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Retrofitting Buildings with Solar-Reflective Roofs and Exterior Walls and their Impact on Energy Savings and Peak Power Demand

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Buildings and Transportation Science Division

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ABSTRACT

Buildings are a major consumer of electricity in the United States and a significant portion of the consumption comes from heating, ventilation, and air-conditioning (HVAC) applications. Passive cooling strategies in the building envelope help to reduce the energy consumption for HVAC as well as peak electricity demand. Although being one of the most cost-effective passive cooling strategies, modern reflective roofing and reflective exterior wall technology is not well documented for its impact on peak demand. This study utilized whole building energy simulations on residential and commercial building prototype models to quantify the impact of cool roofs and cool exterior walls. The analysis was performed in three climate zones with varying insulation levels and solar reflectances for roofs and exterior walls. For both the residential and commercial buildings, the baseline building had a roof solar reflectance value of 0.10 and an exterior wall solar reflectance value of 0.25. The results from the simulations show that roofs and exterior walls with higher reflectance values increase cooling energy savings but can also increase heating energy consumption. The impact of changes in solar reflectances was greater in buildings with low roof/wall insulation levels compared to roofs/walls with higher insulation levels. A baseline for the simulations was set with the roof and exterior wall solar reflectances set at 0.1 and 0.25, respectively and simulations having varying roof and exterior wall thermal resistances were compared to the baselines.

For the residential cases that were simulated, the annual demand savings compared to the baseline for Houston, Baltimore, and Minneapolis ranged from $1 - $119, $1 - $80, and $0 - $29, respectively, while the annual total savings (energy plus demand) compared to the baseline for Houston, Baltimore, and Minneapolis ranged from $7 - $308, -$2 - $83, and -$21 - $4, respectively. For the commercial cases that were simulated, the annual demand savings compared to the baseline for Houston, Baltimore, and Minneapolis ranged from $33 - $1,704, $35 - $1,272, and $11 - $589, respectively, while the annual total savings (energy plus demand) compared to the baseline for Houston, Baltimore, and Minneapolis ranged from $67 - $3,810, $69 - $1,510, and -$296 - $294, respectively. See Tables 18 through 23 for more complete details.

1. INTRODUCTION

Buildings consume approximately 74% of the electricity generated in the United States (US EIA 2019). A sharp peak in electrical demand can be observed in almost every building during the busiest hours of the day. Although a share of this peak may be attributed to equipment used in the building, a significant portion is caused by increased demand for air conditioning in the late afternoon/early evening. The peak in demand requires additional power plant capacity; causes more demand than supply in the power grid, requiring the utility to purchase power at typically higher rates to satisfy the demand; and may result in increased air pollution. Most importantly, for the building owner or tenants, excessive peak demand might result in monthly expenses that are many times greater than basic electrical rates. One of the most effective ways to reduce peak demand is to lower the heat load on a building, particularly the solar load that drives the need for air conditioning. Few passive heat reduction strategies can match the energy-savings potential of modern reflective roofing technology. Energy impacts of solar-reflective exterior walls are less well documented, which the Cool Roof Rating Council (CRRC) research efforts seek to address. The mission of the CRRC is to bring objective, scientific information related to cool surfaces to critical discussions and informed decisions about the impacts of heat islands, extreme heat, and energy use in the built environment.

To help building owners and designers become more cognizant of the energy and economic impact of peak electrical demand, this research quantifies the reductions in peak demand and economic costs associated with cool roofs and cool exterior wall technologies. This information is especially important since few articles to date on building energy savings have adequately addressed peak demand issues.

The impact of cool roofs and cool exterior walls on peak cooling load and the resulting peak power demand is important to the CRRC and its membership. Part of the CRRC's mission is to conduct research into energy-related radiative properties of roof and exterior wall surfaces. In 2019, the CRRC membership approved changing the organization's scope to include the rating of exterior wall products, with the CRRC Wall Rating Program launching in January 2022. This change signaled a shift to consider the building envelope holistically when researching the benefits of reflective surfaces.

This report summarizes an investigation into how retrofitting buildings with cool roofs and cool exterior walls affects the buildings' peak power demand, A series of EnergyPlus whole building simulations using prototypical commercial and residential buildings were performed, and variables such as climate, roof and exterior wall solar reflectance, roof and exterior wall thermal resistance ("R-value"), building type, and building vintage studied. Using demand surcharge rates from utilities, the demand reductions were also converted into cost savings benefits for the building owner.

2. SIMULATION MATRIX INCLUDING R-VALUE ASSUMPTIONS

The simulations were conducted with different roof and exterior wall solar reflectances and different insulation levels for residential and commercial buildings. The matrix for performing simulation with various parameters is shown in Table 1. This matrix was developed by the CRRC project review team and was presented to the CRRC Board of Directors and the Technical Committee on 2 February and 16 February 2023, respectively. Both bodies approved the modeling matrix.

Table 1. Simulation matrix with variation in roof and exterior wall properties.

Variable Name	Number of variations	Inputs	
		Residential	Commercial
Roof solar reflectance	3	0.1, 0.25, 0.4	0.1, 0.4, 0.7
Wall solar reflectance	3	0.25, 0.4, 0.6	
Roof insulation level	2	IECC 2006	IECC 2006, IECC 2021
Wall insulation level	2	None, IECC 2021	
Climate	3	Zone 2 (Houston), Zone 4 (Baltimore), Zone 6 (Minneapolis)	

3. BUILDING DESCRIPTIONS INCLUDING DEFAULTS FOR OTHER BUILDING PARAMETERS AND EQUIPMENT EFFICIENCIES

For this modeling effort, two building types were used to represent a typical residential and commercial building.

Residential building: The IECC 2021 residential prototype building model used for energy simulation was a two-story single-family home with a crawl space as the foundation and a natural gas system for heating (PNNL 2019b). The building has a footprint of 1188 ft^2. The attic insulation was changed for the building to the IECC 2006 insulation level as described in the matrix in Table 1. Some basic characteristics of the residential building used for the energy simulations are listed in Table 2 and the geometry of the building is shown in Figure 1. The window and exterior wall properties of these buildings vary by climate zone. The window properties are left as-is for the simulation and the changes in the exterior wall properties are discussed in the later portion of this report. Additional characteristics of the

building model not listed in this report are available from the Pacific Northwest National Laboratory (PNNL 2019b).

Table 2. Characteristics of the residential prototype building model.

Building Characteristic	Value
Floor area	Two Story Conditioned: 2377 ft^2
Window-to-wall ratio	15% for conditioned space
Foundation type	Crawlspace
Cooling system	Split system with COP ~4
Heating system	Gas furnace with efficiency 0.8
Number of occupants	2
Ventilation type	Exhaust
Heating/Cooling setpoint	72ºF/ 75ºF

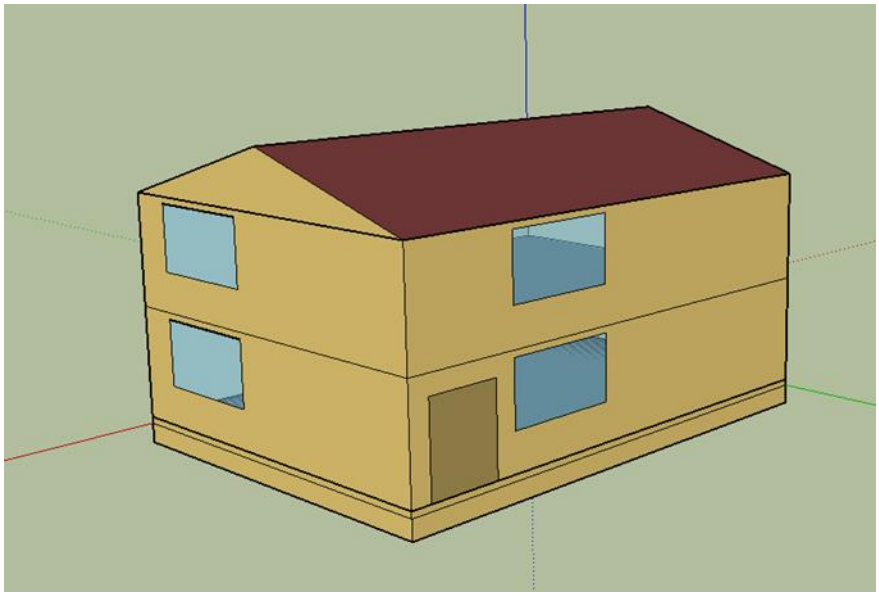

Figure 1. Geometry of residential prototype buildings (single-family home) used for the energy simulation.

Commercial building: For the commercial building, the IECC 2021 prototype standalone retail building was chosen for the EnergyPlus simulations (PNNL 2019a). The major characteristics of this building are listed in Table 3 and the geometry of the building is shown in Figure 2. Additional information on the building model is available at (PNNL 2019a).

