EH.SSFan.CS1.DCV0	652	19.0	157	4.5	356	15.1	169	4.9
4	IEcon.DB.SSFan.CS1.DCV0	838	24.5	159	4.5	371	15.7	205	5.9
5	IEcon.EH.SSFan.CS1.DCV0	663	19.4	162	4.6	362	15.3	173	5.0
6	NoEcon.MSFan.CS1.DCV0	1566	45.7	849	24.2	1170	49.5	884	25.5
7	NIEcon.DB.MSFan.CS1.DCV0	2051	59.9	915	26.1	1370	58.0	971	28.0
8	NIEcon.EH.MSFan.CS1.DCV0	1946	56.8	915	26.1	1365	57.8	962	27.7
9	IEcon.DB.MSFan.CS1.DCV0	2083	60.8	920	26.2	1380	58.4	966	27.8
10	IEcon.EH.MSFan.CS1.DCV0	1965	57.4	921	26.2	1374	58.2	966	27.8
11	NoEcon.MSFan.CS2.DCV0	1867	54.5	1120	31.9	1285	54.4	1056	30.4
12	IEcon.DB.MSFan.CS2.DCV0	2168	63.3	1159	33.0	1417	60.0	1092	31.5
13	IEcon.EH.MSFan.CS2.DCV0	2159	63.0	1158	33.0	1417	60.0	1108	31.9
14	NoEcon.SSFan.CS1.DCV1	-48	-1.4	183	5.2	-7	-0.3	355	10.2
15	IEcon.DB.SSFan.CS1.DCV1	867	25.3	381	10.8	483	20.5	594	17.1
16	IEcon.EH.SSFan.CS1.DCV1	691	20.2	383	10.9	471	20.0	570	16.4
17	NoEcon.MSFan.CS1.DCV1	1531	44.7	1102	31.4	1226	51.9	1346	38.8
18	IEcon.DB.MSFan.CS1.DCV1	2125	62.0	1204	34.3	1537	65.0	1453	41.9
19	IEcon.EH.MSFan.CS1.DCV1	2003	58.5	1204	34.3	1529	64.7	1462	42.1
20	NoEcon.MSFan.CS2.DCV1	1831	53.5	1369	39.0	1357	57.5	1501	43.3
21	IEcon.DB.MSFan.CS2.DCV1	2211	64.6	1431	40.8	1573	66.6	1557	44.9
22	IEcon.EH.MSFan.CS2.DCV1	2203	64.3	1428	40.7	1573	66.6	1583	45.6

Table D-3: HVAC Energy Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 4B, 4C and 5

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	174	7.0	145	7.6	159	5.0	167	6.5
3	NIEcon.EH.SSFan.CS1.DCV0	155	6.2	137	7.2	117	3.7	147	5.7
4	IEcon.DB.SSFan.CS1.DCV0	179	7.2	148	7.7	162	5.1	171	6.6
5	IEcon.EH.SSFan.CS1.DCV0	157	6.4	139	7.3	117	3.7	147	5.7
6	NoEcon.MSFan.CS1.DCV0	744	30.1	433	22.6	621	19.6	818	31.6
7	NIEcon.DB.MSFan.CS1.DCV0	827	33.4	505	26.4	687	21.7	884	34.2
8	NIEcon.EH.MSFan.CS1.DCV0	818	33.0	501	26.1	671	21.2	877	33.9
9	IEcon.DB.MSFan.CS1.DCV0	833	33.6	509	26.6	690	21.8	888	34.3
10	IEcon.EH.MSFan.CS1.DCV0	822	33.2	504	26.3	673	21.2	879	34.0
11	NoEcon.MSFan.CS2.DCV0	921	37.2	487	25.4	742	23.4	951	36.7
12	IEcon.DB.MSFan.CS2.DCV0	970	39.2	533	27.8	775	24.4	988	38.2
13	IEcon.EH.MSFan.CS2.DCV0	969	39.1	533	27.8	778	24.5	986	38.1
14	NoEcon.SSFan.CS1.DCV1	133	5.4	247	12.9	412	13.0	178	6.9
15	IEcon.DB.SSFan.CS1.DCV1	344	13.9	444	23.2	599	18.9	391	15.1
16	IEcon.EH.SSFan.CS1.DCV1	322	13.0	433	22.6	556	17.5	362	14.0
17	NoEcon.MSFan.CS1.DCV1	946	38.2	783	40.9	1139	35.9	1085	41.9
18	IEcon.DB.MSFan.CS1.DCV1	1061	42.8	900	46.9	1227	38.7	1188	45.9
19	IEcon.EH.MSFan.CS1.DCV1	1049	42.4	894	46.6	1213	38.3	1177	45.4
20	NoEcon.MSFan.CS2.DCV1	1111	44.9	843	44.0	1252	39.5	1218	47.1
21	IEcon.DB.MSFan.CS2.DCV1	1182	47.7	923	48.1	1301	41.0	1279	49.4
22	IEcon.EH.MSFan.CS2.DCV1	1181	47.7	923	48.1	1307	41.2	1276	49.3

Table D-4: HVAC Energy Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	164	5.5	149	5.2	138	4.6	252	4.2
3	NIEcon.EH.SSFan.CS1.DCV0	138	4.6	139	4.8	119	4.0	245	4.0
4	IEcon.DB.SSFan.CS1.DCV0	167	5.6	151	5.3	139	4.6	255	4.2
5	IEcon.EH.SSFan.CS1.DCV0	138	4.6	139	4.8	120	4.0	245	4.0
6	NoEcon.MSFan.CS1.DCV0	651	21.8	677	23.5	619	20.5	1286	21.2
7	NIEcon.DB.MSFan.CS1.DCV0	724	24.3	739	25.7	687	22.8	1421	23.4
8	NIEcon.EH.MSFan.CS1.DCV0	715	24.0	736	25.6	679	22.5	1417	23.4
9	IEcon.DB.MSFan.CS1.DCV0	728	24.4	742	25.8	689	22.9	1425	23.5
10	IEcon.EH.MSFan.CS1.DCV0	717	24.1	738	25.7	680	22.6	1421	23.4
11	NoEcon.MSFan.CS2.DCV0	755	25.3	768	26.7	678	22.5	1376	22.7
12	IEcon.DB.MSFan.CS2.DCV0	791	26.5	804	28.0	716	23.8	1457	24.0
13	IEcon.EH.MSFan.CS2.DCV0	797	26.7	804	28.0	716	23.8	1457	24.0
14	NoEcon.SSFan.CS1.DCV1	377	12.7	317	11.0	395	13.1	699	11.5
15	IEcon.DB.SSFan.CS1.DCV1	574	19.3	514	17.9	581	19.3	1003	16.5
16	IEcon.EH.SSFan.CS1.DCV1	549	18.4	500	17.4	560	18.6	992	16.4
17	NoEcon.MSFan.CS1.DCV1	1120	37.6	1117	38.9	1136	37.7	2153	35.5
18	IEcon.DB.MSFan.CS1.DCV1	1222	41.0	1215	42.3	1240	41.1	2362	39.0
19	IEcon.EH.MSFan.CS1.DCV1	1214	40.7	1210	42.1	1231	40.8	2357	38.9
20	NoEcon.MSFan.CS2.DCV1	1222	41.0	1209	42.1	1199	39.8	2256	37.2
21	IEcon.DB.MSFan.CS2.DCV1	1280	42.9	1272	44.3	1264	41.9	2393	39.5
22	IEcon.EH.MSFan.CS2.DCV1	1289	43.2	1271	44.2	1266	42.0	2393	39.5

Table D-5: HVAC Energy Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	779	2.9	591	2.6	374	1.6	617	2.7
3	NIEcon.EH.SSFan.CS1.DCV0	461	1.7	392	1.7	415	1.8	477	2.1
4	IEcon.DB.SSFan.CS1.DCV0	772	2.9	592	2.6	383	1.6	625	2.7
5	IEcon.EH.SSFan.CS1.DCV0	481	1.8	406	1.8	424	1.8	490	2.1
6	NoEcon.MSFan.CS1.DCV0	4302	16.1	3816	16.9	3888	16.4	3528	15.2
7	NIEcon.DB.MSFan.CS1.DCV0	4603	17.2	4009	17.7	4001	16.9	3711	16.0
8	NIEcon.EH.MSFan.CS1.DCV0	4451	16.6	3924	17.4	4028	17.0	3655	15.7
9	IEcon.DB.MSFan.CS1.DCV0	4598	17.2	4009	17.7	4015	17.0	3722	16.0
10	IEcon.EH.MSFan.CS1.DCV0	4480	16.7	3940	17.4	4039	17.1	3676	15.8
11	NoEcon.MSFan.CS2.DCV0	6679	24.9	5244	23.2	5575	23.6	4574	19.7
12	IEcon.DB.MSFan.CS2.DCV0	6899	25.8	5362	23.7	5622	23.8	4685	20.1
13	IEcon.EH.MSFan.CS2.DCV0	6833	25.5	5341	23.6	5636	23.8	4673	20.1
14	NoEcon.SSFan.CS1.DCV1	3586	13.4	3699	16.4	3729	15.8	4459	19.2
15	IEcon.DB.SSFan.CS1.DCV1	4122	15.4	4139	18.3	4045	17.1	4887	21.0
16	IEcon.EH.SSFan.CS1.DCV1	3887	14.5	3999	17.7	4089	17.3	4790	20.6
17	NoEcon.MSFan.CS1.DCV1	8241	30.8	7958	35.2	8263	34.9	8531	36.7
18	IEcon.DB.MSFan.CS1.DCV1	8516	31.8	8179	36.2	8424	35.6	8757	37.7
19	IEcon.EH.MSFan.CS1.DCV1	8420	31.4	8125	35.9	8436	35.7	8712	37.5
20	NoEcon.MSFan.CS2.DCV1	10310	38.5	9276	41.0	9888	41.8	9406	40.4
21	IEcon.DB.MSFan.CS2.DCV1	10476	39.1	9403	41.6	9964	42.1	9530	41.0
22	IEcon.EH.MSFan.CS2.DCV1	10453	39.0	9395	41.6	9960	42.1	9529	41.0

Table D-6: HVAC Energy Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zone 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2213	13.2	305	1.4	636	4.1	516	1.8
3	NIEcon.EH.SSFan.CS1.DCV0	1891	11.3	326	1.5	637	4.1	401	1.4
4	IEcon.DB.SSFan.CS1.DCV0	2311	13.8	314	1.5	662	4.3	525	1.9
5	IEcon.EH.SSFan.CS1.DCV0	1972	11.8	333	1.5	664	4.3	417	1.5
6	NoEcon.MSFan.CS1.DCV0	7033	42.1	3707	17.2	5192	33.7	4188	14.8
7	NIEcon.DB.MSFan.CS1.DCV0	8060	48.2	3802	17.7	5433	35.3	4337	15.4
8	NIEcon.EH.MSFan.CS1.DCV0	7832	46.8	3808	17.7	5433	35.3	4290	15.2
9	IEcon.DB.MSFan.CS1.DCV0	8177	48.9	3811	17.7	5466	35.5	4344	15.4
10	IEcon.EH.MSFan.CS1.DCV0	7945	47.5	3819	17.8	5465	35.5	4309	15.3
11	NoEcon.MSFan.CS2.DCV0	7937	47.5	4708	21.9	5463	35.5	5058	17.9
12	IEcon.DB.MSFan.CS2.DCV0	8680	51.9	4756	22.1	5617	36.5	5154	18.3
13	IEcon.EH.MSFan.CS2.DCV0	8613	51.5	4766	22.2	5625	36.5	5146	18.2
14	NoEcon.SSFan.CS1.DCV1	1689	10.1	3649	17.0	2705	17.6	5998	21.3
15	IEcon.DB.SSFan.CS1.DCV1	3401	20.3	3950	18.4	3318	21.5	6375	22.6
16	IEcon.EH.SSFan.CS1.DCV1	3098	18.5	3971	18.5	3315	21.5	6303	22.3
17	NoEcon.MSFan.CS1.DCV1	8194	49.0	8013	37.3	7950	51.6	10970	38.9
18	IEcon.DB.MSFan.CS1.DCV1	9608	57.4	8170	38.0	8405	54.6	11149	39.5
19	IEcon.EH.MSFan.CS1.DCV1	9338	55.8	8173	38.0	8404	54.6	11119	39.4
20	NoEcon.MSFan.CS2.DCV1	9179	54.9	8959	41.7	8246	53.6	11723	41.5
21	IEcon.DB.MSFan.CS2.DCV1	10118	60.5	9042	42.0	8566	55.6	11827	41.9
22	IEcon.EH.MSFan.CS2.DCV1	10031	60.0	9042	42.0	8571	55.7	11834	41.9

Table D-7: HVAC Energy Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 4B, 4C and 5

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	352	2.0	232	1.2	456	1.5	372	1.7
3	NIEcon.EH.SSFan.CS1.DCV0	335	1.9	225	1.2	355	1.2	357	1.7
4	IEcon.DB.SSFan.CS1.DCV0	364	2.0	243	1.3	465	1.6	380	1.8
5	IEcon.EH.SSFan.CS1.DCV0	344	1.9	234	1.3	362	1.2	362	1.7
6	NoEcon.MSFan.CS1.DCV0	3487	19.4	1819	9.8	3134	10.7	3985	18.5
7	NIEcon.DB.MSFan.CS1.DCV0	3590	20.0	1894	10.2	3260	11.1	4070	18.9
8	NIEcon.EH.MSFan.CS1.DCV0	3584	19.9	1893	10.2	3226	11.0	4069	18.9
9	IEcon.DB.MSFan.CS1.DCV0	3606	20.1	1906	10.2	3274	11.1	4078	18.9
10	IEcon.EH.MSFan.CS1.DCV0	3599	20.0	1902	10.2	3238	11.0	4075	18.9
11	NoEcon.MSFan.CS2.DCV0	4270	23.8	1977	10.6	3785	12.9	4540	21.1
12	IEcon.DB.MSFan.CS2.DCV0	4325	24.1	2025	10.9	3846	13.1	4577	21.2
13	IEcon.EH.MSFan.CS2.DCV0	4344	24.2	2028	10.9	3848	13.1	4580	21.3
14	NoEcon.SSFan.CS1.DCV1	3066	17.1	5791	31.1	6588	22.4	3952	18.4
15	IEcon.DB.SSFan.CS1.DCV1	3378	18.8	6012	32.3	6902	23.5	4272	19.8
16	IEcon.EH.SSFan.CS1.DCV1	3365	18.7	6002	32.2	6815	23.2	4257	19.8
17	NoEcon.MSFan.CS1.DCV1	7068	39.3	7764	41.7	10610	36.1	8635	40.1
18	IEcon.DB.MSFan.CS1.DCV1	7232	40.3	7903	42.4	10825	36.8	8790	40.8
19	IEcon.EH.MSFan.CS1.DCV1	7219	40.2	7899	42.4	10786	36.7	8774	40.7
20	NoEcon.MSFan.CS2.DCV1	7772	43.3	7920	42.5	11186	38.0	9185	42.6
21	IEcon.DB.MSFan.CS2.DCV1	7856	43.7	8011	43.0	11289	38.4	9245	42.9
22	IEcon.EH.MSFan.CS2.DCV1	7864	43.8	8015	43.0	11292	38.4	9233	42.9

Table D-8: HVAC Energy Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	501	1.8	414	1.4	395	1.2	2273	3.5
3	NIEcon.EH.SSFan.CS1.DCV0	428	1.5	413	1.4	364	1.1	2264	3.5
4	IEcon.DB.SSFan.CS1.DCV0	512	1.8	417	1.4	399	1.3	2274	3.5
5	IEcon.EH.SSFan.CS1.DCV0	434	1.5	416	1.4	366	1.2	2262	3.5
6	NoEcon.MSFan.CS1.DCV0	3685	13.0	3471	12.0	3244	10.2	7591	11.6
7	NIEcon.DB.MSFan.CS1.DCV0	3896	13.7	3663	12.7	3513	11.1	10164	15.6
8	NIEcon.EH.MSFan.CS1.DCV0	3871	13.6	3667	12.7	3506	11.1	10167	15.6
9	IEcon.DB.MSFan.CS1.DCV0	3907	13.8	3669	12.7	3517	11.1	10168	15.6
10	IEcon.EH.MSFan.CS1.DCV0	3878	13.7	3673	12.7	3509	11.1	10164	15.6
11	NoEcon.MSFan.CS2.DCV0	4287	15.1	3907	13.5	3556	11.2	9671	14.8
12	IEcon.DB.MSFan.CS2.DCV0	4370	15.4	4001	13.8	3674	11.6	10309	15.8
13	IEcon.EH.MSFan.CS2.DCV0	4369	15.4	4002	13.8	3675	11.6	10300	15.8
14	NoEcon.SSFan.CS1.DCV1	5816	20.5	6058	20.9	6848	21.6	12338	18.9
15	IEcon.DB.SSFan.CS1.DCV1	6164	21.7	6326	21.9	7181	22.7	13192	20.2
16	IEcon.EH.SSFan.CS1.DCV1	6103	21.5	6323	21.9	7153	22.6	13186	20.2
17	NoEcon.MSFan.CS1.DCV1	10425	36.7	10593	36.6	11337	35.8	20702	31.7
18	IEcon.DB.MSFan.CS1.DCV1	10716	37.8	10913	37.7	11694	36.9	23657	36.3
19	IEcon.EH.MSFan.CS1.DCV1	10691	37.7	10912	37.7	11682	36.9	23656	36.3
20	NoEcon.MSFan.CS2.DCV1	10989	38.7	11082	38.3	11706	36.9	23231	35.6
21	IEcon.DB.MSFan.CS2.DCV1	11094	39.1	11213	38.8	11820	37.3	23790	36.5
22	IEcon.EH.MSFan.CS2.DCV1	11093	39.1	11206	38.7	11819	37.3	23779	36.5