Table 3. Characteristics of commercial prototype building model

Building Characteristic	Value
Floor area	Total/Conditioned: ~ 24700 ft^2
Window-to-wall ratio	7.1%
Cooling system	Packaged air conditioner with multistate cooling coil
Heating system	Gas furnace inside the packaged air conditioning unit

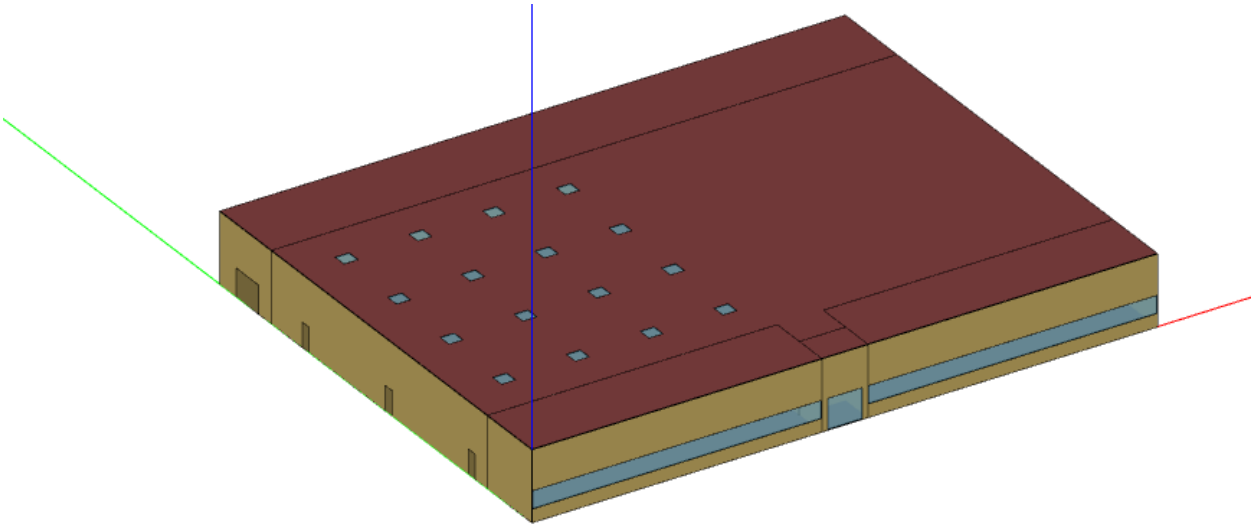

Figure 2. Geometry of commercial prototype buildings (standalone retail) used for the energy simulation.

The roof and exterior wall insulation levels were modified to match different insulation levels as listed in Table 1 for their respective simulations. The R-value of roofs and exterior walls at the different insulation levels are shown in Table 4. The table shows the R-value of exterior walls with no insulation and IECC 2021 insulation levels for both residential and commercial buildings for three climate zones where the simulations were performed. For roof insulation, the residential building only utilized R-values corresponding to IECC 2006; the commercial building utilized the R-values corresponding to both IECC 2006 and IECC 2021. R-value data is depicted with and without boundary layer air films and the table contains those values for an interior and exterior windspeed 0.5 and 15 miles per hour. EnergyPlus updates these values on an hourly basis based on the windspeed reported in the weather data file.

Table 4. R-value for roofs and exterior walls for different code requirements.

	Code	Climate Zone	R-value ($ft^2 \cdot h \cdot °F/Btu$)			
			Residential		Commercial	
			Without air films	With air films	Without air films	With air films
Wall	None	2	2.1	3.0	1.4	2.3
		4	2.1	3.0	1.4	2.3
		6	2.1	3.0	1.4	2.3
	IECC 2021	2	14.1	14.9	7.1	8.0
		4	24.4	25.0	11.0	11.8
		6	24.4	25.0	14.5	15.4
Roof	IECC 2006	2	30.3	32.3	14.9	15.9
		4	38.5	40.0	14.9	15.9
		6	50.0	50.0	20.0	20.8
	IECC 2021	2	–	–	25.0	25.6
		4	–	–	30.3	31.3
		6	–	–	30.3	31.3

4. BRIEF ENERGYPLUS DESCRIPTION

EnergyPlus (US Department of Energy 2021), the whole building energy simulation tool developed by the US DOE, was used to perform the energy simulations. Note that EnergyPlus does not account for the possibility of snow on roofs; this limitation may impact the performance of the roofing assembly in climate zones with snow accumulation. The energy simulations were performed using all of the possible combinations of the parameters listed in Table 1. This resulted in 54 energy simulations for the residential building (single-family home) and 108 energy simulations for the commercial (standalone retail) building. For the varying climate zones, roof and exterior wall solar reflectance levels for the baseline case were the simulation with the lowest exterior wall and roof reflectance values (i.e., cases when the wall reflectance was 0.25 and the roof reflectance was 0.1, respectively). While determining the energy savings, peak load reduction, and cost savings calculation comparisons were made with the baseline case using the same combination of location and roof and exterior wall insulation. Electricity, natural gas, and electricity demand charges were compiled for the cities that were modeled. The average annual energy prices from the Energy Information Administration for 2022 were used for this purpose. To obtain electricity demand charges, the Open EI Utility Rate database (https://openei.org/wiki/Utility_Rate_Database) was used. It was discovered that utilities impose several demand charges. To address this issue, a "high" and "low" demand charge for each region was used. The rates of electricity and natural gas for energy consumption and the rate of peak pricing for different locations are provided in Table 5.

Table 5. Electricity, natural gas, and demand charges.

Building	Climate Zone	Electricity ($/kWh)	Natural Gas ($/1000 ft^3)	Peak demand ($/kW)	
				high	low
Residential	2	0.1385	14.95	15	10
	4	0.1415	17.08	15	10
	6	0.1281	13.19	10	5
Commercial	2	0.0927	9.85	15	10
	4	0.1084	11.24	15	10
	6	0.1041	10.77	10	5

5. RESULTS

5.1 ENERGY SAVINGS AND PEAK DEMAND REDUCTION

5.1.1 Energy savings

The energy consumption data was utilized to analyze the energy savings or penalties by comparing the simulation to the appropriate baseline case for different roof and exterior wall insulations and building locations. The results for residential buildings are provided in Figures 3 and 4. The results for commercial buildings are shown in Figures 5 through 8. In these figures, the information is provided for HVAC-related electricity and natural gas consumption, and savings compared to the baseline case. In the sub-figures with savings, a positive value represents energy savings and a negative value represents energy penalty. For both building types, the electricity consumption decreased while the natural gas consumption increased with increases in roof and/or exterior wall solar reflectance. For example, in Figure 3, the electricity savings were less than 100 kWh when the exterior wall reflectance was 0.25 (blue bars) when

the roof reflectance increased to 0.4 from 0.1, and at least 900 kWh when the exterior wall reflectance increased to 0.60 from 0.25 for all value of roof reflectances. It can also be seen that the energy savings do not vary significantly for the selected levels of roof reflectance because of high attic insulation levels (IECC 2006). This phenomenon can also be seen in Figure 4 (wall with IECC 2021 insulation), where both the energy consumption and difference (savings/penalty) from the baseline case was lower compared to Figure 3 (wall with no insulation) When exterior walls have no insulation, the "best case" reduction in electricity consumption was 1,813 kWh in Houston, 1,282 kWh in Baltimore, and 926kWh in Minneapolis with 0.60 exterior wall reflectance and 0.40 roof reflectance. For the same scenarios in Houston, Baltimore, and Minneapolis, the electricity savings were 440 kWh, 201 kWh, and 179 kWh respectively for the cases that had IECC 2021 exterior wall insulation levels.

When the solar reflectance increases, the building absorbs less heat from the solar radiation, resulting in increases in natural gas consumption during heating periods. The increase in natural gas consumption or heating penalty was also lower for exterior walls having IECC 2021 insulation compared with exterior walls without insulation.

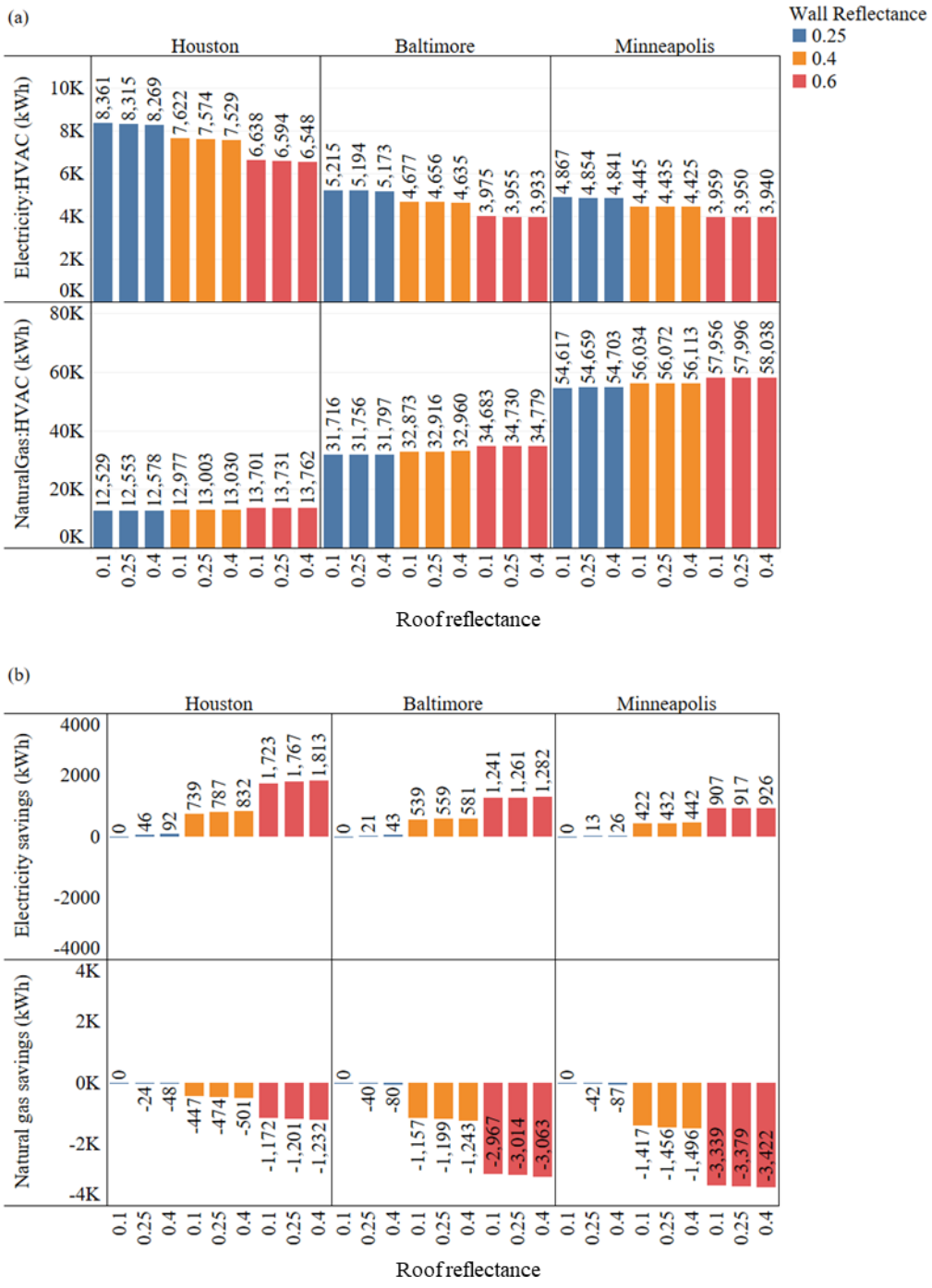

Figure 3. Electricity and natural gas for HVAC application (residential building without wall insulation): (a) consumption (b) savings.

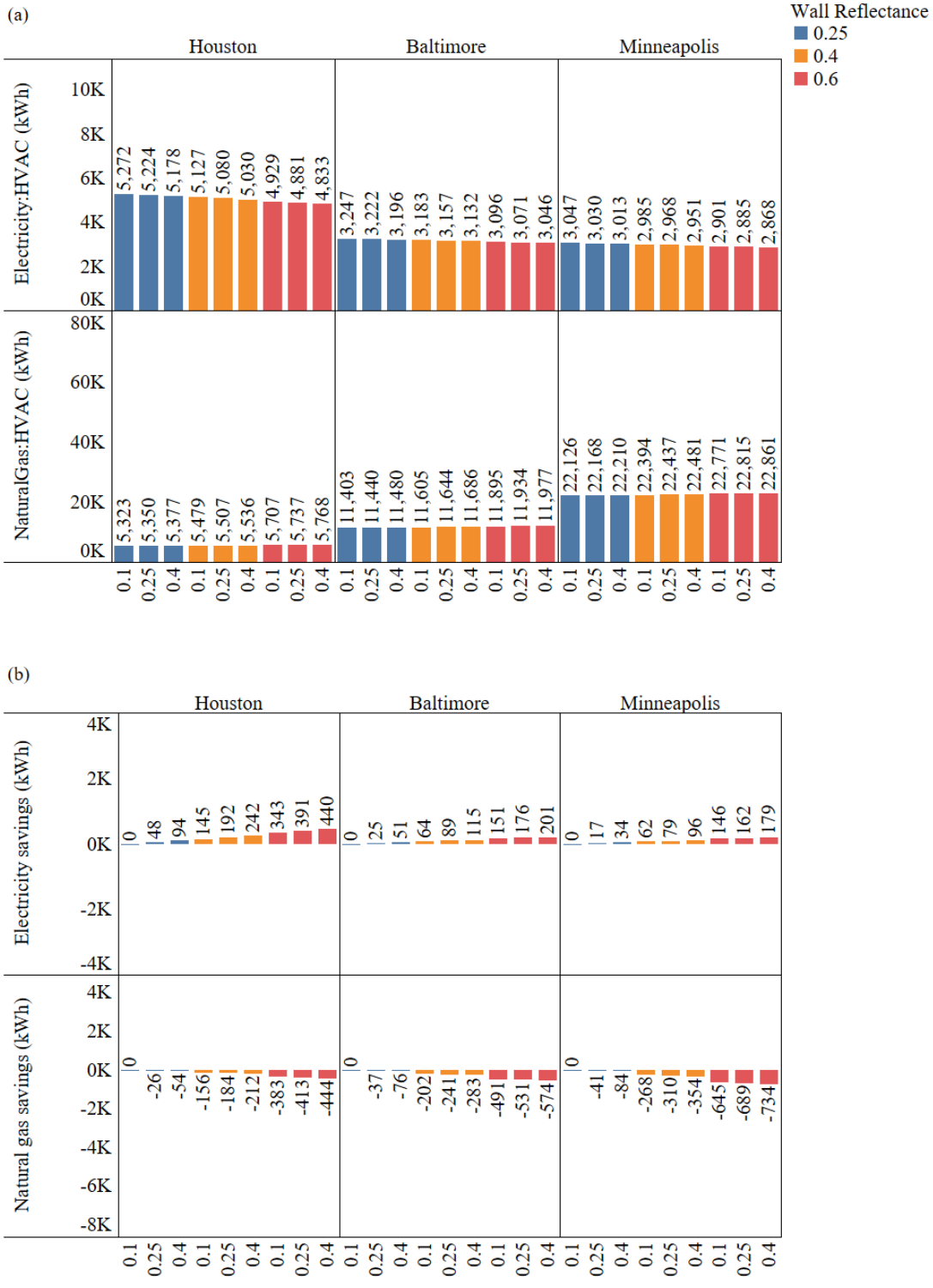

Figure 4. Electricity and natural gas for HVAC application (residential building with IECC 2021 wall insulation): (a) consumption (b) savings.

Similar to residential buildings, commercial building electricity consumption decreased, and natural gas consumption increased when roof and exterior wall solar reflectivity increased. However, in the case of commercial buildings, the changes in electricity savings and natural gas increases were higher due to changes in solar reflectance when compared with residential buildings. The reason for this behavior is likely due to the higher levels of solar reflectance for commercial roofs and the lower R-values for commercial roofs compared to the residential attic insulation R-value. The highest electricity savings were seen for buildings with low insulation levels (no wall insulation and IECC 2006 roof insulation), where the highest electricity savings were 27,618 kWh, 15,710 kWh, and 10,693respectively for Houston, Baltimore, and Minneapolis (Figure 5). Increases in natural gas consumption were also highest for this case compared to buildings with higher insulation levels for roofs and/or exterior walls. The increase in natural gas consumption was 13,744 kWh, 39,014 kWh, and 44,731 kWh % respectively for Houston, Baltimore, and Minneapolis for simulations with 0.60 exterior wall solar reflectance and 0.70 roof solar reflectance. For simulations with the highest insulation levels (both roof and exterior wall at IECC 2021 levels), the greatest electricity savings were 13,508 kWh, 7,578 kWh, and 4,434 kWh respectively for Houston, Baltimore, and Minneapolis. The increase in natural gas for these cases were 4,352 kWh, 12,180 kWh, and 15,197 kWh respectively for Houston, Baltimore, and Minneapolis (Figure 8).

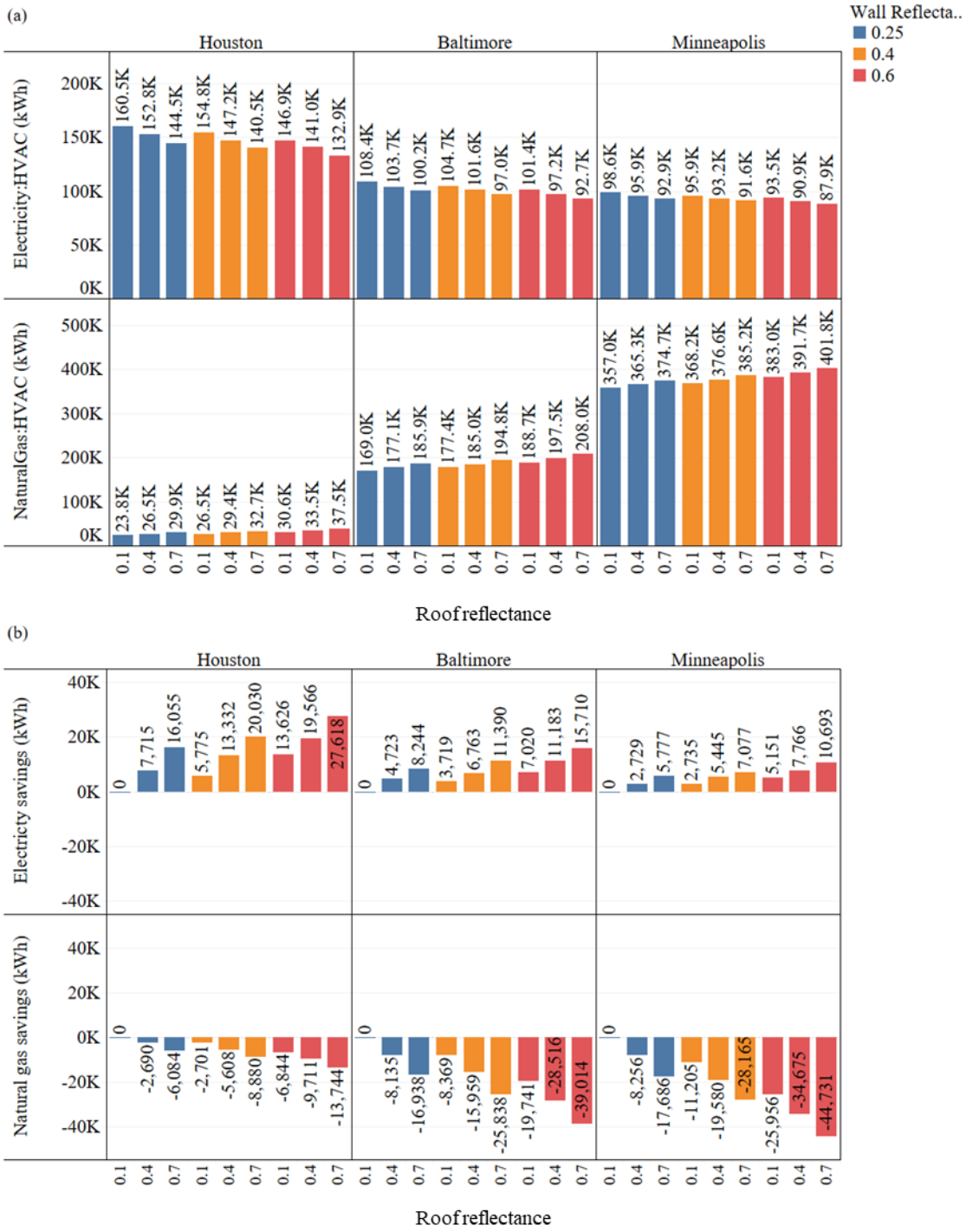

Figure 5. Electricity and natural gas for HVAC application (commercial building without wall insulation and IECC 2006 roof insulation): (a) consumption (b)savings