Table D-9: HVAC Energy Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	1087	3.6	703	3.1	466	2.0	754	3.3
3	NIEcon.EH.SSFan.CS1.DCV0	621	2.1	487	2.2	535	2.2	604	2.6
4	IEcon.DB.SSFan.CS1.DCV0	1129	3.8	717	3.2	478	2.0	772	3.4
5	IEcon.EH.SSFan.CS1.DCV0	641	2.1	500	2.2	547	2.3	620	2.7
6	NoEcon.MSFan.CS1.DCV0	4977	16.6	3900	17.3	3923	16.5	3490	15.3
7	NIEcon.DB.MSFan.CS1.DCV0	5485	18.3	4160	18.5	4080	17.1	3775	16.6
8	NIEcon.EH.MSFan.CS1.DCV0	5248	17.5	4071	18.1	4131	17.3	3705	16.3
9	IEcon.DB.MSFan.CS1.DCV0	5528	18.5	4177	18.5	4095	17.2	3796	16.7
10	IEcon.EH.MSFan.CS1.DCV0	5279	17.6	4089	18.1	4148	17.4	3726	16.3
11	NoEcon.MSFan.CS2.DCV0	7828	26.2	5436	24.1	5668	23.8	4622	20.3
12	IEcon.DB.MSFan.CS2.DCV0	8112	27.1	5589	24.8	5734	24.1	4774	20.9
13	IEcon.EH.MSFan.CS2.DCV0	8046	26.9	5561	24.7	5760	24.2	4767	20.9
14	NoEcon.SSFan.CS1.DCV1	3835	12.8	3769	16.7	3778	15.9	4566	20.0
15	IEcon.DB.SSFan.CS1.DCV1	4564	15.2	4141	18.4	3936	16.5	4873	21.4
16	IEcon.EH.SSFan.CS1.DCV1	4127	13.8	3982	17.7	4014	16.8	4760	20.9
17	NoEcon.MSFan.CS1.DCV1	9111	30.4	8073	35.8	8250	34.6	8574	37.6
18	IEcon.DB.MSFan.CS1.DCV1	9625	32.2	8328	36.9	8352	35.1	8823	38.7
19	IEcon.EH.MSFan.CS1.DCV1	9331	31.2	8232	36.5	8397	35.2	8753	38.4
20	NoEcon.MSFan.CS2.DCV1	11685	39.0	9446	41.9	9864	41.4	9484	41.6
21	IEcon.DB.MSFan.CS2.DCV1	11875	39.7	9560	42.4	9878	41.5	9582	42.0
22	IEcon.EH.MSFan.CS2.DCV1	11807	39.4	9530	42.3	9896	41.5	9570	42.0

Table D-10: HVAC Energy Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zone 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2932	15.4	443	2.0	980	6.3	630	2.3
3	NIEcon.EH.SSFan.CS1.DCV0	2551	13.4	483	2.2	979	6.3	498	1.8
4	IEcon.DB.SSFan.CS1.DCV0	3061	16.1	453	2.1	1015	6.6	642	2.3
5	IEcon.EH.SSFan.CS1.DCV0	2652	13.9	492	2.3	1013	6.5	514	1.8
6	NoEcon.MSFan.CS1.DCV0	7633	40.1	3951	18.2	5223	33.7	3917	14.0
7	NIEcon.DB.MSFan.CS1.DCV0	9129	48.0	4096	18.9	5619	36.3	4151	14.9
8	NIEcon.EH.MSFan.CS1.DCV0	8861	46.6	4126	19.0	5619	36.3	4088	14.6
9	IEcon.DB.MSFan.CS1.DCV0	9296	48.9	4109	18.9	5668	36.6	4165	14.9
10	IEcon.EH.MSFan.CS1.DCV0	9007	47.4	4138	19.1	5668	36.6	4111	14.7
11	NoEcon.MSFan.CS2.DCV0	8845	46.5	5070	23.4	5587	36.1	4858	17.4
12	IEcon.DB.MSFan.CS2.DCV0	9797	51.5	5134	23.7	5851	37.8	4990	17.9
13	IEcon.EH.MSFan.CS2.DCV0	9751	51.3	5147	23.7	5858	37.8	4982	17.8
14	NoEcon.SSFan.CS1.DCV1	2901	15.3	3730	17.2	3166	20.5	6044	21.6
15	IEcon.DB.SSFan.CS1.DCV1	4140	21.8	3856	17.8	3398	22.0	6339	22.7
16	IEcon.EH.SSFan.CS1.DCV1	3848	20.2	3902	18.0	3397	21.9	6254	22.4
17	NoEcon.MSFan.CS1.DCV1	9364	49.2	8247	38.0	8425	54.4	10793	38.7
18	IEcon.DB.MSFan.CS1.DCV1	10888	57.2	8336	38.4	8827	57.0	11006	39.4
19	IEcon.EH.MSFan.CS1.DCV1	10568	55.6	8360	38.5	8826	57.0	10950	39.2
20	NoEcon.MSFan.CS2.DCV1	10705	56.3	9248	42.6	8829	57.0	11595	41.5
21	IEcon.DB.MSFan.CS2.DCV1	11372	59.8	9264	42.7	9011	58.2	11674	41.8
22	IEcon.EH.MSFan.CS2.DCV1	11296	59.4	9273	42.7	9018	58.3	11677	41.8

Table D-11: HVAC Energy Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 4 and 4B, 4C and 5

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	440	2.5	340	1.8	553	1.9	460	2.2
3	NIEcon.EH.SSFan.CS1.DCV0	425	2.4	327	1.7	443	1.5	452	2.2
4	IEcon.DB.SSFan.CS1.DCV0	454	2.6	355	1.9	569	1.9	469	2.2
5	IEcon.EH.SSFan.CS1.DCV0	432	2.5	340	1.8	454	1.6	456	2.2
6	NoEcon.MSFan.CS1.DCV0	3258	18.6	1426	7.6	2935	10.0	3705	17.6
7	NIEcon.DB.MSFan.CS1.DCV0	3416	19.5	1551	8.3	3122	10.7	3842	18.3
8	NIEcon.EH.MSFan.CS1.DCV0	3417	19.5	1546	8.3	3076	10.5	3845	18.3
9	IEcon.DB.MSFan.CS1.DCV0	3433	19.6	1571	8.4	3141	10.7	3854	18.3
10	IEcon.EH.MSFan.CS1.DCV0	3430	19.6	1564	8.4	3090	10.6	3852	18.3
11	NoEcon.MSFan.CS2.DCV0	4077	23.3	1624	8.7	3625	12.4	4349	20.7
12	IEcon.DB.MSFan.CS2.DCV0	4146	23.7	1702	9.1	3716	12.7	4399	20.9
13	IEcon.EH.MSFan.CS2.DCV0	4166	23.8	1707	9.1	3714	12.7	4402	20.9
14	NoEcon.SSFan.CS1.DCV1	3151	18.0	5761	30.8	6625	22.6	4027	19.1
15	IEcon.DB.SSFan.CS1.DCV1	3342	19.1	5880	31.4	6855	23.4	4202	20.0
16	IEcon.EH.SSFan.CS1.DCV1	3336	19.1	5868	31.4	6769	23.1	4203	20.0
17	NoEcon.MSFan.CS1.DCV1	6878	39.3	7880	42.1	10612	36.2	8482	40.3
18	IEcon.DB.MSFan.CS1.DCV1	7010	40.1	8009	42.8	10779	36.8	8594	40.8
19	IEcon.EH.MSFan.CS1.DCV1	7003	40.0	8000	42.8	10728	36.6	8589	40.8
20	NoEcon.MSFan.CS2.DCV1	7580	43.3	8075	43.2	11183	38.2	9087	43.2
21	IEcon.DB.MSFan.CS2.DCV1	7615	43.5	8125	43.4	11234	38.4	9107	43.3
22	IEcon.EH.MSFan.CS2.DCV1	7633	43.6	8130	43.5	11229	38.4	9095	43.2

Table D-12: HVAC Energy Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	680	2.4	581	2.0	663	2.1	2899	4.4
3	NIEcon.EH.SSFan.CS1.DCV0	593	2.1	578	2.0	620	2.0	2895	4.4
4	IEcon.DB.SSFan.CS1.DCV0	692	2.4	586	2.0	667	2.1	2901	4.4
5	IEcon.EH.SSFan.CS1.DCV0	595	2.1	580	2.0	620	2.0	2892	4.4
6	NoEcon.MSFan.CS1.DCV0	3542	12.5	3337	11.5	3180	10.0	7653	11.7
7	NIEcon.DB.MSFan.CS1.DCV0	3843	13.5	3599	12.4	3571	11.3	10492	16.1
8	NIEcon.EH.MSFan.CS1.DCV0	3810	13.4	3604	12.4	3556	11.2	10495	16.1
9	IEcon.DB.MSFan.CS1.DCV0	3856	13.6	3607	12.4	3577	11.3	10497	16.1
10	IEcon.EH.MSFan.CS1.DCV0	3817	13.4	3608	12.4	3559	11.2	10500	16.1
11	NoEcon.MSFan.CS2.DCV0	4235	14.9	3898	13.4	3625	11.4	9991	15.3
12	IEcon.DB.MSFan.CS2.DCV0	4340	15.3	4020	13.9	3758	11.8	10656	16.3
13	IEcon.EH.MSFan.CS2.DCV0	4336	15.3	4019	13.9	3755	11.8	10654	16.3
14	NoEcon.SSFan.CS1.DCV1	5991	21.1	6296	21.7	7137	22.5	13533	20.7
15	IEcon.DB.SSFan.CS1.DCV1	6176	21.7	6411	22.1	7232	22.8	13579	20.8
16	IEcon.EH.SSFan.CS1.DCV1	6100	21.5	6410	22.1	7203	22.7	13583	20.8
17	NoEcon.MSFan.CS1.DCV1	10459	36.8	10757	37.1	11457	36.1	19358	29.7
18	IEcon.DB.MSFan.CS1.DCV1	10686	37.6	10929	37.7	11729	37.0	23271	35.7
19	IEcon.EH.MSFan.CS1.DCV1	10642	37.5	10931	37.7	11713	36.9	23271	35.7
20	NoEcon.MSFan.CS2.DCV1	11011	38.8	11235	38.8	11783	37.1	23142	35.5
21	IEcon.DB.MSFan.CS2.DCV1	11076	39.0	11311	39.0	11886	37.5	23420	35.9
22	IEcon.EH.MSFan.CS2.DCV1	11064	38.9	11304	39.0	11881	37.4	23414	35.9

Table D-13: HVAC Energy Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	797	2.3	908	2.1	745	1.6	1277	2.2
3	NIEcon.EH.SSFan.CS1.DCV0	415	1.2	613	1.4	744	1.6	1009	1.7
4	IEcon.DB.SSFan.CS1.DCV0	790	2.2	912	2.1	758	1.6	1287	2.2
5	IEcon.EH.SSFan.CS1.DCV0	421	1.2	615	1.4	754	1.6	1009	1.7
6	NoEcon.MSFan.CS1.DCV0	11116	31.6	12980	29.7	10661	23.0	11170	19.3
7	NIEcon.DB.MSFan.CS1.DCV0	11553	32.9	13542	31.0	11208	24.2	12066	20.9
8	NIEcon.EH.MSFan.CS1.DCV0	11341	32.3	13409	30.7	11213	24.2	11939	20.7
9	IEcon.DB.MSFan.CS1.DCV0	11539	32.8	13541	31.0	11222	24.2	12077	20.9
10	IEcon.EH.MSFan.CS1.DCV0	11351	32.3	13416	30.7	11228	24.2	11946	20.7
11	NoEcon.MSFan.CS2.DCV0	13909	39.6	15502	35.5	13205	28.5	12934	22.4
12	IEcon.DB.MSFan.CS2.DCV0	14182	40.3	15769	36.1	13428	29.0	13289	23.0
13	IEcon.EH.MSFan.CS2.DCV0	14059	40.0	15711	36.0	13433	29.0	13254	23.0
14	NoEcon.SSFan.CS1.DCV1	3959	11.3	5541	12.7	6568	14.2	8271	14.3
15	IEcon.DB.SSFan.CS1.DCV1	4756	13.5	6466	14.8	7328	15.8	9576	16.6
16	IEcon.EH.SSFan.CS1.DCV1	4379	12.5	6146	14.1	7323	15.8	9267	16.0
17	NoEcon.MSFan.CS1.DCV1	15435	43.9	19461	44.5	18043	39.0	20171	34.9
18	IEcon.DB.MSFan.CS1.DCV1	15837	45.0	20002	45.8	18581	40.1	21038	36.4
19	IEcon.EH.MSFan.CS1.DCV1	15662	44.6	19876	45.5	18585	40.1	20901	36.2
20	NoEcon.MSFan.CS2.DCV1	17748	50.5	21293	48.7	20052	43.3	21643	37.5
21	IEcon.DB.MSFan.CS2.DCV1	18005	51.2	21544	49.3	20270	43.8	21976	38.1
22	IEcon.EH.MSFan.CS2.DCV1	17897	50.9	21494	49.2	20275	43.8	21945	38.0

Table D-14: HVAC Energy Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zone 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2616	6.7	860	1.6	1312	2.6	1261	1.7
3	NIEcon.EH.SSFan.CS1.DCV0	2164	5.5	864	1.7	1296	2.6	1023	1.4
4	IEcon.DB.SSFan.CS1.DCV0	2687	6.8	874	1.7	1333	2.7	1263	1.7
5	IEcon.EH.SSFan.CS1.DCV0	2209	5.6	876	1.7	1316	2.6	1027	1.4
6	NoEcon.MSFan.CS1.DCV0	15498	39.5	12497	23.9	13240	26.4	14923	20.3
7	NIEcon.DB.MSFan.CS1.DCV0	17048	43.4	13101	25.0	14097	28.1	15926	21.6
8	NIEcon.EH.MSFan.CS1.DCV0	16835	42.9	13103	25.0	14087	28.1	15822	21.5
9	IEcon.DB.MSFan.CS1.DCV0	17132	43.6	13118	25.1	14128	28.2	15931	21.6
10	IEcon.EH.MSFan.CS1.DCV0	16896	43.0	13120	25.1	14114	28.2	15834	21.5
11	NoEcon.MSFan.CS2.DCV0	16654	42.4	14377	27.5	13789	27.5	16652	22.6
12	IEcon.DB.MSFan.CS2.DCV0	17541	44.7	14643	28.0	14287	28.5	17025	23.1
13	IEcon.EH.MSFan.CS2.DCV0	17494	44.6	14647	28.0	14287	28.5	16999	23.1
14	NoEcon.SSFan.CS1.DCV1	3181	8.1	6865	13.1	6505	13.0	10646	14.5
15	IEcon.DB.SSFan.CS1.DCV1	6017	15.3	7735	14.8	7839	15.6	11915	16.2
16	IEcon.EH.SSFan.CS1.DCV1	5357	13.6	7738	14.8	7817	15.6	11644	15.8
17	NoEcon.MSFan.CS1.DCV1	19502	49.7	20003	38.2	20787	41.5	26687	36.2
18	IEcon.DB.MSFan.CS1.DCV1	21120	53.8	20614	39.4	21645	43.2	27656	37.6
19	IEcon.EH.MSFan.CS1.DCV1	20879	53.2	20614	39.4	21629	43.2	27547	37.4
20	NoEcon.MSFan.CS2.DCV1	20666	52.6	21611	41.3	21311	42.5	28087	38.1
21	IEcon.DB.MSFan.CS2.DCV1	21523	54.8	21877	41.8	21791	43.5	28452	38.6
22	IEcon.EH.MSFan.CS2.DCV1	21498	54.8	21879	41.8	21789	43.5	28426	38.6

Table D-15: HVAC Energy Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 4B, 4C and 5

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	966	1.9	775	1.3	1187	1.5	1076	1.7
3	NIEcon.EH.SSFan.CS1.DCV0	876	1.7	752	1.3	979	1.3	1010	1.6
4	IEcon.DB.SSFan.CS1.DCV0	982	1.9	785	1.4	1202	1.5	1087	1.7
5	IEcon.EH.SSFan.CS1.DCV0	884	1.7	759	1.3	984	1.3	1012	1.6
6	NoEcon.MSFan.CS1.DCV0	12357	24.2	3725	6.5	10448	13.4	13301	21.1
7	NIEcon.DB.MSFan.CS1.DCV0	13010	25.5	4370	7.6	11545	14.8	14064	22.3
8	NIEcon.EH.MSFan.CS1.DCV0	12965	25.4	4355	7.6	11458	14.7	14031	22.2
9	IEcon.DB.MSFan.CS1.DCV0	13032	25.5	4384	7.6	11562	14.8	14082	22.3
10	IEcon.EH.MSFan.CS1.DCV0	12977	25.4	4365	7.6	11463	14.7	14041	22.3
11	NoEcon.MSFan.CS2.DCV0	13729	26.9	4226	7.4	11898	15.3	14305	22.7
12	IEcon.DB.MSFan.CS2.DCV0	14013	27.4	4495	7.8	12206	15.7	14645	23.2
13	IEcon.EH.MSFan.CS2.DCV0	14005	27.4	4491	7.8	12179	15.6	14642	23.2
14	NoEcon.SSFan.CS1.DCV1	6116	12.0	11164	19.4	11842	15.2	7702	12.2
15	IEcon.DB.SSFan.CS1.DCV1	7101	13.9	11942	20.8	13433	17.2	8912	14.1
16	IEcon.EH.SSFan.CS1.DCV1	6983	13.7	11910	20.7	13126	16.9	8807	14.0
17	NoEcon.MSFan.CS1.DCV1	18985	37.2	15371	26.8	22995	29.5	21425	34.0
18	IEcon.DB.MSFan.CS1.DCV1	19619	38.4	15993	27.8	24635	31.6	22342	35.4
19	IEcon.EH.MSFan.CS1.DCV1	19560	38.3	15969	27.8	24384	31.3	22282	35.3
20	NoEcon.MSFan.CS2.DCV1	20106	39.4	15833	27.6	24638	31.6	22446	35.6
21	IEcon.DB.MSFan.CS2.DCV1	20374	39.9	16093	28.0	25180	32.3	22853	36.2
22	IEcon.EH.MSFan.CS2.DCV1	20366	39.9	16087	28.0	25120	32.2	22846	36.2