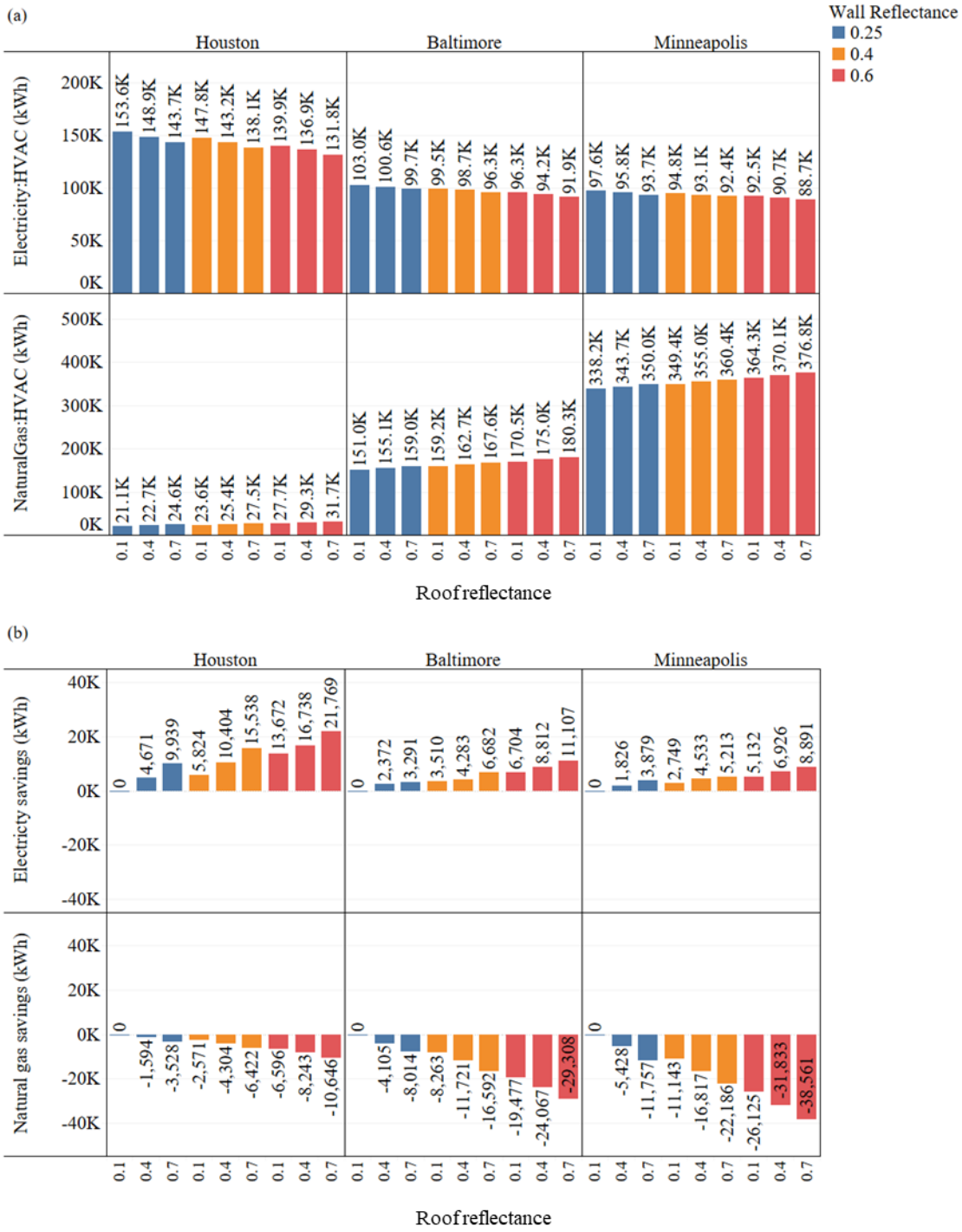

Figure 6. Electricity and natural gas for HVAC application (commercial building without wall insulation and IECC 2021 roof insulation): (a) consumption (b)savings

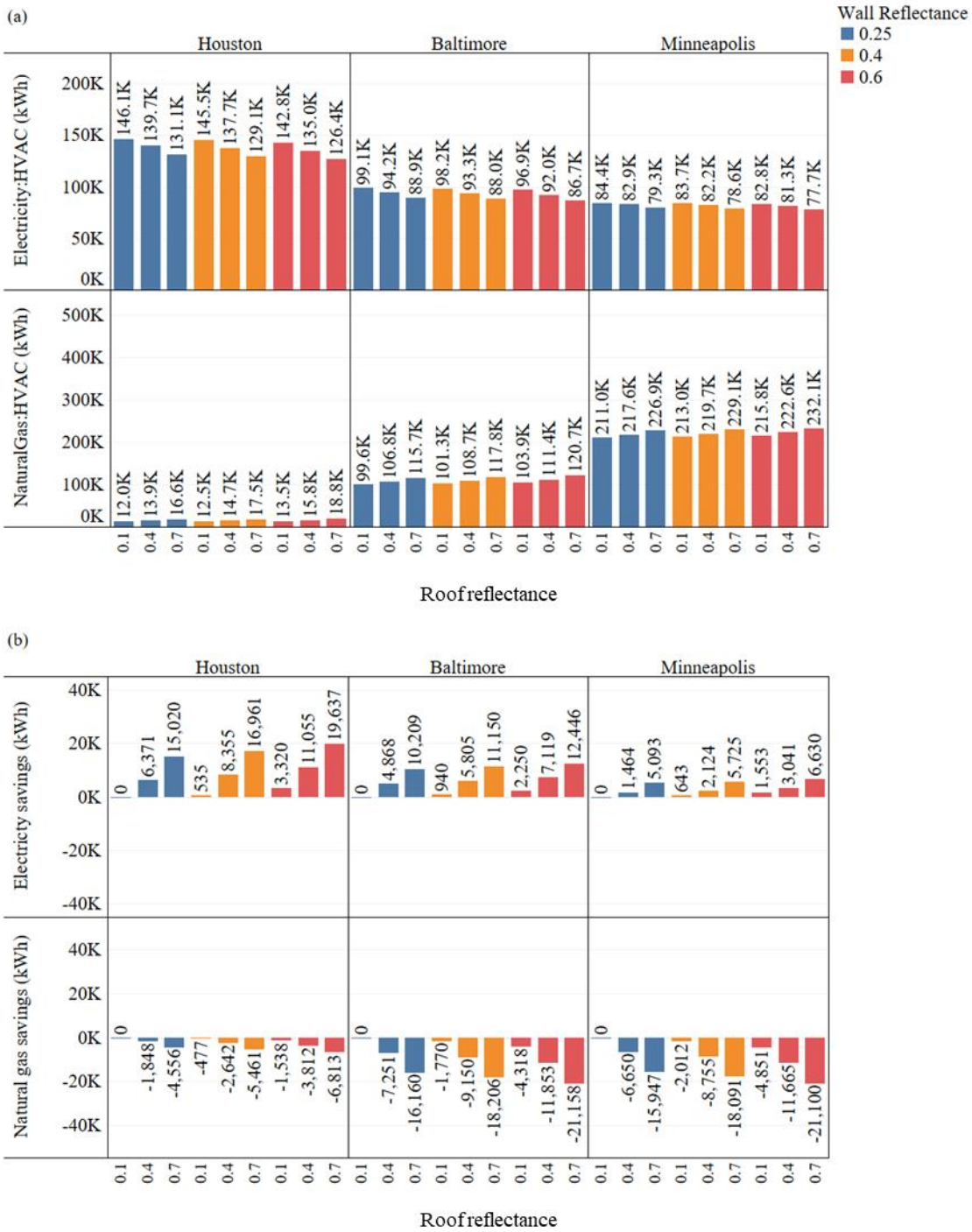

Figure 7. Electricity and natural gas for HVAC application (commercial building with IECC 2021 wall insulation and IECC 2006 roof insulation): (a) consumption (b)savings

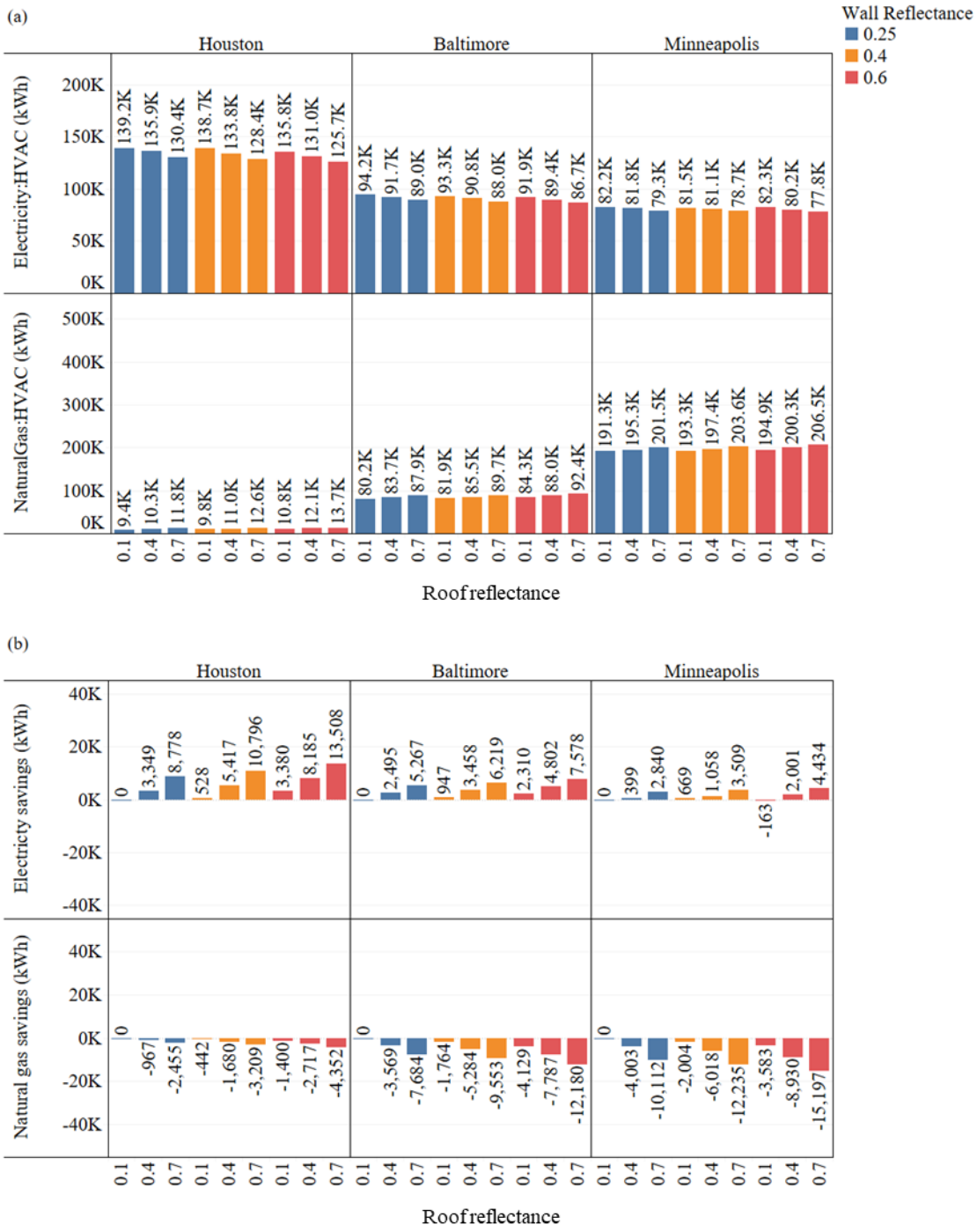

Figure 8. Electricity and natural gas for HVAC application (commercial building with IECC 2021 wall insulation and IECC 2021 roof insulation): (a) consumption (b)savings

5.1.2 Peak demand reduction

The monthly peak electricity use for different roof and exterior wall solar reflectances was compared for the same combination of roof and exterior wall insulations and building locations. The monthly peak was chosen to be the maximum of 15-minute averages of power consumption during each month. The results for the peak demand are shown in Figures 9 through 14 and Tables 6 through 11. Tables 12 through 17

summarize the reductions in peak demand from the baseline cases. In the figures, the line colors represent the exterior wall solar reflectance level, dash line styles represent roof solar reflectance levels, and the combination of line color and style represents that combination of exterior wall and roof reflectance.

In residential buildings (Figures 9 and 10 and Tables 6, 7, 12, and 13), the peak electricity demand is highest for the cases with the lowest roof and exterior wall solar reflectance. It can also be seen in these figures that the peak electricity load is always highest during the summer months, when cooling demand is maximized. While examining the impacts of roof vs. exterior wall solar reflectance, the differences in peak demand are higher due to a variation in exterior wall solar reflectance compared with a variation in roof solar reflectance. This can be clearly seen in Figure 9, where the lines of different dash styles with the same color are close to each other compared to lines with different colors. It is presumed that the variation in exterior wall solar reflectance has a greater impact because these modeled wall assemblies are uninsulated, causing wall solar reflectance to have a greater effect on the building's peak demand. When insulation is added to the modeled wall systems (Figure 10), the impact of exterior wall solar reflectance on the peak demand is comparatively less.

Similar to the residential buildings results, in commercial buildings the peak load reduction is greatest for buildings with the highest wall and roof solar reflectance. When the wall has no insulation (Figures 11-12), the peak electricity demand is similarly affected by changes in wall solar reflectance when the roof has either IECC 2006 or IECC 2021 level insulation values. With IECC 2021 wall insulation levels (Figures 13-14), peak electricity load reduction is greater with changes in roof solar reflectance compared to wall solar reflectance. For example, in Figure 13, all solid lines (roof solar reflectance = 0.1) are close to each other for varying wall solar reflectances (different colors) but lines depicting varying roof solar reflectance (different dash styles) are substantially different.

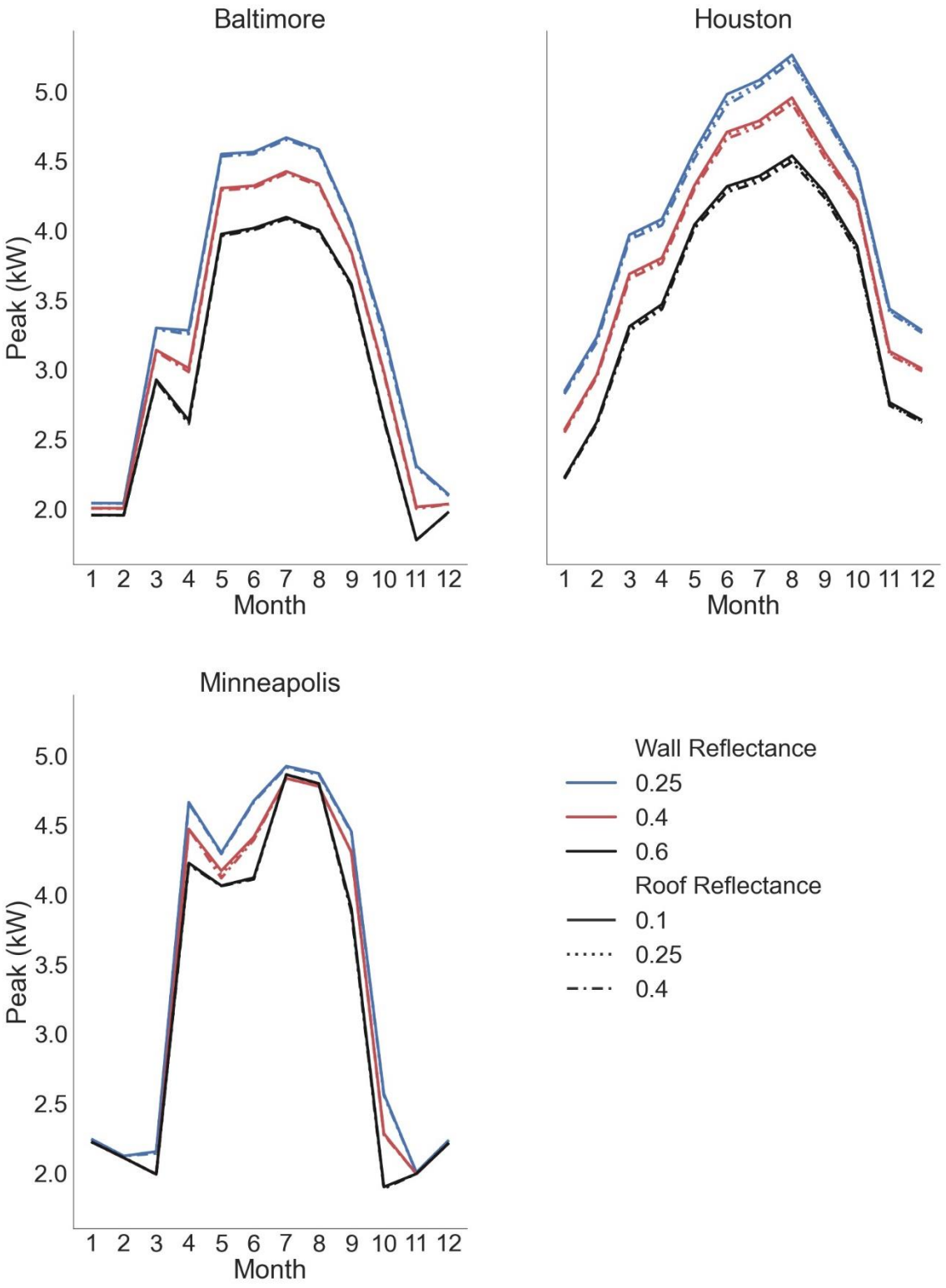

Figure 9. Peak demand for varying roof and exterior wall solar reflectance levels (residential building without wall insulation).