Table D-16: HVAC Energy Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	1565	2.1	1664	2.0	1758	2.1	5459	3.4
3	NIEcon.EH.SSFan.CS1.DCV0	1415	1.9	1626	2.0	1681	2.0	5426	3.3
4	IEcon.DB.SSFan.CS1.DCV0	1577	2.1	1666	2.0	1766	2.1	5459	3.4
5	IEcon.EH.SSFan.CS1.DCV0	1416	1.9	1627	2.0	1682	2.0	5417	3.3
6	NoEcon.MSFan.CS1.DCV0	11485	15.5	9931	12.2	9495	11.3	23186	14.2
7	NIEcon.DB.MSFan.CS1.DCV0	13295	18.0	11840	14.6	11522	13.7	30008	18.4
8	NIEcon.EH.MSFan.CS1.DCV0	13186	17.8	11751	14.4	11399	13.5	29915	18.4
9	IEcon.DB.MSFan.CS1.DCV0	13308	18.0	11846	14.6	11532	13.7	30013	18.4
10	IEcon.EH.MSFan.CS1.DCV0	13191	17.8	11753	14.4	11403	13.6	29917	18.4
11	NoEcon.MSFan.CS2.DCV0	13247	17.9	11330	13.9	10851	12.9	28181	17.3
12	IEcon.DB.MSFan.CS2.DCV0	13806	18.7	12195	15.0	11664	13.9	30175	18.5
13	IEcon.EH.MSFan.CS2.DCV0	13789	18.7	12184	15.0	11639	13.8	30147	18.5
14	NoEcon.SSFan.CS1.DCV1	9792	13.2	10599	13.0	11470	13.6	17581	10.8
15	IEcon.DB.SSFan.CS1.DCV1	12064	16.3	12678	15.6	13919	16.5	24297	14.9
16	IEcon.EH.SSFan.CS1.DCV1	11846	16.0	12622	15.5	13796	16.4	24245	14.9
17	NoEcon.MSFan.CS1.DCV1	22137	30.0	20898	25.7	22166	26.3	42812	26.3
18	IEcon.DB.MSFan.CS1.DCV1	24974	33.8	24244	29.8	25420	30.2	52063	32.0
19	IEcon.EH.MSFan.CS1.DCV1	24604	33.3	23945	29.4	25034	29.8	51709	31.8
20	NoEcon.MSFan.CS2.DCV1	24420	33.0	23111	28.4	24226	28.8	50538	31.0
21	IEcon.DB.MSFan.CS2.DCV1	25399	34.4	24667	30.3	25560	30.4	52277	32.1
22	IEcon.EH.MSFan.CS2.DCV1	25299	34.2	24616	30.3	25465	30.3	52217	32.1

Table D-17: Electricity Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	138	3.0	158	4.7	147	3.7	218	9.0
3	NIEcon.EH.SSFan.CS1.DCV0	121	2.6	133	4.0	155	3.9	181	7.5
4	IEcon.DB.SSFan.CS1.DCV0	137	3.0	156	4.6	151	3.8	220	9.0
5	IEcon.EH.SSFan.CS1.DCV0	124	2.7	136	4.0	159	4.0	182	7.5
6	NoEcon.MSFan.CS1.DCV0	871	18.8	896	26.7	937	23.7	946	39.0
7	NIEcon.DB.MSFan.CS1.DCV0	942	20.3	966	28.8	1011	25.6	1047	43.1
8	NIEcon.EH.MSFan.CS1.DCV0	931	20.1	958	28.5	1012	25.6	1032	42.5
9	IEcon.DB.MSFan.CS1.DCV0	934	20.2	960	28.6	1017	25.7	1047	43.1
10	IEcon.EH.MSFan.CS1.DCV0	936	20.2	961	28.6	1018	25.8	1035	42.6
11	NoEcon.MSFan.CS2.DCV0	1359	29.3	1200	35.8	1355	34.3	1151	47.4
12	IEcon.DB.MSFan.CS2.DCV0	1362	29.4	1214	36.2	1402	35.5	1190	49.0
13	IEcon.EH.MSFan.CS2.DCV0	1406	30.3	1246	37.1	1403	35.5	1209	49.8
14	NoEcon.SSFan.CS1.DCV1	364	7.8	229	6.8	170	4.3	70	2.9
15	IEcon.DB.SSFan.CS1.DCV1	477	10.3	392	11.7	354	8.9	311	12.8
16	IEcon.EH.SSFan.CS1.DCV1	495	10.7	382	11.4	363	9.2	285	11.7
17	NoEcon.MSFan.CS1.DCV1	1289	27.8	1169	34.8	1150	29.1	1048	43.1
18	IEcon.DB.MSFan.CS1.DCV1	1331	28.7	1237	36.9	1253	31.7	1164	47.9
19	IEcon.EH.MSFan.CS1.DCV1	1363	29.4	1251	37.3	1257	31.8	1165	48.0
20	NoEcon.MSFan.CS2.DCV1	1717	37.0	1436	42.8	1538	38.9	1236	50.9
21	IEcon.DB.MSFan.CS2.DCV1	1704	36.8	1451	43.2	1605	40.6	1289	53.0
22	IEcon.EH.MSFan.CS2.DCV1	1774	38.3	1498	44.6	1605	40.6	1319	54.3

Table D-18: Electricity Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	813	24.4	151	4.7	360	17.9	205	8.1
3	NIEcon.EH.SSFan.CS1.DCV0	654	19.7	154	4.8	353	17.5	166	6.5
4	IEcon.DB.SSFan.CS1.DCV0	841	25.3	156	4.9	367	18.2	202	8.0
5	IEcon.EH.SSFan.CS1.DCV0	665	20.0	159	5.0	359	17.8	171	6.7
6	NoEcon.MSFan.CS1.DCV0	1634	49.1	976	30.6	1320	65.4	1106	43.6
7	NIEcon.DB.MSFan.CS1.DCV0	2114	63.6	1038	32.6	1516	75.2	1191	46.9
8	NIEcon.EH.MSFan.CS1.DCV0	2008	60.4	1038	32.6	1512	74.9	1182	46.6
9	IEcon.DB.MSFan.CS1.DCV0	2146	64.5	1043	32.7	1526	75.7	1186	46.7
10	IEcon.EH.MSFan.CS1.DCV0	2028	61.0	1044	32.7	1521	75.4	1187	46.8
11	NoEcon.MSFan.CS2.DCV0	1930	58.1	1243	39.0	1432	71.0	1276	50.3
12	IEcon.DB.MSFan.CS2.DCV0	2230	67.1	1281	40.2	1563	77.5	1312	51.7
13	IEcon.EH.MSFan.CS2.DCV0	2221	66.8	1280	40.2	1564	77.5	1328	52.3
14	NoEcon.SSFan.CS1.DCV1	-73	-2.2	94	3.0	-118	-5.8	66	2.6
15	IEcon.DB.SSFan.CS1.DCV1	848	25.5	289	9.1	369	18.3	303	11.9
16	IEcon.EH.SSFan.CS1.DCV1	671	20.2	291	9.1	358	17.7	279	11.0
17	NoEcon.MSFan.CS1.DCV1	1550	46.6	1106	34.7	1223	60.6	1224	48.2
18	IEcon.DB.MSFan.CS1.DCV1	2138	64.3	1204	37.8	1530	75.9	1329	52.4
19	IEcon.EH.MSFan.CS1.DCV1	2017	60.6	1204	37.8	1523	75.5	1338	52.7
20	NoEcon.MSFan.CS2.DCV1	1845	55.5	1370	43.0	1352	67.0	1377	54.3
21	IEcon.DB.MSFan.CS2.DCV1	2224	66.9	1431	44.9	1566	77.6	1432	56.4
22	IEcon.EH.MSFan.CS2.DCV1	2216	66.7	1429	44.8	1567	77.7	1459	57.5

Table D-19: Electricity Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 4B, 4C, and 5

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	172	8.7	143	13.1	156	8.6	162	8.9
3	NIEcon.EH.SSFan.CS1.DCV0	153	7.7	135	12.4	115	6.3	142	7.8
4	IEcon.DB.SSFan.CS1.DCV0	177	9.0	146	13.4	160	8.7	166	9.1
5	IEcon.EH.SSFan.CS1.DCV0	155	7.9	137	12.5	115	6.3	142	7.8
6	NoEcon.MSFan.CS1.DCV0	885	44.9	716	65.5	905	49.5	1017	55.7
7	NIEcon.DB.MSFan.CS1.DCV0	963	48.8	786	71.9	968	53.0	1079	59.1
8	NIEcon.EH.MSFan.CS1.DCV0	954	48.4	782	71.5	953	52.1	1071	58.7
9	IEcon.DB.MSFan.CS1.DCV0	970	49.2	790	72.2	971	53.2	1082	59.3
10	IEcon.EH.MSFan.CS1.DCV0	958	48.6	785	71.8	954	52.2	1074	58.9
11	NoEcon.MSFan.CS2.DCV0	1059	53.7	768	70.2	1024	56.0	1146	62.8
12	IEcon.DB.MSFan.CS2.DCV0	1106	56.1	814	74.4	1056	57.8	1182	64.8
13	IEcon.EH.MSFan.CS2.DCV0	1105	56.1	814	74.4	1059	58.0	1180	64.7
14	NoEcon.SSFan.CS1.DCV1	5	0.3	-46	-4.2	18	1.0	-20	-1.1
15	IEcon.DB.SSFan.CS1.DCV1	217	11.0	149	13.6	204	11.2	188	10.3
16	IEcon.EH.SSFan.CS1.DCV1	195	9.9	137	12.5	161	8.8	159	8.7
17	NoEcon.MSFan.CS1.DCV1	920	46.7	694	63.5	966	52.9	1035	56.7
18	IEcon.DB.MSFan.CS1.DCV1	1030	52.3	807	73.8	1052	57.6	1133	62.1
19	IEcon.EH.MSFan.CS1.DCV1	1019	51.7	801	73.3	1038	56.8	1121	61.4
20	NoEcon.MSFan.CS2.DCV1	1082	54.9	751	68.7	1078	59.0	1163	63.7
21	IEcon.DB.MSFan.CS2.DCV1	1151	58.4	830	75.9	1126	61.6	1222	67.0
22	IEcon.EH.MSFan.CS2.DCV1	1151	58.4	830	75.9	1133	62.0	1219	66.8

Table D-20: Electricity Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	162	9.6	146	9.1	135	9.3	254	9.2
3	NIEcon.EH.SSFan.CS1.DCV0	136	8.0	136	8.5	117	8.1	247	8.9
4	IEcon.DB.SSFan.CS1.DCV0	165	9.7	148	9.2	137	9.4	257	9.3
5	IEcon.EH.SSFan.CS1.DCV0	136	8.0	136	8.5	118	8.1	247	9.0
6	NoEcon.MSFan.CS1.DCV0	880	51.9	980	61.1	898	61.9	1707	61.9
7	NIEcon.DB.MSFan.CS1.DCV0	952	56.2	1038	64.8	964	66.4	1832	66.4
8	NIEcon.EH.MSFan.CS1.DCV0	943	55.6	1035	64.6	956	65.9	1828	66.3
9	IEcon.DB.MSFan.CS1.DCV0	955	56.4	1042	65.0	966	66.6	1836	66.5
10	IEcon.EH.MSFan.CS1.DCV0	945	55.8	1038	64.7	957	66.0	1832	66.4
11	NoEcon.MSFan.CS2.DCV0	982	58.0	1068	66.7	955	65.8	1787	64.8
12	IEcon.DB.MSFan.CS2.DCV0	1019	60.1	1103	68.9	993	68.5	1868	67.7
13	IEcon.EH.MSFan.CS2.DCV0	1025	60.5	1103	68.8	993	68.5	1868	67.7
14	NoEcon.SSFan.CS1.DCV1	3	0.2	-33	-2.0	-38	-2.6	-73	-2.6
15	IEcon.DB.SSFan.CS1.DCV1	197	11.7	160	10.0	145	10.0	259	9.4
16	IEcon.EH.SSFan.CS1.DCV1	172	10.2	146	9.1	125	8.6	247	9.0
17	NoEcon.MSFan.CS1.DCV1	928	54.8	994	62.0	917	63.2	1737	63.0
18	IEcon.DB.MSFan.CS1.DCV1	1028	60.7	1088	67.9	1016	70.1	1933	70.1
19	IEcon.EH.MSFan.CS1.DCV1	1020	60.2	1083	67.6	1008	69.5	1928	69.9
20	NoEcon.MSFan.CS2.DCV1	1029	60.7	1083	67.6	978	67.4	1830	66.3
21	IEcon.DB.MSFan.CS2.DCV1	1085	64.1	1144	71.4	1041	71.8	1964	71.2
22	IEcon.EH.MSFan.CS2.DCV1	1095	64.6	1143	71.3	1042	71.8	1964	71.2

Table D-21: Electricity Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	777	2.9	588	3.0	369	1.8	611	4.5
3	NIEcon.EH.SSFan.CS1.DCV0	460	1.7	390	2.0	409	2.0	473	3.5
4	IEcon.DB.SSFan.CS1.DCV0	770	2.9	590	3.1	378	1.9	619	4.6
5	IEcon.EH.SSFan.CS1.DCV0	480	1.8	405	2.1	417	2.1	485	3.6
6	NoEcon.MSFan.CS1.DCV0	4408	16.6	4357	22.6	4627	22.8	4928	36.4
7	NIEcon.DB.MSFan.CS1.DCV0	4708	17.7	4546	23.5	4734	23.3	5108	37.7
8	NIEcon.EH.MSFan.CS1.DCV0	4556	17.2	4463	23.1	4759	23.4	5051	37.3
9	IEcon.DB.MSFan.CS1.DCV0	4702	17.7	4547	23.5	4749	23.4	5119	37.8
10	IEcon.EH.MSFan.CS1.DCV0	4585	17.3	4480	23.2	4771	23.5	5072	37.4
11	NoEcon.MSFan.CS2.DCV0	6784	25.6	5783	29.9	6307	31.1	5972	44.1
12	IEcon.DB.MSFan.CS2.DCV0	7004	26.4	5900	30.6	6353	31.3	6081	44.9
13	IEcon.EH.MSFan.CS2.DCV0	6938	26.1	5878	30.4	6365	31.3	6070	44.8
14	NoEcon.SSFan.CS1.DCV1	3448	13.0	2466	12.8	2446	12.0	1108	8.2
15	IEcon.DB.SSFan.CS1.DCV1	3982	15.0	2902	15.0	2754	13.6	1532	11.3
16	IEcon.EH.SSFan.CS1.DCV1	3747	14.1	2763	14.3	2797	13.8	1435	10.6
17	NoEcon.MSFan.CS1.DCV1	8157	30.7	7082	36.7	7450	36.7	6144	45.3
18	IEcon.DB.MSFan.CS1.DCV1	8430	31.8	7301	37.8	7607	37.5	6367	47.0
19	IEcon.EH.MSFan.CS1.DCV1	8334	31.4	7248	37.5	7616	37.5	6322	46.7
20	NoEcon.MSFan.CS2.DCV1	10225	38.5	8399	43.5	9069	44.7	7016	51.8
21	IEcon.DB.MSFan.CS2.DCV1	10390	39.1	8524	44.1	9143	45.0	7139	52.7
22	IEcon.EH.MSFan.CS2.DCV1	10367	39.1	8517	44.1	9137	45.0	7137	52.7

Table D-22: Electricity Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2208	15.3	298	1.8	632	7.1	513	3.6
3	NIEcon.EH.SSFan.CS1.DCV0	1887	13.1	318	2.0	632	7.1	399	2.8
4	IEcon.DB.SSFan.CS1.DCV0	2306	16.0	306	1.9	658	7.4	522	3.7
5	IEcon.EH.SSFan.CS1.DCV0	1968	13.7	325	2.0	659	7.4	414	2.9
6	NoEcon.MSFan.CS1.DCV0	7730	53.7	4600	28.5	5958	66.8	5674	39.7
7	NIEcon.DB.MSFan.CS1.DCV0	8750	60.8	4688	29.1	6196	69.5	5820	40.7
8	NIEcon.EH.MSFan.CS1.DCV0	8523	59.2	4694	29.1	6196	69.5	5774	40.4
9	IEcon.DB.MSFan.CS1.DCV0	8868	61.6	4699	29.1	6229	69.9	5828	40.8
10	IEcon.EH.MSFan.CS1.DCV0	8636	60.0	4706	29.2	6228	69.9	5793	40.5
11	NoEcon.MSFan.CS2.DCV0	8630	60.0	5595	34.7	6228	69.9	6544	45.8
12	IEcon.DB.MSFan.CS2.DCV0	9370	65.1	5642	35.0	6379	71.6	6638	46.4
13	IEcon.EH.MSFan.CS2.DCV0	9302	64.6	5651	35.0	6387	71.6	6629	46.4
14	NoEcon.SSFan.CS1.DCV1	725	5.0	1752	10.9	85	1.0	1085	7.6
15	IEcon.DB.SSFan.CS1.DCV1	2434	16.9	2046	12.7	694	7.8	1459	10.2
16	IEcon.EH.SSFan.CS1.DCV1	2131	14.8	2067	12.8	691	7.8	1388	9.7
17	NoEcon.MSFan.CS1.DCV1	7650	53.2	6715	41.6	6057	67.9	7102	49.7
18	IEcon.DB.MSFan.CS1.DCV1	9059	62.9	6867	42.6	6509	73.0	7279	50.9
19	IEcon.EH.MSFan.CS1.DCV1	8789	61.1	6870	42.6	6507	73.0	7249	50.7
20	NoEcon.MSFan.CS2.DCV1	8631	60.0	7656	47.5	6350	71.2	7854	55.0
21	IEcon.DB.MSFan.CS2.DCV1	9569	66.5	7737	48.0	6668	74.8	7957	55.7
22	IEcon.EH.MSFan.CS2.DCV1	9482	65.9	7735	47.9	6673	74.8	7963	55.7

Table D-23: Electricity Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 4B, 4C and 5

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	344	3.4	229	4.6	437	4.1	356	3.5
3	NIEcon.EH.SSFan.CS1.DCV0	327	3.2	222	4.5	338	3.2	341	3.4
4	IEcon.DB.SSFan.CS1.DCV0	357	3.5	240	4.8	446	4.2	365	3.6
5	IEcon.EH.SSFan.CS1.DCV0	337	3.3	231	4.6	345	3.3	347	3.4
6	NoEcon.MSFan.CS1.DCV0	4491	43.7	3093	62.2	5151	48.5	5509	54.1
7	NIEcon.DB.MSFan.CS1.DCV0	4590	44.7	3164	63.6	5266	49.6	5588	54.9
8	NIEcon.EH.MSFan.CS1.DCV0	4583	44.6	3162	63.6	5231	49.3	5587	54.9
9	IEcon.DB.MSFan.CS1.DCV0	4605	44.8	3176	63.8	5279	49.7	5596	55.0
10	IEcon.EH.MSFan.CS1.DCV0	4598	44.8	3172	63.8	5243	49.4	5594	54.9
11	NoEcon.MSFan.CS2.DCV0	5268	51.3	3249	65.3	5791	54.5	6055	59.5
12	IEcon.DB.MSFan.CS2.DCV0	5321	51.8	3294	66.2	5850	55.1	6089	59.8
13	IEcon.EH.MSFan.CS2.DCV0	5339	52.0	3298	66.3	5851	55.1	6091	59.8
14	NoEcon.SSFan.CS1.DCV1	475	4.6	59	1.2	538	5.1	327	3.2
15	IEcon.DB.SSFan.CS1.DCV1	780	7.6	275	5.5	868	8.2	631	6.2
16	IEcon.EH.SSFan.CS1.DCV1	767	7.5	265	5.3	782	7.4	616	6.0
17	NoEcon.MSFan.CS1.DCV1	5188	50.5	3312	66.6	5951	56.1	6111	60.0
18	IEcon.DB.MSFan.CS1.DCV1	5345	52.1	3447	69.3	6124	57.7	6251	61.4
19	IEcon.EH.MSFan.CS1.DCV1	5331	51.9	3444	69.2	6085	57.3	6235	61.2
20	NoEcon.MSFan.CS2.DCV1	5886	57.3	3465	69.7	6502	61.2	6644	65.3
21	IEcon.DB.MSFan.CS2.DCV1	5967	58.1	3556	71.5	6587	62.1	6702	65.8
22	IEcon.EH.MSFan.CS2.DCV1	5973	58.2	3559	71.5	6588	62.1	6689	65.7

Table D-24: Electricity Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	474	4.5	388	3.8	385	4.1	1599	7.5
3	NIEcon.EH.SSFan.CS1.DCV0	401	3.8	386	3.8	355	3.8	1593	7.5
4	IEcon.DB.SSFan.CS1.DCV0	485	4.6	391	3.9	389	4.1	1602	7.5
5	IEcon.EH.SSFan.CS1.DCV0	408	3.9	389	3.8	357	3.8	1591	7.5
6	NoEcon.MSFan.CS1.DCV0	5506	52.2	6121	60.4	5708	60.7	11999	56.4
7	NIEcon.DB.MSFan.CS1.DCV0	5658	53.6	6238	61.6	5870	62.5	13528	63.5
8	NIEcon.EH.MSFan.CS1.DCV0	5633	53.4	6241	61.6	5863	62.4	13529	63.6
9	IEcon.DB.MSFan.CS1.DCV0	5668	53.7	6245	61.6	5875	62.5	13532	63.6
10	IEcon.EH.MSFan.CS1.DCV0	5640	53.4	6247	61.7	5866	62.4	13529	63.6
11	NoEcon.MSFan.CS2.DCV0	6068	57.5	6531	64.5	5959	63.4	13169	61.9
12	IEcon.DB.MSFan.CS2.DCV0	6130	58.1	6570	64.8	6031	64.2	13662	64.2
13	IEcon.EH.MSFan.CS2.DCV0	6129	58.1	6570	64.8	6031	64.2	13654	64.1
14	NoEcon.SSFan.CS1.DCV1	466	4.4	226	2.2	162	1.7	800	3.8
15	IEcon.DB.SSFan.CS1.DCV1	812	7.7	534	5.3	474	5.0	1630	7.7
16	IEcon.EH.SSFan.CS1.DCV1	751	7.1	531	5.2	446	4.7	1625	7.6
17	NoEcon.MSFan.CS1.DCV1	6250	59.2	6668	65.8	6279	66.8	13227	62.1
18	IEcon.DB.MSFan.CS1.DCV1	6462	61.2	6863	67.7	6500	69.2	14803	69.5
19	IEcon.EH.MSFan.CS1.DCV1	6436	61.0	6863	67.7	6489	69.1	14801	69.5
20	NoEcon.MSFan.CS2.DCV1	6752	64.0	7084	69.9	6535	69.5	14431	67.8
21	IEcon.DB.MSFan.CS2.DCV1	6838	64.8	7158	70.6	6625	70.5	14925	70.1
22	IEcon.EH.MSFan.CS2.DCV1	6836	64.8	7149	70.6	6623	70.5	14914	70.1

Table D-25: Electricity Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	1067	3.6	695	3.6	449	2.2	739	5.4
3	NIEcon.EH.SSFan.CS1.DCV0	602	2.0	481	2.5	516	2.5	590	4.3
4	IEcon.DB.SSFan.CS1.DCV0	1108	3.8	709	3.7	461	2.3	757	5.6
5	IEcon.EH.SSFan.CS1.DCV0	622	2.1	494	2.6	528	2.6	607	4.5
6	NoEcon.MSFan.CS1.DCV0	5136	17.4	4467	23.1	4674	23.1	4849	35.7
7	NIEcon.DB.MSFan.CS1.DCV0	5628	19.1	4721	24.4	4821	23.8	5125	37.7
8	NIEcon.EH.MSFan.CS1.DCV0	5392	18.3	4634	24.0	4868	24.0	5057	37.2
9	IEcon.DB.MSFan.CS1.DCV0	5671	19.2	4738	24.5	4837	23.9	5147	37.9
10	IEcon.EH.MSFan.CS1.DCV0	5423	18.4	4652	24.1	4887	24.1	5079	37.4
11	NoEcon.MSFan.CS2.DCV0	7975	27.0	5999	31.0	6407	31.6	5976	44.0
12	IEcon.DB.MSFan.CS2.DCV0	8254	28.0	6150	31.8	6467	31.9	6123	45.0
13	IEcon.EH.MSFan.CS2.DCV0	8189	27.7	6123	31.7	6490	32.0	6116	45.0
14	NoEcon.SSFan.CS1.DCV1	3665	12.4	2591	13.4	2565	12.7	1370	10.1
15	IEcon.DB.SSFan.CS1.DCV1	4392	14.9	2959	15.3	2718	13.4	1674	12.3
16	IEcon.EH.SSFan.CS1.DCV1	3955	13.4	2802	14.5	2793	13.8	1561	11.5
17	NoEcon.MSFan.CS1.DCV1	9036	30.6	7227	37.4	7501	37.0	6207	45.7
18	IEcon.DB.MSFan.CS1.DCV1	9545	32.3	7478	38.7	7597	37.5	6449	47.4
19	IEcon.EH.MSFan.CS1.DCV1	9252	31.4	7383	38.2	7639	37.7	6380	46.9
20	NoEcon.MSFan.CS2.DCV1	11607	39.3	8597	44.5	9104	45.0	7111	52.3
21	IEcon.DB.MSFan.CS2.DCV1	11794	40.0	8709	45.0	9116	45.0	7207	53.0
22	IEcon.EH.MSFan.CS2.DCV1	11727	39.7	8679	44.9	9130	45.1	7195	52.9

Table D-26: Electricity Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2918	17.6	428	2.6	974	10.1	624	4.4
3	NIEcon.EH.SSFan.CS1.DCV0	2538	15.3	467	2.9	972	10.1	493	3.5
4	IEcon.DB.SSFan.CS1.DCV0	3048	18.4	438	2.7	1009	10.4	637	4.5
5	IEcon.EH.SSFan.CS1.DCV0	2639	15.9	476	2.9	1007	10.4	509	3.6
6	NoEcon.MSFan.CS1.DCV0	8416	50.8	4824	29.5	6241	64.5	5402	37.8
7	NIEcon.DB.MSFan.CS1.DCV0	9897	59.8	4960	30.3	6633	68.6	5632	39.4
8	NIEcon.EH.MSFan.CS1.DCV0	9631	58.2	4988	30.5	6633	68.6	5570	39.0
9	IEcon.DB.MSFan.CS1.DCV0	10064	60.8	4974	30.4	6682	69.1	5647	39.5
10	IEcon.EH.MSFan.CS1.DCV0	9778	59.1	5001	30.5	6682	69.1	5593	39.2
11	NoEcon.MSFan.CS2.DCV0	9619	58.1	5935	36.3	6602	68.2	6341	44.4
12	IEcon.DB.MSFan.CS2.DCV0	10566	63.8	5995	36.6	6865	71.0	6471	45.3
13	IEcon.EH.MSFan.CS2.DCV0	10520	63.6	6007	36.7	6871	71.0	6463	45.3
14	NoEcon.SSFan.CS1.DCV1	1995	12.1	1969	12.0	837	8.6	1286	9.0
15	IEcon.DB.SSFan.CS1.DCV1	3232	19.5	2092	12.8	1067	11.0	1579	11.1
16	IEcon.EH.SSFan.CS1.DCV1	2939	17.8	2136	13.0	1066	11.0	1494	10.5
17	NoEcon.MSFan.CS1.DCV1	8905	53.8	7021	42.9	6666	68.9	6947	48.6
18	IEcon.DB.MSFan.CS1.DCV1	10420	63.0	7106	43.4	7064	73.0	7157	50.1
19	IEcon.EH.MSFan.CS1.DCV1	10101	61.0	7128	43.5	7063	73.0	7103	49.7
20	NoEcon.MSFan.CS2.DCV1	10239	61.9	8015	49.0	7067	73.1	7748	54.2
21	IEcon.DB.MSFan.CS2.DCV1	10904	65.9	8029	49.0	7248	74.9	7825	54.8
22	IEcon.EH.MSFan.CS2.DCV1	10828	65.4	8036	49.1	7254	75.0	7827	54.8

Table D-27: Electricity Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	427	4.2	334	6.3	530	4.9	442	4.4
3	NIEcon.EH.SSFan.CS1.DCV0	414	4.1	322	6.1	422	3.9	434	4.3
4	IEcon.DB.SSFan.CS1.DCV0	442	4.4	348	6.6	546	5.1	451	4.5
5	IEcon.EH.SSFan.CS1.DCV0	421	4.2	335	6.3	433	4.0	438	4.4
6	NoEcon.MSFan.CS1.DCV0	4191	41.5	3178	60.1	5014	46.7	5180	51.4
7	NIEcon.DB.MSFan.CS1.DCV0	4341	43.0	3299	62.4	5191	48.4	5310	52.7
8	NIEcon.EH.MSFan.CS1.DCV0	4341	43.0	3294	62.3	5145	47.9	5311	52.7
9	IEcon.DB.MSFan.CS1.DCV0	4358	43.2	3319	62.7	5210	48.5	5322	52.8
10	IEcon.EH.MSFan.CS1.DCV0	4355	43.2	3312	62.6	5160	48.1	5319	52.8
11	NoEcon.MSFan.CS2.DCV0	5001	49.6	3374	63.8	5694	53.1	5811	57.7
12	IEcon.DB.MSFan.CS2.DCV0	5068	50.2	3450	65.2	5781	53.9	5857	58.1
13	IEcon.EH.MSFan.CS2.DCV0	5086	50.4	3454	65.3	5779	53.8	5859	58.1
14	NoEcon.SSFan.CS1.DCV1	672	6.7	275	5.2	749	7.0	540	5.4
15	IEcon.DB.SSFan.CS1.DCV1	860	8.5	392	7.4	977	9.1	711	7.1
16	IEcon.EH.SSFan.CS1.DCV1	854	8.5	380	7.2	892	8.3	711	7.1
17	NoEcon.MSFan.CS1.DCV1	5001	49.6	3531	66.7	5969	55.6	5921	58.8
18	IEcon.DB.MSFan.CS1.DCV1	5128	50.8	3656	69.1	6131	57.1	6029	59.8
19	IEcon.EH.MSFan.CS1.DCV1	5120	50.7	3647	68.9	6081	56.7	6022	59.8
20	NoEcon.MSFan.CS2.DCV1	5697	56.5	3724	70.4	6536	60.9	6518	64.7
21	IEcon.DB.MSFan.CS2.DCV1	5729	56.8	3771	71.3	6585	61.4	6534	64.8
22	IEcon.EH.MSFan.CS2.DCV1	5744	56.9	3776	71.4	6579	61.3	6520	64.7

Table D-28: Electricity Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	598	5.6	497	4.8	513	5.4	1871	8.7
3	NIEcon.EH.SSFan.CS1.DCV0	512	4.8	493	4.8	471	4.9	1867	8.7
4	IEcon.DB.SSFan.CS1.DCV0	610	5.7	502	4.9	517	5.4	1874	8.7
5	IEcon.EH.SSFan.CS1.DCV0	514	4.8	496	4.8	471	4.9	1866	8.7
6	NoEcon.MSFan.CS1.DCV0	5381	50.3	5985	58.2	5639	59.0	11968	55.6
7	NIEcon.DB.MSFan.CS1.DCV0	5606	52.4	6149	59.8	5870	61.4	13549	62.9
8	NIEcon.EH.MSFan.CS1.DCV0	5573	52.1	6154	59.9	5856	61.3	13552	62.9
9	IEcon.DB.MSFan.CS1.DCV0	5618	52.5	6157	59.9	5876	61.5	13555	62.9
10	IEcon.EH.MSFan.CS1.DCV0	5581	52.2	6159	59.9	5859	61.3	13557	62.9
11	NoEcon.MSFan.CS2.DCV0	6020	56.3	6501	63.3	5973	62.5	13247	61.5
12	IEcon.DB.MSFan.CS2.DCV0	6100	57.0	6561	63.8	6057	63.4	13711	63.6
13	IEcon.EH.MSFan.CS2.DCV0	6095	57.0	6559	63.8	6053	63.3	13708	63.6
14	NoEcon.SSFan.CS1.DCV1	764	7.1	539	5.2	511	5.3	1782	8.3
15	IEcon.DB.SSFan.CS1.DCV1	945	8.8	646	6.3	600	6.3	1912	8.9
16	IEcon.EH.SSFan.CS1.DCV1	871	8.1	646	6.3	572	6.0	1913	8.9
17	NoEcon.MSFan.CS1.DCV1	6334	59.2	6765	65.8	6431	67.3	12976	60.2
18	IEcon.DB.MSFan.CS1.DCV1	6501	60.8	6864	66.8	6586	68.9	14916	69.2
19	IEcon.EH.MSFan.CS1.DCV1	6458	60.4	6866	66.8	6571	68.7	14917	69.2
20	NoEcon.MSFan.CS2.DCV1	6852	64.1	7214	70.2	6694	70.0	14711	68.3
21	IEcon.DB.MSFan.CS2.DCV1	6890	64.4	7237	70.4	6741	70.5	15059	69.9
22	IEcon.EH.MSFan.CS2.DCV1	6877	64.3	7227	70.3	6736	70.5	15053	69.9

Table D-29: Electricity Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	778	2.3	834	2.5	597	1.8	1055	3.6
3	NIEcon.EH.SSFan.CS1.DCV0	396	1.2	539	1.6	595	1.8	790	2.7
4	IEcon.DB.SSFan.CS1.DCV0	772	2.3	838	2.5	610	1.8	1065	3.6
5	IEcon.EH.SSFan.CS1.DCV0	403	1.2	542	1.6	605	1.8	790	2.7
6	NoEcon.MSFan.CS1.DCV0	11563	34.4	15235	45.7	13379	40.2	17030	57.5
7	NIEcon.DB.MSFan.CS1.DCV0	11975	35.6	15685	47.1	13736	41.3	17622	59.5
8	NIEcon.EH.MSFan.CS1.DCV0	11765	35.0	15556	46.7	13740	41.3	17501	59.1
9	IEcon.DB.MSFan.CS1.DCV0	11961	35.5	15684	47.1	13754	41.3	17633	59.5
10	IEcon.EH.MSFan.CS1.DCV0	11777	35.0	15563	46.7	13757	41.4	17508	59.1
11	NoEcon.MSFan.CS2.DCV0	14336	42.6	17672	53.1	15755	47.4	18557	62.7
12	IEcon.DB.MSFan.CS2.DCV0	14603	43.4	17910	53.8	15938	47.9	18838	63.6
13	IEcon.EH.MSFan.CS2.DCV0	14481	43.0	17855	53.6	15944	47.9	18805	63.5
14	NoEcon.SSFan.CS1.DCV1	3464	10.3	2724	8.2	3507	10.5	1047	3.5
15	IEcon.DB.SSFan.CS1.DCV1	4239	12.6	3572	10.7	4121	12.4	2131	7.2
16	IEcon.EH.SSFan.CS1.DCV1	3861	11.5	3253	9.8	4115	12.4	1826	6.2
17	NoEcon.MSFan.CS1.DCV1	15462	45.9	18970	57.0	17956	54.0	18944	64.0
18	IEcon.DB.MSFan.CS1.DCV1	15842	47.1	19402	58.3	18321	55.1	19530	65.9
19	IEcon.EH.MSFan.CS1.DCV1	15669	46.6	19279	57.9	18322	55.1	19399	65.5
20	NoEcon.MSFan.CS2.DCV1	17759	52.8	20718	62.2	19811	59.6	20203	68.2
21	IEcon.DB.MSFan.CS2.DCV1	18009	53.5	20939	62.9	19990	60.1	20462	69.1
22	IEcon.EH.MSFan.CS2.DCV1	17903	53.2	20892	62.7	19993	60.1	20434	69.0