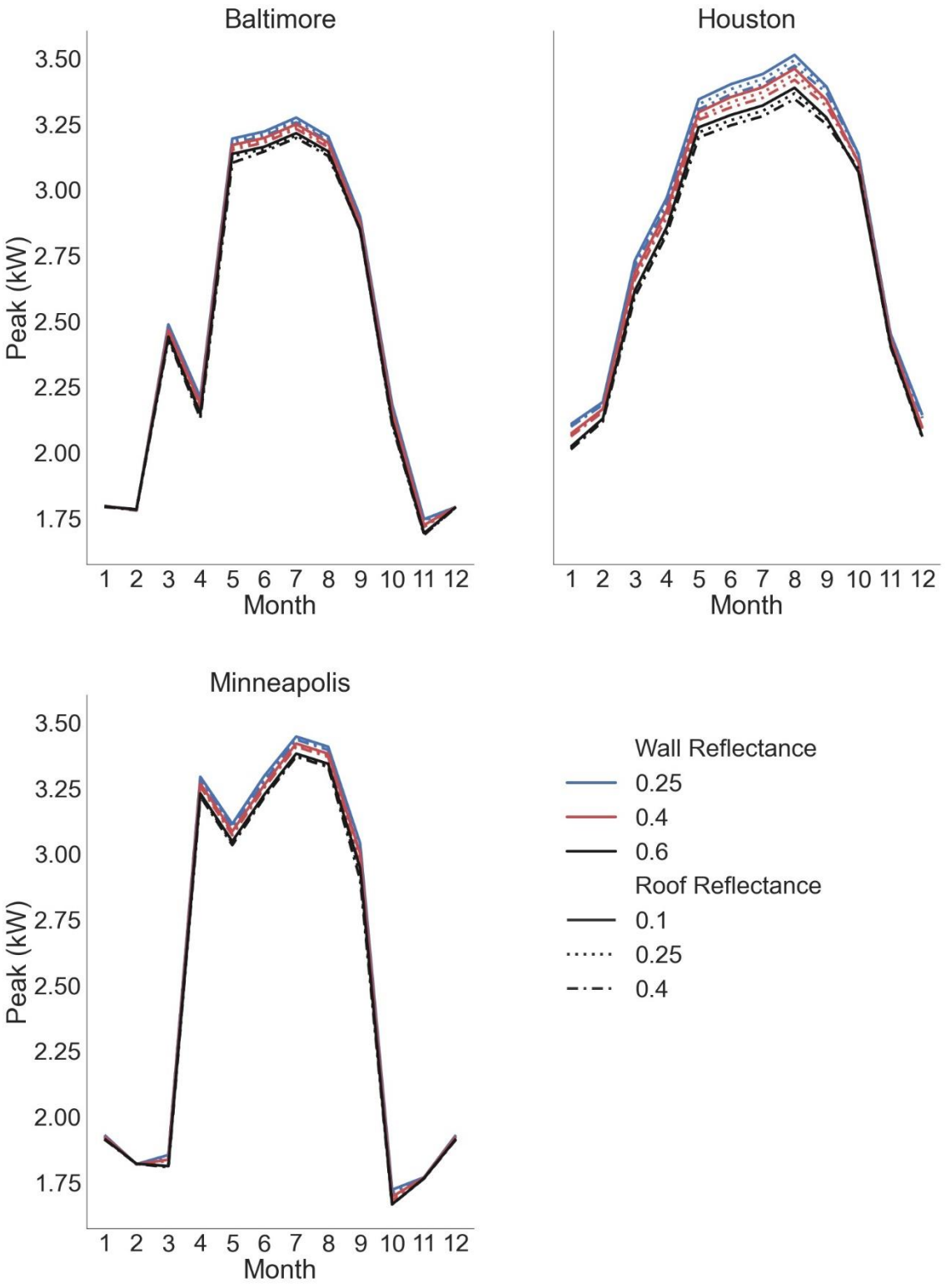

Figure 10. Peak demand for varying roof and exterior wall solar reflectance levels (residential building with IECC 2021 wall insulation).

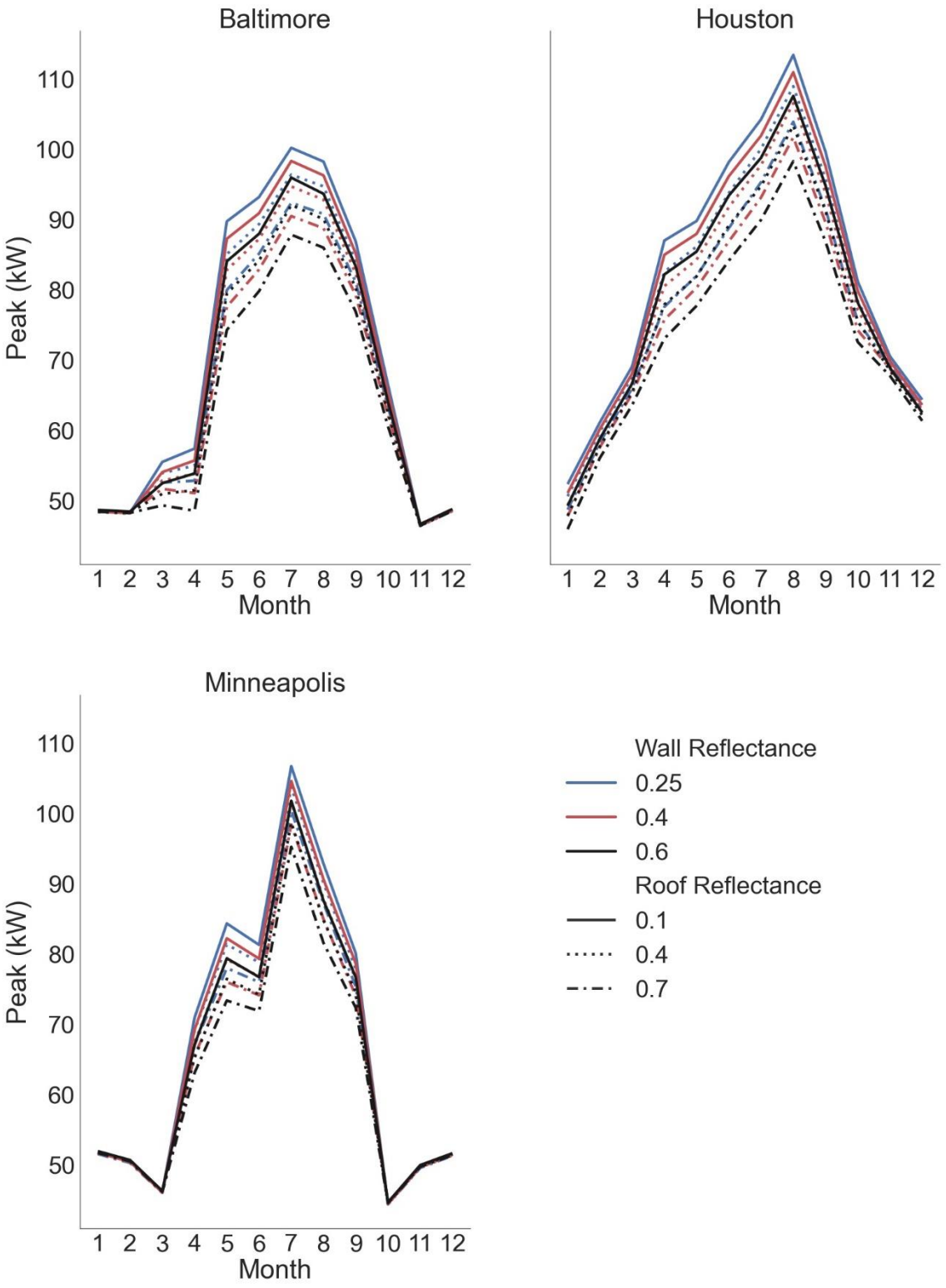

Figure 11. Peak demand for varying roof and exterior wall solar reflectance levels (commercial building without wall insulation and IECC 2006 roof insulation).

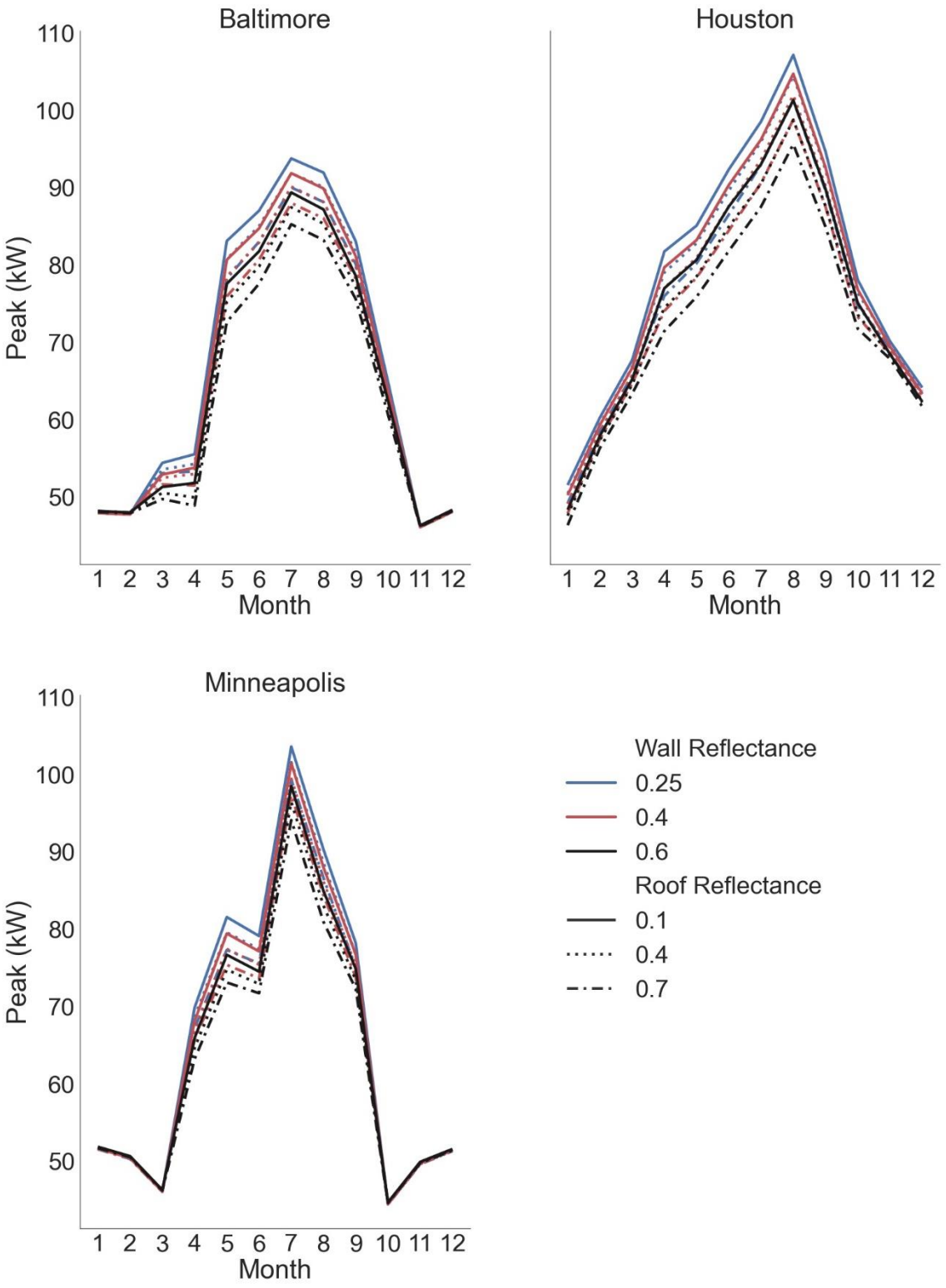

Figure 12. Peak demand for varying roof and exterior wall solar reflectance levels (commercial building without wall insulation and IECC 2021 roof insulation).