Table D-30: Electricity Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2546	9.0	674	2.0	1265	4.7	1034	2.9
3	NIEcon.EH.SSFan.CS1.DCV0	2094	7.4	679	2.1	1250	4.6	799	2.2
4	IEcon.DB.SSFan.CS1.DCV0	2617	9.3	687	2.1	1287	4.8	1038	2.9
5	IEcon.EH.SSFan.CS1.DCV0	2140	7.6	690	2.1	1271	4.7	804	2.2
6	NoEcon.MSFan.CS1.DCV0	18392	65.3	16395	49.8	17687	65.3	21156	58.9
7	NIEcon.DB.MSFan.CS1.DCV0	19876	70.5	16807	51.1	18500	68.3	21790	60.7
8	NIEcon.EH.MSFan.CS1.DCV0	19664	69.8	16809	51.1	18491	68.3	21689	60.4
9	IEcon.DB.MSFan.CS1.DCV0	19960	70.8	16824	51.1	18532	68.4	21798	60.7
10	IEcon.EH.MSFan.CS1.DCV0	19725	70.0	16826	51.2	18519	68.4	21703	60.4
11	NoEcon.MSFan.CS2.DCV0	19496	69.2	18116	55.1	18199	67.2	22588	62.9
12	IEcon.DB.MSFan.CS2.DCV0	20367	72.3	18338	55.7	18687	69.0	22886	63.7
13	IEcon.EH.MSFan.CS2.DCV0	20321	72.1	18341	55.8	18687	69.0	22859	63.6
14	NoEcon.SSFan.CS1.DCV1	-42	-0.1	2512	7.6	63	0.2	1138	3.2
15	IEcon.DB.SSFan.CS1.DCV1	2714	9.6	3195	9.7	1344	5.0	2191	6.1
16	IEcon.EH.SSFan.CS1.DCV1	2056	7.3	3199	9.7	1322	4.9	1921	5.3
17	NoEcon.MSFan.CS1.DCV1	19046	67.6	19910	60.5	18921	69.9	23636	65.8
18	IEcon.DB.MSFan.CS1.DCV1	20592	73.1	20332	61.8	19744	72.9	24255	67.5
19	IEcon.EH.MSFan.CS1.DCV1	20355	72.2	20332	61.8	19728	72.9	24150	67.2
20	NoEcon.MSFan.CS2.DCV1	20152	71.5	21361	64.9	19418	71.7	24765	68.9
21	IEcon.DB.MSFan.CS2.DCV1	20994	74.5	21576	65.6	19887	73.4	25046	69.7
22	IEcon.EH.MSFan.CS2.DCV1	20969	74.4	21578	65.6	19884	73.4	25021	69.6

Table D-31: Electricity Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	756	2.7	562	3.4	848	2.8	788	2.5
3	NIEcon.EH.SSFan.CS1.DCV0	666	2.4	539	3.3	646	2.1	719	2.3
4	IEcon.DB.SSFan.CS1.DCV0	772	2.8	571	3.5	865	2.9	800	2.5
5	IEcon.EH.SSFan.CS1.DCV0	674	2.4	546	3.3	651	2.2	725	2.3
6	NoEcon.MSFan.CS1.DCV0	17083	61.3	10554	63.9	18988	62.9	20272	64.6
7	NIEcon.DB.MSFan.CS1.DCV0	17520	62.9	10930	66.2	19548	64.8	20748	66.1
8	NIEcon.EH.MSFan.CS1.DCV0	17476	62.7	10916	66.1	19467	64.5	20718	66.0
9	IEcon.DB.MSFan.CS1.DCV0	17542	63.0	10944	66.3	19565	64.9	20767	66.1
10	IEcon.EH.MSFan.CS1.DCV0	17488	62.8	10927	66.2	19472	64.6	20730	66.0
11	NoEcon.MSFan.CS2.DCV0	18284	65.6	10851	65.7	19958	66.2	21073	67.1
12	IEcon.DB.MSFan.CS2.DCV0	18509	66.4	11052	67.0	20200	67.0	21313	67.9
13	IEcon.EH.MSFan.CS2.DCV0	18502	66.4	11048	66.9	20175	66.9	21309	67.9
14	NoEcon.SSFan.CS1.DCV1	688	2.5	68	0.4	393	1.3	396	1.3
15	IEcon.DB.SSFan.CS1.DCV1	1477	5.3	636	3.9	1425	4.7	1259	4.0
16	IEcon.EH.SSFan.CS1.DCV1	1360	4.9	605	3.7	1155	3.8	1163	3.7
17	NoEcon.MSFan.CS1.DCV1	18584	66.7	11388	69.0	20355	67.5	21530	68.6
18	IEcon.DB.MSFan.CS1.DCV1	19032	68.3	11767	71.3	21150	70.1	22090	70.3
19	IEcon.EH.MSFan.CS1.DCV1	18973	68.1	11744	71.2	20987	69.6	22041	70.2
20	NoEcon.MSFan.CS2.DCV1	19559	70.2	11670	70.7	21335	70.7	22289	71.0
21	IEcon.DB.MSFan.CS2.DCV1	19775	71.0	11862	71.9	21657	71.8	22555	71.8
22	IEcon.EH.MSFan.CS2.DCV1	19767	71.0	11857	71.8	21616	71.7	22548	71.8

Table D-32: Electricity Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	1039	3.4	998	3.1	1072	3.6	4150	6.4
3	NIEcon.EH.SSFan.CS1.DCV0	893	2.9	961	3.0	1006	3.3	4124	6.4
4	IEcon.DB.SSFan.CS1.DCV0	1051	3.4	1004	3.1	1079	3.6	4154	6.4
5	IEcon.EH.SSFan.CS1.DCV0	896	2.9	964	3.0	1007	3.3	4122	6.4
6	NoEcon.MSFan.CS1.DCV0	19008	62.1	20415	63.8	18472	61.3	36647	56.6
7	NIEcon.DB.MSFan.CS1.DCV0	19955	65.2	21318	66.6	19515	64.7	41020	63.3
8	NIEcon.EH.MSFan.CS1.DCV0	19870	64.9	21273	66.5	19440	64.5	40966	63.3
9	IEcon.DB.MSFan.CS1.DCV0	19967	65.2	21330	66.7	19524	64.8	41027	63.3
10	IEcon.EH.MSFan.CS1.DCV0	19875	64.9	21280	66.5	19444	64.5	40970	63.3
11	NoEcon.MSFan.CS2.DCV0	20092	65.6	21226	66.3	19196	63.7	39564	61.1
12	IEcon.DB.MSFan.CS2.DCV0	20450	66.8	21653	67.7	19658	65.2	41156	63.5
13	IEcon.EH.MSFan.CS2.DCV0	20437	66.8	21648	67.7	19642	65.2	41145	63.5
14	NoEcon.SSFan.CS1.DCV1	112	0.4	-124	-0.4	-341	-1.1	-996	-1.5
15	IEcon.DB.SSFan.CS1.DCV1	1491	4.9	1297	4.1	1193	4.0	4159	6.4
16	IEcon.EH.SSFan.CS1.DCV1	1302	4.3	1245	3.9	1100	3.7	4119	6.4
17	NoEcon.MSFan.CS1.DCV1	20046	65.5	21044	65.8	19270	63.9	37563	58.0
18	IEcon.DB.MSFan.CS1.DCV1	21494	70.2	22611	70.7	20960	69.5	43728	67.5
19	IEcon.EH.MSFan.CS1.DCV1	21276	69.5	22471	70.2	20752	68.9	43528	67.2
20	NoEcon.MSFan.CS2.DCV1	21330	69.7	22215	69.4	20350	67.5	41895	64.7
21	IEcon.DB.MSFan.CS2.DCV1	21885	71.5	22931	71.7	21083	70.0	43885	67.8
22	IEcon.EH.MSFan.CS2.DCV1	21837	71.4	22905	71.6	21037	69.8	43856	67.7

Table D-33: Gas Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	-3	-35.7	0	0.1	1	0.5	2	0.3
3	NIEcon.EH.SSFan.CS1.DCV0	-2	-35.4	0	0.0	1	0.6	2	0.3
4	IEcon.DB.SSFan.CS1.DCV0	-2	-35.3	0	0.1	1	0.6	2	0.3
5	IEcon.EH.SSFan.CS1.DCV0	-2	-35.4	0	0.0	1	0.8	2	0.3
6	NoEcon.MSFan.CS1.DCV0	-4	-60.5	-76	-31.8	-90	-49.4	-203	-28.3
7	NIEcon.DB.MSFan.CS1.DCV0	-4	-52.6	-74	-31.0	-87	-47.9	-200	-27.9
8	NIEcon.EH.MSFan.CS1.DCV0	-4	-54.0	-75	-31.2	-87	-47.8	-200	-27.9
9	IEcon.DB.MSFan.CS1.DCV0	-4	-53.4	-74	-31.0	-87	-47.9	-200	-27.9
10	IEcon.EH.MSFan.CS1.DCV0	-4	-54.5	-75	-31.2	-87	-47.8	-200	-27.9
11	NoEcon.MSFan.CS2.DCV0	-4	-54.5	-75	-31.1	-87	-47.6	-200	-28.0
12	IEcon.DB.MSFan.CS2.DCV0	-4	-53.0	-74	-31.0	-87	-47.5	-200	-27.9
13	IEcon.EH.MSFan.CS2.DCV0	-4	-53.3	-74	-31.0	-86	-47.4	-200	-27.9
14	NoEcon.SSFan.CS1.DCV1	2	23.2	64	26.8	55	29.9	190	26.5
15	IEcon.DB.SSFan.CS1.DCV1	-2	-21.7	61	25.7	55	30.0	188	26.3
16	IEcon.EH.SSFan.CS1.DCV1	-2	-21.4	61	25.6	55	30.0	188	26.3
17	NoEcon.MSFan.CS1.DCV1	0	-0.7	6	2.6	-12	-6.3	35	4.9
18	IEcon.DB.MSFan.CS1.DCV1	1	7.7	8	3.4	-8	-4.6	38	5.3
19	IEcon.EH.MSFan.CS1.DCV1	0	6.3	8	3.3	-8	-4.6	38	5.3
20	NoEcon.MSFan.CS2.DCV1	0	6.5	8	3.3	-9	-4.8	38	5.3
21	IEcon.DB.MSFan.CS2.DCV1	1	8.1	8	3.5	-8	-4.3	39	5.4
22	IEcon.EH.MSFan.CS2.DCV1	1	7.7	8	3.5	-8	-4.3	38	5.4

Table D-34: Gas Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	-2	-2.1	4	1.1	3	1.0	3	0.3
3	NIEcon.EH.SSFan.CS1.DCV0	-2	-2.1	4	1.1	3	1.0	3	0.3
4	IEcon.DB.SSFan.CS1.DCV0	-2	-2.1	4	1.2	3	1.0	3	0.3
5	IEcon.EH.SSFan.CS1.DCV0	-2	-2.1	4	1.1	3	0.9	3	0.3
6	NoEcon.MSFan.CS1.DCV0	-67	-67.3	-127	-39.3	-150	-43.5	-223	-23.9
7	NIEcon.DB.MSFan.CS1.DCV0	-63	-62.6	-123	-38.1	-146	-42.5	-220	-23.6
8	NIEcon.EH.MSFan.CS1.DCV0	-63	-62.5	-123	-38.1	-147	-42.5	-220	-23.6
9	IEcon.DB.MSFan.CS1.DCV0	-63	-62.6	-123	-38.2	-146	-42.5	-220	-23.6
10	IEcon.EH.MSFan.CS1.DCV0	-63	-62.6	-123	-38.1	-147	-42.5	-220	-23.6
11	NoEcon.MSFan.CS2.DCV0	-63	-63.0	-123	-38.3	-148	-42.8	-221	-23.6
12	IEcon.DB.MSFan.CS2.DCV0	-62	-62.4	-122	-37.9	-146	-42.5	-220	-23.6
13	IEcon.EH.MSFan.CS2.DCV0	-62	-62.4	-122	-37.9	-146	-42.5	-220	-23.6
14	NoEcon.SSFan.CS1.DCV1	25	24.8	89	27.6	111	32.2	290	31.0
15	IEcon.DB.SSFan.CS1.DCV1	20	19.7	92	28.6	114	33.0	291	31.2
16	IEcon.EH.SSFan.CS1.DCV1	20	19.7	92	28.6	114	33.0	291	31.2
17	NoEcon.MSFan.CS1.DCV1	-18	-18.4	-4	-1.3	3	0.8	122	13.0
18	IEcon.DB.MSFan.CS1.DCV1	-13	-13.2	0	-0.1	6	1.8	124	13.3
19	IEcon.EH.MSFan.CS1.DCV1	-13	-13.3	0	-0.1	6	1.8	124	13.3
20	NoEcon.MSFan.CS2.DCV1	-13	-13.3	-1	-0.3	6	1.6	124	13.3
21	IEcon.DB.MSFan.CS2.DCV1	-13	-13.0	0	0.0	6	1.9	124	13.3
22	IEcon.EH.MSFan.CS2.DCV1	-13	-13.0	0	0.0	7	1.9	124	13.3

Table D-35: Gas Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2	0.4	2	0.3	2	0.2	5	0.7
3	NIEcon.EH.SSFan.CS1.DCV0	2	0.4	2	0.3	2	0.1	5	0.7
4	IEcon.DB.SSFan.CS1.DCV0	2	0.4	2	0.3	2	0.2	5	0.6
5	IEcon.EH.SSFan.CS1.DCV0	2	0.4	2	0.3	2	0.1	5	0.6
6	NoEcon.MSFan.CS1.DCV0	-141	-27.8	-283	-34.4	-283	-21.1	-199	-26.0
7	NIEcon.DB.MSFan.CS1.DCV0	-136	-27.0	-281	-34.1	-281	-21.0	-195	-25.5
8	NIEcon.EH.MSFan.CS1.DCV0	-136	-27.0	-281	-34.1	-282	-21.0	-195	-25.5
9	IEcon.DB.MSFan.CS1.DCV0	-136	-27.0	-281	-34.1	-281	-21.0	-195	-25.5
10	IEcon.EH.MSFan.CS1.DCV0	-136	-27.0	-281	-34.1	-282	-21.0	-195	-25.5
11	NoEcon.MSFan.CS2.DCV0	-137	-27.1	-281	-34.1	-282	-21.0	-196	-25.6
12	IEcon.DB.MSFan.CS2.DCV0	-136	-26.9	-280	-34.0	-281	-20.9	-194	-25.4
13	IEcon.EH.MSFan.CS2.DCV0	-136	-26.9	-280	-34.0	-281	-20.9	-194	-25.3
14	NoEcon.SSFan.CS1.DCV1	128	25.3	294	35.6	394	29.3	199	26.0
15	IEcon.DB.SSFan.CS1.DCV1	127	25.2	296	35.9	395	29.4	203	26.6
16	IEcon.EH.SSFan.CS1.DCV1	127	25.2	295	35.9	395	29.4	203	26.6
17	NoEcon.MSFan.CS1.DCV1	26	5.1	89	10.8	172	12.8	51	6.6
18	IEcon.DB.MSFan.CS1.DCV1	30	6.0	93	11.3	175	13.0	56	7.3
19	IEcon.EH.MSFan.CS1.DCV1	30	6.0	93	11.3	174	13.0	56	7.3
20	NoEcon.MSFan.CS2.DCV1	29	5.8	92	11.2	174	13.0	55	7.2
21	IEcon.DB.MSFan.CS2.DCV1	31	6.0	93	11.3	175	13.0	57	7.4
22	IEcon.EH.MSFan.CS2.DCV1	31	6.1	93	11.3	175	13.0	57	7.4

Table D-36: Gas Cost Savings Compared to Case 1 for the Small Office Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2	0.2	4	0.3	2	0.2	-2	-0.1
3	NIEcon.EH.SSFan.CS1.DCV0	2	0.2	3	0.3	2	0.1	-2	-0.1
4	IEcon.DB.SSFan.CS1.DCV0	2	0.2	4	0.3	2	0.2	-3	-0.1
5	IEcon.EH.SSFan.CS1.DCV0	2	0.2	3	0.3	2	0.1	-2	-0.1
6	NoEcon.MSFan.CS1.DCV0	-229	-17.8	-303	-23.9	-279	-17.8	-421	-12.7
7	NIEcon.DB.MSFan.CS1.DCV0	-228	-17.7	-300	-23.6	-277	-17.7	-411	-12.4
8	NIEcon.EH.MSFan.CS1.DCV0	-228	-17.7	-300	-23.6	-277	-17.7	-411	-12.4
9	IEcon.DB.MSFan.CS1.DCV0	-228	-17.7	-300	-23.6	-277	-17.7	-411	-12.4
10	IEcon.EH.MSFan.CS1.DCV0	-228	-17.7	-300	-23.6	-277	-17.7	-411	-12.4
11	NoEcon.MSFan.CS2.DCV0	-228	-17.7	-300	-23.6	-277	-17.7	-411	-12.4
12	IEcon.DB.MSFan.CS2.DCV0	-227	-17.7	-299	-23.5	-277	-17.7	-411	-12.4
13	IEcon.EH.MSFan.CS2.DCV0	-227	-17.7	-299	-23.5	-277	-17.7	-411	-12.4
14	NoEcon.SSFan.CS1.DCV1	375	29.1	350	27.5	433	27.7	772	23.4
15	IEcon.DB.SSFan.CS1.DCV1	377	29.3	354	27.9	436	27.9	744	22.5
16	IEcon.EH.SSFan.CS1.DCV1	377	29.3	354	27.8	436	27.9	744	22.5
17	NoEcon.MSFan.CS1.DCV1	192	14.9	123	9.7	219	14.0	415	12.6
18	IEcon.DB.MSFan.CS1.DCV1	194	15.1	127	10.0	223	14.3	429	13.0
19	IEcon.EH.MSFan.CS1.DCV1	195	15.1	127	10.0	223	14.3	429	13.0
20	NoEcon.MSFan.CS2.DCV1	194	15.0	126	9.9	221	14.1	426	12.9
21	IEcon.DB.MSFan.CS2.DCV1	194	15.1	128	10.1	223	14.3	429	13.0
22	IEcon.EH.MSFan.CS2.DCV1	194	15.1	128	10.1	223	14.3	429	13.0

Table D-37: Gas Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	2	0.7	3	0.1	5	0.1	5	0.1
3	NIEcon.EH.SSFan.CS1.DCV0	1	0.4	2	0.1	7	0.2	4	0.0
4	IEcon.DB.SSFan.CS1.DCV0	2	0.7	2	0.1	5	0.1	5	0.1
5	IEcon.EH.SSFan.CS1.DCV0	1	0.4	2	0.0	6	0.2	5	0.1
6	NoEcon.MSFan.CS1.DCV0	-107	-43.0	-541	-16.4	-740	-22.2	-1400	-14.4
7	NIEcon.DB.MSFan.CS1.DCV0	-105	-42.3	-538	-16.3	-733	-22.0	-1397	-14.4
8	NIEcon.EH.MSFan.CS1.DCV0	-105	-42.4	-539	-16.4	-731	-21.9	-1397	-14.4
9	IEcon.DB.MSFan.CS1.DCV0	-105	-42.3	-538	-16.3	-733	-22.0	-1397	-14.4
10	IEcon.EH.MSFan.CS1.DCV0	-105	-42.4	-539	-16.4	-731	-21.9	-1397	-14.4
11	NoEcon.MSFan.CS2.DCV0	-105	-42.5	-539	-16.4	-731	-21.9	-1398	-14.4
12	IEcon.DB.MSFan.CS2.DCV0	-105	-42.4	-538	-16.3	-731	-21.9	-1397	-14.4
13	IEcon.EH.MSFan.CS2.DCV0	-105	-42.4	-538	-16.3	-728	-21.8	-1396	-14.4
14	NoEcon.SSFan.CS1.DCV1	139	55.9	1233	37.4	1283	38.4	3351	34.5
15	IEcon.DB.SSFan.CS1.DCV1	140	56.5	1236	37.5	1291	38.7	3355	34.6
16	IEcon.EH.SSFan.CS1.DCV1	140	56.4	1235	37.5	1292	38.7	3355	34.6
17	NoEcon.MSFan.CS1.DCV1	84	34.0	875	26.6	813	24.4	2387	24.6
18	IEcon.DB.MSFan.CS1.DCV1	86	34.6	878	26.7	817	24.5	2390	24.6
19	IEcon.EH.MSFan.CS1.DCV1	86	34.5	878	26.7	819	24.5	2390	24.6
20	NoEcon.MSFan.CS2.DCV1	85	34.4	877	26.6	819	24.5	2390	24.6
21	IEcon.DB.MSFan.CS2.DCV1	86	34.7	879	26.7	821	24.6	2391	24.6
22	IEcon.EH.MSFan.CS2.DCV1	86	34.6	879	26.7	823	24.6	2391	24.6

Table D-38: Gas Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	5	0.2	7	0.1	4	0.1	3	0.0
3	NIEcon.EH.SSFan.CS1.DCV0	5	0.2	8	0.1	4	0.1	2	0.0
4	IEcon.DB.SSFan.CS1.DCV0	5	0.2	8	0.1	4	0.1	3	0.0
5	IEcon.EH.SSFan.CS1.DCV0	4	0.2	8	0.1	4	0.1	3	0.0
6	NoEcon.MSFan.CS1.DCV0	-697	-29.9	-893	-16.6	-766	-11.8	-1486	-10.7
7	NIEcon.DB.MSFan.CS1.DCV0	-690	-29.6	-887	-16.5	-763	-11.8	-1483	-10.7
8	NIEcon.EH.MSFan.CS1.DCV0	-691	-29.6	-887	-16.5	-763	-11.8	-1484	-10.7
9	IEcon.DB.MSFan.CS1.DCV0	-690	-29.6	-888	-16.5	-763	-11.8	-1483	-10.7
10	IEcon.EH.MSFan.CS1.DCV0	-691	-29.6	-887	-16.5	-763	-11.8	-1484	-10.7
11	NoEcon.MSFan.CS2.DCV0	-693	-29.7	-888	-16.5	-764	-11.8	-1485	-10.7
12	IEcon.DB.MSFan.CS2.DCV0	-689	-29.5	-885	-16.5	-763	-11.8	-1483	-10.6
13	IEcon.EH.MSFan.CS2.DCV0	-689	-29.5	-885	-16.5	-762	-11.8	-1483	-10.6
14	NoEcon.SSFan.CS1.DCV1	963	41.3	1897	35.3	2620	40.4	4913	35.3
15	IEcon.DB.SSFan.CS1.DCV1	967	41.4	1904	35.4	2624	40.5	4916	35.3
16	IEcon.EH.SSFan.CS1.DCV1	967	41.4	1905	35.4	2624	40.5	4915	35.3
17	NoEcon.MSFan.CS1.DCV1	544	23.3	1298	24.1	1893	29.2	3868	27.8
18	IEcon.DB.MSFan.CS1.DCV1	549	23.5	1303	24.2	1897	29.3	3870	27.8
19	IEcon.EH.MSFan.CS1.DCV1	549	23.5	1303	24.2	1897	29.3	3870	27.8
20	NoEcon.MSFan.CS2.DCV1	548	23.5	1303	24.2	1896	29.3	3869	27.8
21	IEcon.DB.MSFan.CS2.DCV1	549	23.5	1305	24.3	1898	29.3	3870	27.8
22	IEcon.EH.MSFan.CS2.DCV1	549	23.5	1307	24.3	1898	29.3	3871	27.8

Table D-39: Gas Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	8	0.1	3	0.0	19	0.1	16	0.1
3	NIEcon.EH.SSFan.CS1.DCV0	8	0.1	3	0.0	17	0.1	16	0.1
4	IEcon.DB.SSFan.CS1.DCV0	8	0.1	3	0.0	19	0.1	16	0.1
5	IEcon.EH.SSFan.CS1.DCV0	8	0.1	3	0.0	17	0.1	16	0.1
6	NoEcon.MSFan.CS1.DCV0	-1004	-13.0	-1274	-9.3	-2017	-10.7	-1523	-13.4
7	NIEcon.DB.MSFan.CS1.DCV0	-999	-13.0	-1270	-9.3	-2006	-10.7	-1517	-13.4
8	NIEcon.EH.MSFan.CS1.DCV0	-999	-13.0	-1270	-9.3	-2005	-10.7	-1518	-13.4
9	IEcon.DB.MSFan.CS1.DCV0	-999	-13.0	-1270	-9.3	-2005	-10.7	-1517	-13.4
10	IEcon.EH.MSFan.CS1.DCV0	-999	-13.0	-1271	-9.3	-2005	-10.7	-1518	-13.4
11	NoEcon.MSFan.CS2.DCV0	-998	-13.0	-1271	-9.3	-2006	-10.7	-1515	-13.3
12	IEcon.DB.MSFan.CS2.DCV0	-996	-12.9	-1270	-9.3	-2003	-10.7	-1512	-13.3
13	IEcon.EH.MSFan.CS2.DCV0	-995	-12.9	-1269	-9.3	-2003	-10.7	-1511	-13.3
14	NoEcon.SSFan.CS1.DCV1	2590	33.6	5732	42.0	6050	32.2	3626	31.9
15	IEcon.DB.SSFan.CS1.DCV1	2597	33.7	5737	42.0	6034	32.1	3641	32.1
16	IEcon.EH.SSFan.CS1.DCV1	2598	33.7	5737	42.0	6033	32.1	3642	32.1
17	NoEcon.MSFan.CS1.DCV1	1881	24.4	4452	32.6	4659	24.8	2524	22.2
18	IEcon.DB.MSFan.CS1.DCV1	1887	24.5	4456	32.6	4701	25.0	2539	22.4
19	IEcon.EH.MSFan.CS1.DCV1	1887	24.5	4455	32.6	4701	25.0	2539	22.4
20	NoEcon.MSFan.CS2.DCV1	1887	24.5	4455	32.6	4684	24.9	2540	22.4
21	IEcon.DB.MSFan.CS2.DCV1	1889	24.5	4455	32.6	4702	25.0	2543	22.4
22	IEcon.EH.MSFan.CS2.DCV1	1891	24.6	4456	32.6	4703	25.0	2544	22.4

Table D-40: Gas Cost Savings Compared to Case 1 for the Stand-alone Retail Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	27	0.2	26	0.1	10	0.0	674	1.5
3	NIEcon.EH.SSFan.CS1.DCV0	26	0.1	27	0.1	9	0.0	670	1.5
4	IEcon.DB.SSFan.CS1.DCV0	27	0.2	26	0.1	10	0.0	672	1.5
5	IEcon.EH.SSFan.CS1.DCV0	27	0.1	26	0.1	9	0.0	670	1.5
6	NoEcon.MSFan.CS1.DCV0	-1822	-10.2	-2649	-14.1	-2463	-11.0	-4408	-10.0
7	NIEcon.DB.MSFan.CS1.DCV0	-1761	-9.9	-2575	-13.7	-2357	-10.6	-3364	-7.7
8	NIEcon.EH.MSFan.CS1.DCV0	-1762	-9.9	-2573	-13.7	-2357	-10.6	-3362	-7.7
9	IEcon.DB.MSFan.CS1.DCV0	-1761	-9.9	-2575	-13.7	-2357	-10.6	-3364	-7.7
10	IEcon.EH.MSFan.CS1.DCV0	-1762	-9.9	-2573	-13.7	-2357	-10.6	-3365	-7.7
11	NoEcon.MSFan.CS2.DCV0	-1782	-10.0	-2624	-14.0	-2403	-10.8	-3497	-8.0
12	IEcon.DB.MSFan.CS2.DCV0	-1760	-9.9	-2569	-13.7	-2356	-10.6	-3353	-7.6
13	IEcon.EH.MSFan.CS2.DCV0	-1760	-9.9	-2568	-13.7	-2356	-10.6	-3354	-7.6
14	NoEcon.SSFan.CS1.DCV1	5350	30.0	5832	31.0	6686	30.0	11539	26.3
15	IEcon.DB.SSFan.CS1.DCV1	5352	30.0	5792	30.8	6707	30.1	11562	26.3
16	IEcon.EH.SSFan.CS1.DCV1	5353	30.0	5792	30.8	6707	30.1	11561	26.3
17	NoEcon.MSFan.CS1.DCV1	4174	23.4	3925	20.9	5058	22.7	7475	17.0
18	IEcon.DB.MSFan.CS1.DCV1	4254	23.9	4050	21.6	5194	23.3	8855	20.2
19	IEcon.EH.MSFan.CS1.DCV1	4254	23.9	4049	21.6	5194	23.3	8855	20.2
20	NoEcon.MSFan.CS2.DCV1	4237	23.8	3998	21.3	5172	23.2	8800	20.0
21	IEcon.DB.MSFan.CS2.DCV1	4256	23.9	4055	21.6	5195	23.3	8865	20.2
22	IEcon.EH.MSFan.CS2.DCV1	4257	23.9	4056	21.6	5196	23.3	8865	20.2

Table D-41: Gas Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	21	5.0	8	0.3	17	0.5	15	0.2
3	NIEcon.EH.SSFan.CS1.DCV0	19	4.6	6	0.2	19	0.5	14	0.1
4	IEcon.DB.SSFan.CS1.DCV0	21	5.0	8	0.2	16	0.5	15	0.2
5	IEcon.EH.SSFan.CS1.DCV0	19	4.5	6	0.2	19	0.5	14	0.2
6	NoEcon.MSFan.CS1.DCV0	-159	-37.9	-567	-17.6	-752	-21.0	-1359	-14.8
7	NIEcon.DB.MSFan.CS1.DCV0	-142	-33.9	-561	-17.5	-741	-20.7	-1351	-14.7
8	NIEcon.EH.MSFan.CS1.DCV0	-144	-34.4	-563	-17.5	-737	-20.6	-1352	-14.7
9	IEcon.DB.MSFan.CS1.DCV0	-142	-33.9	-562	-17.5	-742	-20.7	-1351	-14.7
10	IEcon.EH.MSFan.CS1.DCV0	-144	-34.4	-563	-17.5	-738	-20.7	-1353	-14.7
11	NoEcon.MSFan.CS2.DCV0	-147	-35.1	-563	-17.5	-738	-20.7	-1354	-14.7
12	IEcon.DB.MSFan.CS2.DCV0	-142	-33.8	-561	-17.5	-733	-20.5	-1349	-14.7
13	IEcon.EH.MSFan.CS2.DCV0	-142	-33.9	-562	-17.5	-730	-20.4	-1349	-14.7
14	NoEcon.SSFan.CS1.DCV1	170	40.5	1178	36.7	1213	33.9	3196	34.7
15	IEcon.DB.SSFan.CS1.DCV1	172	41.0	1181	36.8	1218	34.1	3199	34.8
16	IEcon.EH.SSFan.CS1.DCV1	172	40.9	1180	36.7	1221	34.2	3198	34.8
17	NoEcon.MSFan.CS1.DCV1	75	17.9	846	26.3	749	20.9	2367	25.7
18	IEcon.DB.MSFan.CS1.DCV1	80	19.1	850	26.5	755	21.1	2374	25.8
19	IEcon.EH.MSFan.CS1.DCV1	79	18.8	849	26.4	758	21.2	2373	25.8
20	NoEcon.MSFan.CS2.DCV1	78	18.6	849	26.4	760	21.3	2372	25.8
21	IEcon.DB.MSFan.CS2.DCV1	81	19.2	851	26.5	762	21.3	2375	25.8
22	IEcon.EH.MSFan.CS2.DCV1	80	19.0	851	26.5	765	21.4	2375	25.8

Table D-42: Gas Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	15	0.6	15	0.3	7	0.1	6	0.0
3	NIEcon.EH.SSFan.CS1.DCV0	13	0.5	17	0.3	7	0.1	5	0.0
4	IEcon.DB.SSFan.CS1.DCV0	14	0.6	14	0.3	7	0.1	5	0.0
5	IEcon.EH.SSFan.CS1.DCV0	13	0.5	16	0.3	7	0.1	5	0.0
6	NoEcon.MSFan.CS1.DCV0	-783	-31.7	-874	-16.4	-1018	-17.5	-1485	-10.9
7	NIEcon.DB.MSFan.CS1.DCV0	-768	-31.1	-864	-16.2	-1013	-17.5	-1481	-10.9
8	NIEcon.EH.MSFan.CS1.DCV0	-770	-31.2	-862	-16.2	-1013	-17.5	-1482	-10.9
9	IEcon.DB.MSFan.CS1.DCV0	-768	-31.1	-865	-16.2	-1014	-17.5	-1481	-10.9
10	IEcon.EH.MSFan.CS1.DCV0	-771	-31.2	-863	-16.2	-1014	-17.5	-1482	-10.9
11	NoEcon.MSFan.CS2.DCV0	-774	-31.4	-864	-16.2	-1015	-17.5	-1483	-10.9
12	IEcon.DB.MSFan.CS2.DCV0	-769	-31.2	-861	-16.1	-1013	-17.5	-1481	-10.9
13	IEcon.EH.MSFan.CS2.DCV0	-769	-31.2	-860	-16.1	-1013	-17.5	-1481	-10.9
14	NoEcon.SSFan.CS1.DCV1	906	36.7	1762	33.0	2329	40.1	4758	34.9
15	IEcon.DB.SSFan.CS1.DCV1	909	36.8	1764	33.1	2331	40.2	4760	34.9
16	IEcon.EH.SSFan.CS1.DCV1	909	36.8	1766	33.1	2331	40.2	4760	34.9
17	NoEcon.MSFan.CS1.DCV1	459	18.6	1226	23.0	1760	30.3	3846	28.2
18	IEcon.DB.MSFan.CS1.DCV1	468	19.0	1230	23.1	1763	30.4	3849	28.2
19	IEcon.EH.MSFan.CS1.DCV1	467	18.9	1232	23.1	1763	30.4	3847	28.2
20	NoEcon.MSFan.CS2.DCV1	466	18.9	1233	23.1	1763	30.4	3847	28.2
21	IEcon.DB.MSFan.CS2.DCV1	468	19.0	1234	23.1	1763	30.4	3849	28.2
22	IEcon.EH.MSFan.CS2.DCV1	468	19.0	1237	23.2	1763	30.4	3849	28.2

Table D-43: Gas Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	12	0.2	6	0.0	23	0.1	18	0.2
3	NIEcon.EH.SSFan.CS1.DCV0	12	0.2	6	0.0	21	0.1	18	0.2
4	IEcon.DB.SSFan.CS1.DCV0	12	0.2	6	0.0	23	0.1	18	0.2
5	IEcon.EH.SSFan.CS1.DCV0	11	0.2	5	0.0	21	0.1	18	0.2
6	NoEcon.MSFan.CS1.DCV0	-933	-12.6	-1752	-13.1	-2079	-11.2	-1475	-13.4
7	NIEcon.DB.MSFan.CS1.DCV0	-924	-12.5	-1748	-13.0	-2068	-11.2	-1467	-13.4
8	NIEcon.EH.MSFan.CS1.DCV0	-925	-12.5	-1748	-13.0	-2069	-11.2	-1466	-13.4
9	IEcon.DB.MSFan.CS1.DCV0	-925	-12.5	-1748	-13.0	-2069	-11.2	-1467	-13.4
10	IEcon.EH.MSFan.CS1.DCV0	-925	-12.5	-1748	-13.0	-2070	-11.2	-1466	-13.4
11	NoEcon.MSFan.CS2.DCV0	-924	-12.5	-1750	-13.0	-2069	-11.2	-1462	-13.3
12	IEcon.DB.MSFan.CS2.DCV0	-922	-12.4	-1747	-13.0	-2066	-11.1	-1458	-13.3
13	IEcon.EH.MSFan.CS2.DCV0	-920	-12.4	-1747	-13.0	-2065	-11.1	-1457	-13.3
14	NoEcon.SSFan.CS1.DCV1	2478	33.4	5486	40.9	5876	31.7	3487	31.8
15	IEcon.DB.SSFan.CS1.DCV1	2482	33.5	5489	40.9	5878	31.7	3491	31.8
16	IEcon.EH.SSFan.CS1.DCV1	2483	33.5	5488	40.9	5877	31.7	3492	31.8
17	NoEcon.MSFan.CS1.DCV1	1878	25.3	4349	32.4	4643	25.0	2561	23.4
18	IEcon.DB.MSFan.CS1.DCV1	1882	25.4	4353	32.4	4648	25.1	2566	23.4
19	IEcon.EH.MSFan.CS1.DCV1	1883	25.4	4353	32.4	4647	25.1	2566	23.4
20	NoEcon.MSFan.CS2.DCV1	1884	25.4	4351	32.4	4648	25.1	2569	23.4
21	IEcon.DB.MSFan.CS2.DCV1	1886	25.4	4354	32.4	4650	25.1	2573	23.5
22	IEcon.EH.MSFan.CS2.DCV1	1889	25.5	4354	32.4	4650	25.1	2575	23.5