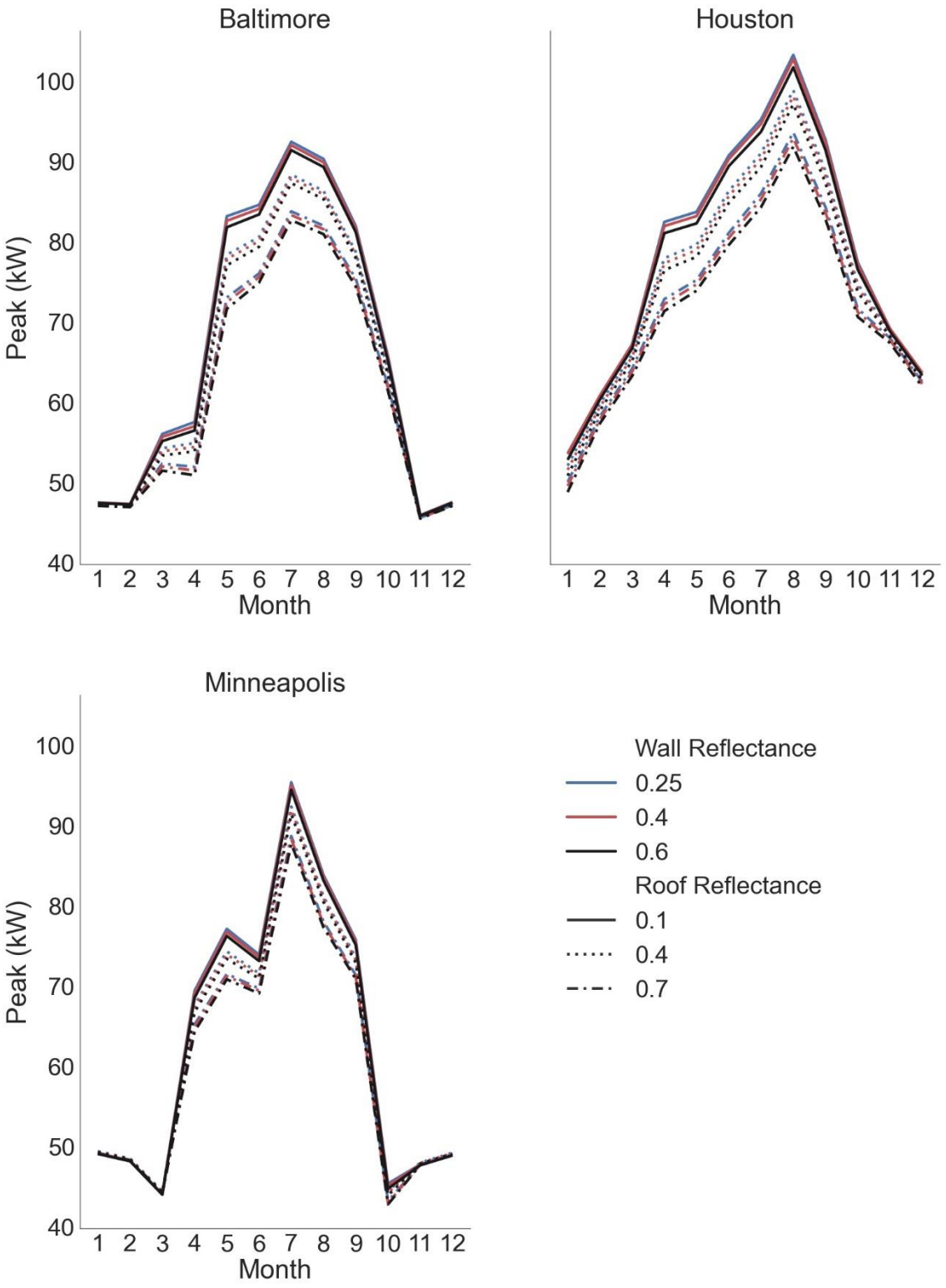

Figure 13. Peak demand for varying roof and exterior wall solar reflectance levels (commercial building with IECC 2021 wall insulation and IECC 2006 roof insulation).

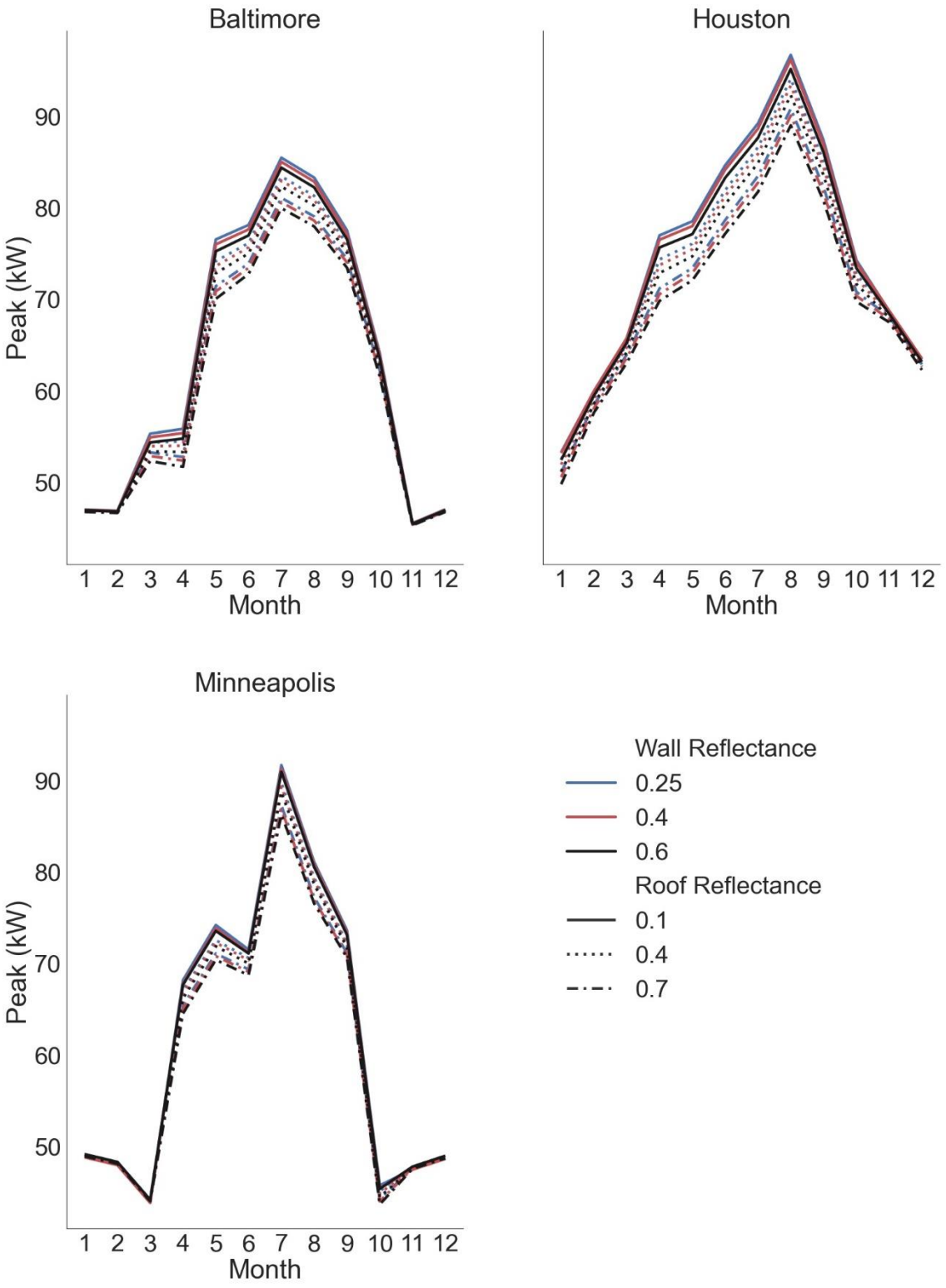

Figure 14. Peak demand for varying roof and exterior wall solar reflectance levels (commercial building with IECC 2021 wall insulation and IECC 2021 roof insulation).

Table 6. Peak demand for varying roof and exterior wall solar reflectance levels (residential building without wall insulation).