Table D-44: Gas Cost Savings Compared to Case 1 for the Strip Mall Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	82	0.5	84	0.4	150	0.7	1027	2.3
3	NIEcon.EH.SSFan.CS1.DCV0	81	0.5	85	0.5	149	0.7	1027	2.4
4	IEcon.DB.SSFan.CS1.DCV0	82	0.5	84	0.4	150	0.7	1026	2.3
5	IEcon.EH.SSFan.CS1.DCV0	81	0.5	84	0.4	149	0.7	1026	2.3
6	NoEcon.MSFan.CS1.DCV0	-1840	-10.4	-2648	-14.1	-2459	-11.1	-4315	-9.9
7	NIEcon.DB.MSFan.CS1.DCV0	-1763	-9.9	-2550	-13.6	-2299	-10.4	-3057	-7.0
8	NIEcon.EH.MSFan.CS1.DCV0	-1763	-10.0	-2550	-13.6	-2300	-10.4	-3057	-7.0
9	IEcon.DB.MSFan.CS1.DCV0	-1762	-9.9	-2551	-13.6	-2299	-10.4	-3058	-7.0
10	IEcon.EH.MSFan.CS1.DCV0	-1764	-10.0	-2550	-13.6	-2300	-10.4	-3058	-7.0
11	NoEcon.MSFan.CS2.DCV0	-1785	-10.1	-2603	-13.9	-2349	-10.6	-3256	-7.4
12	IEcon.DB.MSFan.CS2.DCV0	-1760	-9.9	-2541	-13.6	-2298	-10.4	-3055	-7.0
13	IEcon.EH.MSFan.CS2.DCV0	-1759	-9.9	-2540	-13.6	-2298	-10.4	-3054	-7.0
14	NoEcon.SSFan.CS1.DCV1	5227	29.5	5757	30.8	6627	29.9	11751	26.9
15	IEcon.DB.SSFan.CS1.DCV1	5230	29.5	5764	30.8	6632	29.9	11666	26.7
16	IEcon.EH.SSFan.CS1.DCV1	5230	29.5	5764	30.8	6631	29.9	11671	26.7
17	NoEcon.MSFan.CS1.DCV1	4125	23.3	3992	21.3	5026	22.7	6382	14.6
18	IEcon.DB.MSFan.CS1.DCV1	4184	23.6	4064	21.7	5142	23.2	8355	19.1
19	IEcon.EH.MSFan.CS1.DCV1	4184	23.6	4065	21.7	5142	23.2	8354	19.1
20	NoEcon.MSFan.CS2.DCV1	4160	23.5	4021	21.5	5089	23.0	8431	19.3
21	IEcon.DB.MSFan.CS2.DCV1	4186	23.6	4075	21.8	5144	23.2	8360	19.1
22	IEcon.EH.MSFan.CS2.DCV1	4187	23.6	4077	21.8	5145	23.2	8361	19.1

Table D-45: Gas Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 1, 2 and 3A

Case No	Case Name	Miami-1A		Houston-2A		Phoenix-2B		Atlanta-3A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	19	1.2	74	0.7	148	1.1	222	0.8
3	NIEcon.EH.SSFan.CS1.DCV0	18	1.2	74	0.7	149	1.1	218	0.8
4	IEcon.DB.SSFan.CS1.DCV0	19	1.2	74	0.7	148	1.1	222	0.8
5	IEcon.EH.SSFan.CS1.DCV0	18	1.2	72	0.7	149	1.1	218	0.8
6	NoEcon.MSFan.CS1.DCV0	-447	-29.8	-2255	-21.7	-2718	-20.8	-5860	-20.8
7	NIEcon.DB.MSFan.CS1.DCV0	-422	-28.1	-2143	-20.6	-2528	-19.4	-5555	-19.8
8	NIEcon.EH.MSFan.CS1.DCV0	-424	-28.3	-2147	-20.7	-2527	-19.4	-5561	-19.8
9	IEcon.DB.MSFan.CS1.DCV0	-423	-28.2	-2143	-20.6	-2532	-19.4	-5556	-19.8
10	IEcon.EH.MSFan.CS1.DCV0	-425	-28.4	-2147	-20.7	-2529	-19.4	-5562	-19.8
11	NoEcon.MSFan.CS2.DCV0	-427	-28.5	-2170	-20.9	-2551	-19.5	-5623	-20.0
12	IEcon.DB.MSFan.CS2.DCV0	-421	-28.1	-2141	-20.6	-2511	-19.2	-5549	-19.7
13	IEcon.EH.MSFan.CS2.DCV0	-422	-28.2	-2145	-20.6	-2511	-19.2	-5552	-19.7
14	NoEcon.SSFan.CS1.DCV1	495	33.0	2817	27.1	3060	23.4	7224	25.7
15	IEcon.DB.SSFan.CS1.DCV1	517	34.5	2894	27.8	3207	24.6	7445	26.5
16	IEcon.EH.SSFan.CS1.DCV1	518	34.5	2893	27.8	3208	24.6	7441	26.5
17	NoEcon.MSFan.CS1.DCV1	-26	-1.8	491	4.7	87	0.7	1227	4.4
18	IEcon.DB.MSFan.CS1.DCV1	-6	-0.4	601	5.8	260	2.0	1508	5.4
19	IEcon.EH.MSFan.CS1.DCV1	-7	-0.5	597	5.7	263	2.0	1502	5.3
20	NoEcon.MSFan.CS2.DCV1	-10	-0.7	576	5.5	241	1.8	1440	5.1
21	IEcon.DB.MSFan.CS2.DCV1	-5	-0.3	605	5.8	280	2.1	1515	5.4
22	IEcon.EH.MSFan.CS2.DCV1	-5	-0.4	602	5.8	281	2.2	1511	5.4

Table D-46: Gas Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 3B, 3C and 4A

Case No	Case Name	Los Angeles-3B		Las Vegas-3B		San Francisco-3C		Baltimore-4A	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	71	0.6	186	1.0	47	0.2	227	0.6
3	NIEcon.EH.SSFan.CS1.DCV0	71	0.6	185	1.0	46	0.2	224	0.6
4	IEcon.DB.SSFan.CS1.DCV0	70	0.6	186	1.0	46	0.2	225	0.6
5	IEcon.EH.SSFan.CS1.DCV0	70	0.6	186	1.0	46	0.2	223	0.6
6	NoEcon.MSFan.CS1.DCV0	-2894	-26.1	-3899	-20.0	-4446	-19.3	-6233	-16.5
7	NIEcon.DB.MSFan.CS1.DCV0	-2828	-25.5	-3706	-19.0	-4403	-19.1	-5865	-15.6
8	NIEcon.EH.MSFan.CS1.DCV0	-2829	-25.5	-3706	-19.0	-4403	-19.1	-5867	-15.6
9	IEcon.DB.MSFan.CS1.DCV0	-2828	-25.5	-3706	-19.0	-4404	-19.1	-5867	-15.6
10	IEcon.EH.MSFan.CS1.DCV0	-2829	-25.5	-3706	-19.0	-4405	-19.1	-5868	-15.6
11	NoEcon.MSFan.CS2.DCV0	-2842	-25.7	-3739	-19.2	-4410	-19.1	-5936	-15.7
12	IEcon.DB.MSFan.CS2.DCV0	-2826	-25.5	-3694	-19.0	-4400	-19.1	-5860	-15.5
13	IEcon.EH.MSFan.CS2.DCV0	-2826	-25.5	-3693	-19.0	-4400	-19.1	-5860	-15.5
14	NoEcon.SSFan.CS1.DCV1	3223	29.1	4353	22.4	6441	28.0	9508	25.2
15	IEcon.DB.SSFan.CS1.DCV1	3303	29.8	4540	23.3	6495	28.2	9724	25.8
16	IEcon.EH.SSFan.CS1.DCV1	3301	29.8	4539	23.3	6495	28.2	9723	25.8
17	NoEcon.MSFan.CS1.DCV1	455	4.1	92	0.5	1867	8.1	3052	8.1
18	IEcon.DB.MSFan.CS1.DCV1	527	4.8	282	1.5	1901	8.2	3401	9.0
19	IEcon.EH.MSFan.CS1.DCV1	525	4.7	282	1.4	1901	8.2	3397	9.0
20	NoEcon.MSFan.CS2.DCV1	514	4.6	250	1.3	1894	8.2	3321	8.8
21	IEcon.DB.MSFan.CS2.DCV1	529	4.8	301	1.5	1905	8.3	3406	9.0
22	IEcon.EH.MSFan.CS2.DCV1	529	4.8	301	1.5	1905	8.3	3405	9.0

Table D-47: Gas Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 4B, 4C, 5A and 5B

Case No	Case Name	Albuquerque-4B		Seattle-4C		Chicago-5A		Denver-5B	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	210	0.9	213	0.5	338	0.7	288	0.9
3	NIEcon.EH.SSFan.CS1.DCV0	210	0.9	212	0.5	333	0.7	291	0.9
4	IEcon.DB.SSFan.CS1.DCV0	209	0.9	214	0.5	337	0.7	286	0.9
5	IEcon.EH.SSFan.CS1.DCV0	210	0.9	213	0.5	333	0.7	287	0.9
6	NoEcon.MSFan.CS1.DCV0	-4726	-20.3	-6829	-16.7	-8540	-17.9	-6972	-22.0
7	NIEcon.DB.MSFan.CS1.DCV0	-4510	-19.4	-6561	-16.0	-8003	-16.8	-6684	-21.1
8	NIEcon.EH.MSFan.CS1.DCV0	-4511	-19.4	-6561	-16.0	-8009	-16.8	-6686	-21.1
9	IEcon.DB.MSFan.CS1.DCV0	-4510	-19.4	-6561	-16.0	-8003	-16.8	-6685	-21.1
10	IEcon.EH.MSFan.CS1.DCV0	-4511	-19.4	-6561	-16.0	-8009	-16.8	-6690	-21.1
11	NoEcon.MSFan.CS2.DCV0	-4555	-19.6	-6625	-16.2	-8060	-16.9	-6768	-21.4
12	IEcon.DB.MSFan.CS2.DCV0	-4496	-19.3	-6557	-16.0	-7995	-16.8	-6669	-21.1
13	IEcon.EH.MSFan.CS2.DCV0	-4497	-19.4	-6557	-16.0	-7996	-16.8	-6667	-21.1
14	NoEcon.SSFan.CS1.DCV1	5428	23.4	11096	27.1	11449	24.0	7306	23.1
15	IEcon.DB.SSFan.CS1.DCV1	5624	24.2	11306	27.6	12009	25.2	7653	24.2
16	IEcon.EH.SSFan.CS1.DCV1	5624	24.2	11305	27.6	11971	25.1	7644	24.1
17	NoEcon.MSFan.CS1.DCV1	401	1.7	3983	9.7	2640	5.5	-105	-0.3
18	IEcon.DB.MSFan.CS1.DCV1	586	2.5	4227	10.3	3485	7.3	252	0.8
19	IEcon.EH.MSFan.CS1.DCV1	587	2.5	4224	10.3	3397	7.1	241	0.8
20	NoEcon.MSFan.CS2.DCV1	546	2.4	4163	10.2	3304	6.9	156	0.5
21	IEcon.DB.MSFan.CS2.DCV1	599	2.6	4231	10.3	3524	7.4	298	0.9
22	IEcon.EH.MSFan.CS2.DCV1	599	2.6	4231	10.3	3504	7.3	298	0.9

Table D-48: Gas Cost Savings Compared to Case 1 for the Supermarket Building in Climate Zones 6, 7 and 8

Case No	Case Name	Minneapolis-6A		Helena-6B		Duluth-7		Fairbanks-8	
		Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)	Abs. ($)	Rel. (%)
2	NIEcon.DB.SSFan.CS1.DCV0	526	1.2	667	1.4	687	1.3	1310	1.3
3	NIEcon.EH.SSFan.CS1.DCV0	521	1.2	665	1.3	675	1.3	1302	1.3
4	IEcon.DB.SSFan.CS1.DCV0	526	1.2	662	1.3	687	1.3	1305	1.3
5	IEcon.EH.SSFan.CS1.DCV0	521	1.2	662	1.3	675	1.2	1295	1.3
6	NoEcon.MSFan.CS1.DCV0	-7523	-17.4	-10484	-21.2	-8977	-16.6	-13462	-13.7
7	NIEcon.DB.MSFan.CS1.DCV0	-6660	-15.4	-9478	-19.2	-7993	-14.8	-11013	-11.2
8	NIEcon.EH.MSFan.CS1.DCV0	-6684	-15.4	-9521	-19.3	-8041	-14.9	-11052	-11.3
9	IEcon.DB.MSFan.CS1.DCV0	-6660	-15.4	-9484	-19.2	-7993	-14.8	-11014	-11.2
10	IEcon.EH.MSFan.CS1.DCV0	-6684	-15.4	-9527	-19.3	-8041	-14.9	-11053	-11.3
11	NoEcon.MSFan.CS2.DCV0	-6845	-15.8	-9896	-20.1	-8345	-15.5	-11383	-11.6
12	IEcon.DB.MSFan.CS2.DCV0	-6644	-15.3	-9458	-19.2	-7994	-14.8	-10981	-11.2
13	IEcon.EH.MSFan.CS2.DCV0	-6648	-15.4	-9463	-19.2	-8003	-14.8	-10998	-11.2
14	NoEcon.SSFan.CS1.DCV1	9681	22.4	10723	21.7	11811	21.9	18577	19.0
15	IEcon.DB.SSFan.CS1.DCV1	10573	24.4	11381	23.1	12725	23.6	20137	20.5
16	IEcon.EH.SSFan.CS1.DCV1	10544	24.4	11377	23.1	12696	23.5	20127	20.5
17	NoEcon.MSFan.CS1.DCV1	2091	4.8	-146	-0.3	2896	5.4	5249	5.4
18	IEcon.DB.MSFan.CS1.DCV1	3480	8.0	1633	3.3	4461	8.3	8336	8.5
19	IEcon.EH.MSFan.CS1.DCV1	3327	7.7	1475	3.0	4282	7.9	8181	8.3
20	NoEcon.MSFan.CS2.DCV1	3090	7.1	896	1.8	3876	7.2	8643	8.8
21	IEcon.DB.MSFan.CS2.DCV1	3514	8.1	1735	3.5	4477	8.3	8392	8.6
22	IEcon.EH.MSFan.CS2.DCV1	3462	8.0	1711	3.5	4427	8.2	8361	8.5

Table D-49: Maximum Controller Installed Cost per Unit Supporting Different Retrofits for the Small Office Building Based on the Payback Period of 3 Years and the Original Utility Rates

Climate zone and Location	Multi-speed fan (Case 6 vs. Case 1)	DCV (Case 14 vs. Case 1)	Multi-speed fan + DCV (Case 18 vs. Case 4)	Multi-speed fan + DCV+ economizer (Case 22 vs. Case 1)
Miami-1A	520	219	718	1065
Houston-2A	492	176	654	904
Phoenix-2B	508	135	656	958
Atlanta-3A	446	156	588	814
Los Angeles-3B	940	0	772	1322
Las Vegas-3B	510	110	627	857
San Francisco-3C	702	0	700	944
Baltimore-4A	530	213	749	950
Albuquerque-4B	447	80	529	709
Seattle-4C	260	148	451	554
Chicago-5A	373	247	639	784
Denver-5B	491	107	611	766
Minneapolis-6A	391	226	634	773
Helena-6B	406	190	638	763
Duluth-7	372	237	660	759
Fairbanks-8	772	419	1265	1436

Table D-50: Maximum Controller Installed Cost per Unit Supporting Different Retrofits for the Stand-alone Retail Building Based on the Payback Period of 3 Years and the Original Utility Rates

Climate zone and Location	Multi-speed fan (Case 6 vs. Case 1)	DCV (Case 14 vs. Case 1)	Multi-speed fan + DCV (Case 18 vs. Case 4)	Multi-speed fan + DCV+ economizer (Case 22 vs. Case 1)
Miami-1A	3226	2690	5808	7840
Houston-2A	2862	2774	5690	7046
Phoenix-2B	2916	2797	6031	7470
Atlanta-3A	2646	3345	6099	7147
Los Angeles-3B	5275	1267	5473	7523
Las Vegas-3B	2780	2737	5892	6781
San Francisco-3C	3894	2029	5807	6428
Baltimore-4A	3141	4499	7968	8876
Albuquerque-4B	2615	2299	5151	5898
Seattle-4C	1365	4343	5745	6011
Chicago-5A	2350	4941	7771	8469
Denver-5B	2989	2964	6307	6925
Minneapolis-6A	2764	4362	7653	8320
Helena-6B	2604	4543	7872	8404
Duluth-7	2433	5136	8471	8864
Fairbanks-8	5693	9254	16037	17834

Table D-51: Maximum Controller Installed Cost per Unit Supporting Different Retrofits for the Strip Mall Building Based on the Payback Period of 3 Years and the Original Utility Rates

Climate zone and Location	Multi-speed fan (Case 6 vs. Case 1)	DCV (Case 14 vs. Case 1)	Multi-speed fan + DCV (Case 18 vs. Case 4)	Multi-speed fan + DCV+ economizer (Case 22 vs. Case 1)
Miami-1A	1493	1150	2549	3542
Houston-2A	1170	1131	2284	2859
Phoenix-2B	1177	1133	2362	2969
Atlanta-3A	1047	1370	2415	2871
Los Angeles-3B	2290	870	2348	3389
Las Vegas-3B	1185	1119	2365	2782
San Francisco-3C	1567	950	2344	2705
Baltimore-4A	1175	1813	3109	3503
Albuquerque-4B	977	945	1967	2290
Seattle-4C	428	1728	2296	2439
Chicago-5A	881	1988	3063	3369
Denver-5B	1112	1208	2438	2728
Minneapolis-6A	1062	1797	2998	3319
Helena-6B	1001	1889	3103	3391
Duluth-7	954	2141	3318	3564
Fairbanks-8	2296	4060	6111	7024

Table D-52: Maximum Controller Installed Cost per Unit Supporting Different Retrofits for the Supermarket Building Based on the Payback Period of 3 Years and the Original Utility Rates

Climate zone and Location	Multi-speed fan (Case 6 vs. Case 1)	DCV (Case 14 vs. Case 1)	Multi-speed fan + DCV (Case 18 vs. Case 4)	Multi-speed fan + DCV+ economizer (Case 22 vs. Case 1)
Miami-1A	5558	1980	7523	8949
Houston-2A	6490	2770	9545	10747
Phoenix-2B	5330	3284	8912	10137
Atlanta-3A	5585	4135	9875	10972
Los Angeles-3B	7749	1591	9216	10749
Las Vegas-3B	6248	3433	9870	10940
San Francisco-3C	6620	3252	10156	10894
Baltimore-4A	7461	5323	13196	14213
Albuquerque-4B	6179	3058	9318	10183
Seattle-4C	1862	5582	7604	8044
Chicago-5A	5224	5921	11716	12560
Denver-5B	6650	3851	10627	11423
Minneapolis-6A	5742	4896	11699	12650
Helena-6B	4966	5300	11289	12308
Duluth-7	4748	5735	11827	12732
Fairbanks-8	11593	8790	23302	26109

Table D-53: Maximum Installed Cost per Controller Unit Supporting the Retrofit from Case 4 to Case 18 to Achieve Payback Periods of 1, 3 and 5 Years as Functions of Different Utility Rates in Climate Zones 1A, 2A, 2B, and 3A

Building Type	Utility Rate Change	1A_Miami			2A_Houston			2B_Phoenix			3A_Atlanta		
		1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years
Small Office	0	239	718	1197	218	654	1089	219	656	1093	196	588	981
	5%	251	754	1257	229	686	1144	229	688	1147	206	618	1030
	10%	263	790	1316	240	719	1198	240	721	1202	216	647	1079
	-5%	227	682	1137	207	621	1035	208	623	1038	186	559	932
	-10%	215	646	1077	196	588	980	197	590	983	177	530	883
Standalone Retail	0	1936	5808	9680	1897	5690	9484	2010	6031	10051	2033	6099	10166
	5%	2033	6099	10164	1992	5975	9958	2111	6332	10554	2135	6404	10674
	10%	2130	6389	10648	2086	6259	10432	2211	6634	11056	2236	6709	11182
	-5%	1839	5518	9196	1802	5406	9010	1910	5729	9549	1931	5794	9657
	-10%	1742	5227	8712	1707	5121	8535	1809	5428	9046	1830	5490	9149
Strip Mall	0	850	2549	4248	761	2284	3806	787	2362	3937	805	2415	4025
	5%	892	2676	4460	799	2398	3996	827	2480	4134	845	2536	4227
	10%	935	2804	4673	837	2512	4186	866	2598	4330	886	2657	4428
	-5%	807	2421	4036	723	2169	3616	748	2244	3740	765	2294	3824
	-10%	765	2294	3823	685	2055	3425	709	2126	3543	725	2174	3623
Supermarket	0	2508	7523	12539	3182	9545	15909	2971	8912	14853	3292	9875	16459
	5%	2633	7899	13166	3341	10023	16705	3119	9357	15596	3456	10369	17282
	10%	2758	8275	13792	3500	10500	17500	3268	9803	16338	3621	10863	18105
	-5%	2382	7147	11912	3023	9068	15114	2822	8466	14110	3127	9382	15636
	-10%	2257	6771	11285	2864	8591	14318	2674	8021	13368	2963	8888	14813

Table D-54: Maximum Installed Cost per Controller Unit Supporting the Retrofit from Case 4 to Case 18 to Achieve Payback Periods of 1, 3 and 5 Years as Functions of Different Utility Rates in Climate Zones 3B, 3C, and 4A

Building Type	Utility Rate Change	3B_Los_Angeles			3B_Las_Vegas			3C_San_Francisco			4A_Baltimore		
		1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years
Small Office	0	257	772	1287	209	627	1044	233	700	1166	250	749	1248
	5%	270	811	1351	219	658	1097	245	735	1224	262	786	1311
	10%	283	849	1415	230	689	1149	257	770	1283	275	824	1373
	-5%	244	733	1222	198	595	992	222	665	1108	237	711	1186
	-10%	232	695	1158	188	564	940	210	630	1049	225	674	1123
Standalone Retail	0	1824	5473	9121	1964	5892	9820	1936	5807	9679	2656	7968	13280
	5%	1915	5746	9577	2062	6187	10311	2033	6098	10163	2789	8366	13944
	10%	2007	6020	10033	2161	6482	10803	2129	6388	10646	2922	8765	14608
	-5%	1733	5199	8665	1866	5598	9329	1839	5517	9195	2523	7570	12616
	-10%	1642	4926	8209	1768	5303	8838	1742	5226	8711	2390	7171	11952
Strip Mall	0	783	2348	3913	788	2365	3942	781	2344	3906	1036	3109	5182
	5%	822	2465	4109	828	2483	4139	820	2461	4101	1088	3265	5441
	10%	861	2583	4305	867	2602	4336	859	2578	4297	1140	3420	5700
	-5%	744	2231	3718	749	2247	3745	742	2226	3711	985	2954	4923
	-10%	704	2113	3522	710	2129	3548	703	2109	3515	933	2798	4664
Supermarket	0	3072	9216	15360	3290	9870	16450	3385	10156	16927	4399	13196	21994
	5%	3226	9677	16128	3455	10364	17273	3555	10664	17773	4619	13856	23094
	10%	3379	10138	16896	3619	10857	18095	3724	11172	18619	4839	14516	24193
	-5%	2918	8755	14592	3126	9377	15628	3216	9648	16080	4179	12537	20894
	-10%	2765	8295	13824	2961	8883	14805	3047	9140	15234	3959	11877	19795

Table D-55: Maximum Installed Cost per Controller Unit Supporting the Retrofit from Case 4 to Case 18 to Achieve Payback Periods of 1, 3 and 5 Years as Functions of Different Utility Rates in Climate Zones 4B, 4C, 5A, and 5B

Building Type	Utility Rate Change	4B_Albuquerque			4C_Seattle			5A_Chicago			5B_Boulder		
		1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years
Small Office	0	176	529	881	150	451	752	213	639	1065	204	611	1018
	5%	185	555	925	158	474	789	224	671	1119	214	641	1069
	10%	194	582	969	165	496	827	234	703	1172	224	672	1120
	-5%	167	502	837	143	428	714	202	607	1012	193	580	967
	-10%	159	476	793	135	406	677	192	575	959	183	550	916
Standalone Retail	0	1717	5151	8585	1915	5745	9576	2590	7771	12951	2102	6307	10512
	5%	1803	5408	9014	2011	6033	10054	2720	8159	13599	2207	6622	11037
	10%	1889	5666	9443	2107	6320	10533	2849	8548	14246	2313	6938	11563
	-5%	1631	4893	8155	1819	5458	9097	2461	7382	12303	1997	5992	9986
	-10%	1545	4636	7726	1724	5171	8618	2331	6994	11656	1892	5676	9461
Strip Mall	0	656	1967	3278	765	2296	3827	1021	3063	5105	813	2438	4063
	5%	688	2065	3442	804	2411	4019	1072	3216	5360	853	2559	4266
	10%	721	2164	3606	842	2526	4210	1123	3369	5616	894	2681	4469
	-5%	623	1869	3114	727	2182	3636	970	2910	4850	772	2316	3860
	-10%	590	1770	2950	689	2067	3445	919	2757	4595	731	2194	3656
Supermarket	0	3106	9318	15531	2535	7604	12673	3905	11716	19527	3542	10627	17712
	5%	3261	9784	16307	2661	7984	13307	4101	12302	20504	3720	11159	18598
	10%	3417	10250	17084	2788	8364	13941	4296	12888	21480	3897	11690	19484
	-5%	2951	8852	14754	2408	7224	12040	3710	11131	18551	3365	10096	16827
	-10%	2796	8387	13978	2281	6844	11406	3515	10545	17574	3188	9565	15941

Table D-56: Maximum Installed Cost per Controller Unit Supporting the Retrofit from Case 4 to Case 18 to Achieve Payback Periods of 1, 3 and 5 Years as Functions of Different Utility Rates in Climate Zones 6A, 6B, 7 and 8

Building Type	Utility Rate Change	6A_Minneapolis			6B_Helena			7A_Duluth			8A_Fairbanks		
		1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years
Small Office	0	211	634	1056	213	638	1064	220	660	1100	422	1265	2108
	5%	222	665	1109	223	670	1117	231	693	1155	443	1328	2213
	10%	232	697	1162	234	702	1170	242	726	1210	464	1391	2318
	-5%	201	602	1003	202	606	1011	209	627	1045	400	1201	2002
	-10%	190	570	950	191	574	957	198	594	990	379	1138	1897
Standalone Retail	0	2551	7653	12756	2624	7872	13120	2824	8471	14118	5346	16037	26729
	5%	2679	8036	13393	2755	8265	13776	2965	8895	14824	5613	16839	28065
	10%	2806	8419	14031	2886	8659	14432	3106	9318	15530	5880	17641	29401
	-5%	2424	7271	12118	2493	7478	12464	2682	8047	13412	5078	15235	25392
	-10%	2296	6888	11480	2362	7085	11808	2541	7624	12706	4811	14433	24056
Strip Mall	0	999	2998	4997	1034	3103	5171	1106	3318	5531	2037	6111	10185
	5%	1049	3148	5247	1086	3258	5430	1161	3484	5807	2139	6417	10695
	10%	1099	3298	5497	1138	3413	5688	1217	3650	6084	2241	6722	11204
	-5%	949	2848	4747	983	2948	4913	1051	3153	5254	1935	5806	9676
	-10%	899	2698	4497	931	2792	4654	996	2987	4978	1833	5500	9167
Supermarket	0	3900	11699	19498	3763	11289	18815	3942	11827	19712	7767	23302	38837
	5%	4095	12284	20473	3951	11854	19756	4140	12419	20698	8156	24467	40779
	10%	4290	12869	21448	4139	12418	20697	4337	13010	21683	8544	25632	42721
	-5%	3705	11114	18523	3575	10725	17874	3745	11236	18727	7379	22137	36895
	-10%	3510	10529	17548	3387	10160	16934	3548	10645	17741	6991	20972	34953

Table D-57: Maximum Installed Cost per Controller Unit Supporting the Retrofit from Case 1 to Case 22 to Achieve Payback Periods of 1, 3 and 5 Years as Functions of Different Utility Rates in Climate Zones 1A, 2A, 2B, and 3A

Building Type	Utility Rate Change	Miami-1A			Houston-2A			Phoenix-2B			Atlanta-3A		
		1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years
Small Office	0	355	1065	1774	301	904	1506	319	958	1597	271	814	1357
	5%	373	1118	1863	316	949	1581	335	1006	1677	285	855	1425
	10%	390	1171	1952	331	994	1657	351	1054	1757	299	896	1493
	-5%	337	1011	1686	286	858	1431	303	910	1517	258	774	1290
	-10%	319	958	1597	271	813	1355	288	863	1438	244	733	1222
Stand-alone Retail	0	2613	7840	13066	2349	7046	11744	2490	7470	12450	2382	7147	11911
	5%	2744	8232	13720	2466	7399	12331	2614	7843	13072	2501	7504	12506
	10%	2875	8624	14373	2584	7751	12918	2739	8217	13695	2620	7861	13102
	-5%	2483	7448	12413	2231	6694	11157	2365	7096	11827	2263	6789	11315
	-10%	2352	7056	11760	2114	6342	10569	2241	6723	11205	2144	6432	10720
Strip Mall	0	1181	3542	5904	953	2859	4765	990	2969	4948	957	2871	4785
	5%	1240	3719	6199	1001	3002	5003	1039	3117	5195	1005	3015	5024
	10%	1299	3896	6494	1048	3145	5241	1089	3266	5443	1053	3158	5264
	-5%	1122	3365	5608	905	2716	4527	940	2820	4700	909	2728	4546
	-10%	1063	3188	5313	858	2573	4288	891	2672	4453	861	2584	4307
Supermarket	0	2983	8949	14914	3582	10747	17911	3379	10137	16896	3657	10972	18287
	5%	3132	9396	15660	3761	11284	18807	3548	10644	17740	3840	11521	19202
	10%	3281	9843	16406	3941	11822	19703	3717	11151	18585	4023	12070	20116
	-5%	2834	8501	14169	3403	10209	17016	3210	9631	16051	3475	10424	17373
	-10%	2685	8054	13423	3224	9672	16120	3041	9124	15206	3292	9875	16459

Table D-58: Maximum Installed Cost per Controller Unit Supporting the Retrofit from Case 1 to Case 22 to Achieve Payback Periods of 1, 3 and 5 Years as Functions of Different Utility Rates in Climate Zones 3B, 3C and 4A

Building Type	Utility Rate Change	Los Angeles-3B			Las Vegas-3B			San Francisco-3C			Baltimore-4A		
		1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years
Small Office	0	441	1322	2203	286	857	1428	315	944	1573	317	950	1583
	5%	463	1388	2313	300	900	1500	330	991	1652	332	997	1662
	10%	485	1454	2424	314	943	1571	346	1038	1731	348	1045	1741
	-5%	419	1256	2093	271	814	1357	299	897	1495	301	902	1504
	-10%	397	1190	1983	257	771	1286	283	850	1416	285	855	1425
Stand-alone Retail	0	2508	7523	12539	2260	6781	11302	2143	6428	10713	2959	8876	14793
	5%	2633	7899	13166	2374	7121	11868	2250	6749	11249	3107	9320	15533
	10%	2759	8276	13793	2487	7460	12433	2357	7071	11785	3254	9763	16272
	-5%	2382	7147	11912	2147	6442	10737	2036	6107	10178	2811	8432	14053
	-10%	2257	6771	11285	2034	6103	10172	1928	5785	9642	2663	7988	13314
Strip Mall	0	1130	3389	5648	927	2782	4637	902	2705	4509	1168	3503	5838
	5%	1186	3558	5931	974	2921	4868	947	2841	4734	1226	3678	6130
	10%	1243	3728	6213	1020	3060	5100	992	2976	4960	1284	3853	6422
	-5%	1073	3219	5366	881	2643	4405	857	2570	4283	1109	3328	5546
	-10%	1017	3050	5083	835	2504	4173	812	2435	4058	1051	3153	5255
Supermarket	0	3583	10749	17915	3647	10940	18233	3631	10894	18157	4738	14213	23688
	5%	3762	11286	18811	3829	11487	19144	3813	11439	19065	4974	14923	24872
	10%	3941	11824	19706	4011	12034	20056	3995	11984	19973	5211	15634	26057
	-5%	3404	10211	17019	3464	10393	17321	3450	10350	17249	4501	13502	22504
	-10%	3225	9674	16123	3282	9846	16410	3268	9805	16341	4264	12791	21319

Table D-59: Maximum Installed Cost per Controller Unit Supporting the Retrofit from Case 1 to Case 22 to Achieve Payback Periods of 1, 3 and 5 Years as Functions of Different Utility Rates in Climate Zones 4B, 4C, 5A, and 5B

Building Type	Utility Rate Change	Albuquerque-4B			Seattle-4C			Chicago-5A			Boulder-5B		
		1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years
Small Office	0	236	709	1181	185	554	923	261	784	1307	255	766	1276
	5%	248	744	1240	194	581	969	275	824	1373	268	804	1340
	10%	260	780	1299	203	609	1015	288	863	1438	281	842	1404
	-5%	224	673	1122	175	526	877	248	745	1242	242	727	1212
	-10%	213	638	1063	166	498	831	235	706	1177	230	689	1149
Stand-alone Retail	0	1966	5898	9830	2004	6011	10019	2823	8469	14114	2308	6925	11541
	5%	2064	6193	10322	2104	6312	10520	2964	8892	14820	2424	7271	12118
	10%	2163	6488	10813	2204	6612	11021	3105	9316	15526	2539	7617	12695
	-5%	1868	5603	9339	1904	5711	9518	2682	8045	13409	2193	6578	10964
	-10%	1769	5308	8847	1803	5410	9017	2541	7622	12703	2077	6232	10387
Strip Mall	0	763	2290	3817	813	2439	4065	1123	3369	5614	909	2728	4547
	5%	801	2404	4007	854	2561	4268	1179	3537	5895	955	2865	4775
	10%	840	2519	4198	894	2683	4472	1235	3705	6176	1000	3001	5002
	-5%	725	2175	3626	772	2317	3862	1067	3200	5334	864	2592	4320
	-10%	687	2061	3435	732	2195	3659	1011	3032	5053	819	2456	4093
Supermarket	0	3394	10183	16972	2681	8044	13406	4187	12560	20933	3808	11423	19038
	5%	3564	10692	17821	2815	8446	14076	4396	13188	21980	3998	11994	19990
	10%	3734	11202	18669	2949	8848	14747	4605	13816	23027	4188	12565	20942
	-5%	3225	9674	16123	2547	7642	12736	3977	11932	19887	3617	10852	18086
	-10%	3055	9165	15275	2413	7239	12066	3768	11304	18840	3427	10281	17134

Table D-60: Maximum Installed Cost per Controller Unit Supporting the Retrofit from Case 1 to Case 22 to Achieve Payback Periods of 1, 3 and 5 Years as Functions of Different Utility Rates in Climate Zones 6A, 6B, 7 and 8

Building Type	Utility Rate Change	Minneapolis-6A			Helena-6B			Duluth-7			Fairbanks-8		
		1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years
Small Office	0	258	773	1289	254	763	1271	253	759	1266	479	1436	2393
	5%	271	812	1353	267	801	1335	266	797	1329	503	1508	2513
	10%	284	851	1418	280	839	1398	278	835	1392	526	1579	2632
	-5%	245	735	1224	242	725	1208	240	721	1202	455	1364	2273
	-10%	232	696	1160	229	686	1144	228	683	1139	431	1292	2154
Stand-alone Retail	0	2773	8320	13866	2801	8404	14007	2955	8864	14773	5945	17834	29724
	5%	2912	8736	14559	2941	8824	14707	3102	9307	15512	6242	18726	31210
	10%	3051	9152	15253	3082	9245	15408	3250	9750	16251	6539	19618	32696
	-5%	2635	7904	13173	2661	7984	13307	2807	8421	14035	5647	16942	28237
	-10%	2496	7488	12479	2521	7564	12606	2659	7978	13296	5350	16051	26751
Strip Mall	0	1106	3319	5532	1130	3391	5652	1188	3564	5940	2341	7024	11707
	5%	1162	3485	5809	1187	3561	5935	1247	3742	6237	2458	7375	12292
	10%	1217	3651	6085	1243	3730	6217	1307	3921	6534	2576	7727	12878
	-5%	1051	3153	5255	1074	3222	5369	1129	3386	5643	2224	6673	11122
	-10%	996	2987	4979	1017	3052	5087	1069	3208	5346	2107	6322	10536
Supermarket	0	4217	12650	21083	4103	12308	20513	4244	12732	21221	8703	26109	43514
	5%	4427	13282	22137	4308	12923	21539	4456	13369	22282	9138	27414	45690
	10%	4638	13915	23191	4513	13539	22565	4669	14006	23343	9573	28719	47866
	-5%	4006	12017	20029	3898	11693	19488	4032	12096	20160	8268	24803	41338
	-10%	3795	11385	18974	3692	11077	18462	3820	11459	19099	7833	23498	39163

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