City	Solar Reflectance, Percent		Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	2.84	3.23	3.97	4.08	4.57	4.98	5.08	5.26	4.86	4.44	3.44	3.28	4.17
	0.40	0.10	2.57	2.96	3.69	3.80	4.32	4.71	4.79	4.95	4.56	4.22	3.13	3.01	3.89
	0.60	0.10	2.22	2.62	3.31	3.47	4.04	4.32	4.39	4.54	4.28	3.89	2.76	2.64	3.54
	0.25	0.25	2.83	3.21	3.95	4.06	4.54	4.93	5.06	5.24	4.84	4.43	3.42	3.27	4.15
	0.40	0.25	2.56	2.95	3.67	3.78	4.31	4.69	4.77	4.93	4.54	4.20	3.12	3.00	3.88
	0.60	0.25	2.22	2.61	3.29	3.45	4.03	4.30	4.37	4.52	4.26	3.87	2.75	2.63	3.52
	0.25	0.40	2.82	3.20	3.93	4.04	4.51	4.90	5.04	5.22	4.82	4.42	3.41	3.26	4.13
	0.40	0.40	2.55	2.94	3.65	3.76	4.30	4.66	4.75	4.91	4.52	4.19	3.10	2.99	3.86
	0.60	0.40	2.21	2.61	3.28	3.43	4.01	4.27	4.35	4.49	4.24	3.85	2.74	2.62	3.51
Baltimore	0.25	0.10	2.04	2.04	3.30	3.28	4.55	4.56	4.67	4.58	4.06	3.27	2.31	2.10	3.40
	0.40	0.10	2.00	2.00	3.14	3.01	4.30	4.32	4.42	4.33	3.84	2.99	2.01	2.03	3.20
	0.60	0.10	1.95	1.95	2.93	2.63	3.97	4.02	4.10	4.00	3.62	2.65	1.77	1.98	2.96
	0.25	0.25	2.04	2.04	3.29	3.27	4.54	4.56	4.66	4.57	4.05	3.26	2.30	2.09	3.39
	0.40	0.25	2.00	2.00	3.13	2.99	4.30	4.31	4.42	4.33	3.84	2.98	2.00	2.03	3.20
	0.60	0.25	1.95	1.95	2.92	2.62	3.97	4.01	4.09	3.99	3.61	2.64	1.77	1.98	2.96
	0.25	0.40	2.04	2.04	3.29	3.25	4.53	4.55	4.65	4.57	4.04	3.24	2.29	2.09	3.38
	0.40	0.40	2.00	2.00	3.13	2.98	4.29	4.31	4.41	4.32	3.84	2.97	2.00	2.03	3.19
	0.60	0.40	1.95	1.95	2.92	2.61	3.96	4.00	4.08	3.99	3.60	2.63	1.77	1.97	2.95
Minneapolis	0.25	0.10	2.24	2.12	2.15	4.66	4.30	4.67	4.92	4.87	4.45	2.57	2.00	2.23	3.43
	0.40	0.10	2.22	2.11	1.99	4.47	4.17	4.41	4.84	4.78	4.31	2.28	1.99	2.21	3.32
	0.60	0.10	2.22	2.11	1.99	4.23	4.06	4.12	4.86	4.80	3.90	1.90	1.99	2.21	3.20
	0.25	0.25	2.24	2.12	2.15	4.66	4.30	4.67	4.92	4.87	4.45	2.56	2.00	2.23	3.43
	0.40	0.25	2.22	2.11	1.99	4.47	4.14	4.40	4.84	4.78	4.30	2.28	1.99	2.21	3.31
	0.60	0.25	2.22	2.11	1.99	4.22	4.06	4.12	4.86	4.80	3.89	1.89	1.99	2.21	3.20
	0.25	0.40	2.24	2.12	2.14	4.66	4.29	4.66	4.91	4.86	4.45	2.56	2.00	2.23	3.43
	0.40	0.40	2.22	2.11	1.99	4.47	4.12	4.39	4.84	4.78	4.30	2.27	1.99	2.21	3.31
	0.60	0.40	2.22	2.11	1.99	4.21	4.06	4.11	4.86	4.80	3.87	1.89	1.99	2.21	3.19

Table 7. Peak demand for varying roof and exterior wall solar reflectance levels (residential building with IECC 2021 wall insulation).

City	Solar Reflectance, Percent		Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	2.11	2.19	2.73	2.97	3.34	3.40	3.44	3.51	3.39	3.13	2.45	2.14	2.90
	0.40	0.10	2.07	2.16	2.68	2.92	3.29	3.35	3.39	3.46	3.34	3.10	2.43	2.09	2.86
	0.60	0.10	2.02	2.13	2.62	2.86	3.24	3.28	3.32	3.39	3.27	3.07	2.41	2.06	2.80
	0.25	0.25	2.10	2.19	2.72	2.96	3.32	3.38	3.42	3.49	3.38	3.13	2.45	2.14	2.89
	0.40	0.25	2.07	2.16	2.67	2.91	3.28	3.33	3.37	3.44	3.34	3.10	2.43	2.09	2.85
	0.60	0.25	2.02	2.12	2.60	2.84	3.22	3.26	3.30	3.37	3.27	3.07	2.41	2.06	2.79
	0.25	0.40	2.10	2.18	2.71	2.94	3.30	3.36	3.40	3.47	3.37	3.13	2.45	2.13	2.88
	0.40	0.40	2.06	2.15	2.66	2.89	3.27	3.31	3.35	3.42	3.32	3.10	2.43	2.09	2.84
	0.60	0.40	2.01	2.12	2.59	2.83	3.20	3.24	3.28	3.34	3.25	3.08	2.40	2.05	2.78
Baltimore	0.25	0.10	1.80	1.78	2.49	2.21	3.19	3.22	3.27	3.20	2.90	2.18	1.75	1.79	2.48
	0.40	0.10	1.80	1.78	2.47	2.18	3.17	3.20	3.25	3.18	2.87	2.16	1.72	1.79	2.46
	0.60	0.10	1.79	1.78	2.44	2.15	3.14	3.16	3.21	3.15	2.84	2.12	1.69	1.79	2.44
	0.25	0.25	1.80	1.78	2.48	2.20	3.18	3.21	3.26	3.19	2.89	2.18	1.74	1.79	2.48
	0.40	0.25	1.79	1.78	2.46	2.17	3.16	3.19	3.24	3.17	2.87	2.15	1.72	1.79	2.46
	0.60	0.25	1.79	1.78	2.43	2.14	3.13	3.15	3.21	3.14	2.84	2.11	1.69	1.79	2.43
	0.25	0.40	1.79	1.78	2.48	2.19	3.18	3.20	3.26	3.19	2.88	2.17	1.74	1.79	2.47
	0.40	0.40	1.79	1.78	2.46	2.16	3.15	3.18	3.23	3.16	2.86	2.14	1.72	1.79	2.45
	0.60	0.40	1.79	1.78	2.43	2.13	3.10	3.14	3.20	3.13	2.85	2.11	1.69	1.79	2.43
Minneapolis	0.25	0.10	1.93	1.82	1.85	3.29	3.11	3.30	3.45	3.41	3.04	1.72	1.77	1.93	2.55
	0.40	0.10	1.92	1.82	1.84	3.27	3.09	3.26	3.42	3.38	3.00	1.70	1.77	1.92	2.53
	0.60	0.10	1.92	1.82	1.81	3.23	3.05	3.22	3.38	3.34	2.95	1.67	1.77	1.92	2.51
	0.25	0.25	1.93	1.82	1.85	3.29	3.11	3.28	3.44	3.40	3.02	1.71	1.77	1.93	2.55
	0.40	0.25	1.92	1.82	1.83	3.26	3.08	3.26	3.41	3.37	2.98	1.69	1.77	1.92	2.53
	0.60	0.25	1.91	1.82	1.81	3.22	3.04	3.22	3.38	3.34	2.92	1.67	1.76	1.91	2.50
	0.25	0.40	1.93	1.82	1.85	3.28	3.10	3.28	3.43	3.39	2.99	1.71	1.77	1.93	2.54
	0.40	0.40	1.92	1.82	1.83	3.26	3.07	3.25	3.41	3.37	2.95	1.68	1.77	1.92	2.52
	0.60	0.40	1.91	1.82	1.81	3.22	3.03	3.21	3.37	3.33	2.90	1.67	1.76	1.91	2.50

Table 8. Peak demand for varying roof and exterior wall solar reflectance levels (commercial building without wall insulation and IECC 2006 roof insulation).

City	Solar Reflectance, Percent		Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	52.3	61.1	69.0	87.0	89.7	98.1	104.2	113.4	99.6	81.1	70.5	64.3	82.5
	0.40	0.10	51.0	60.1	68.0	84.9	87.9	96.1	101.9	110.9	97.5	79.8	69.8	63.6	81.0
	0.60	0.10	49.2	58.8	66.6	82.1	85.4	93.4	98.7	107.5	94.8	78.1	68.8	62.5	78.8
	0.25	0.40	50.6	59.8	67.6	82.5	86.1	93.7	100.0	108.9	95.8	78.3	69.9	63.6	79.7
	0.40	0.40	49.3	58.8	66.6	80.5	84.2	91.7	97.7	106.5	93.7	77.1	69.2	62.9	78.2
	0.60	0.40	47.8	57.7	65.4	77.9	81.9	89.1	94.7	103.3	91.1	75.5	68.5	62.1	76.2
	0.25	0.70	48.7	58.2	65.9	77.5	81.9	88.7	95.3	103.9	91.4	75.4	69.1	62.9	76.6
	0.40	0.70	47.7	57.5	65.1	75.7	80.3	86.8	93.1	101.6	89.6	74.2	68.7	62.4	75.2
	0.60	0.70	45.9	56.0	63.5	73.0	77.7	84.1	89.9	98.3	86.8	72.5	67.7	61.3	73.1
Baltimore	0.25	0.10	48.5	48.2	55.5	57.4	89.7	93.1	100.2	98.2	86.8	66.5	46.5	48.7	69.9
	0.40	0.10	48.4	48.1	54.0	55.7	87.2	90.8	98.3	96.2	85.1	65.3	46.4	48.5	68.7
	0.60	0.10	48.6	48.4	52.4	53.8	84.0	87.9	95.9	93.6	83.3	64.0	46.6	48.7	67.3
	0.25	0.40	48.3	48.1	53.9	54.9	85.0	89.3	96.3	94.7	84.1	64.9	46.3	48.5	67.9
	0.40	0.40	48.6	48.3	52.8	53.8	82.8	87.2	94.7	92.8	82.2	63.9	46.6	48.7	66.9
	0.60	0.40	48.5	48.3	50.9	51.4	79.4	84.1	92.0	90.0	80.2	62.4	46.5	48.6	65.2
	0.25	0.70	48.4	48.3	52.5	52.8	79.9	85.1	92.3	90.7	81.0	63.3	46.5	48.6	65.8
	0.40	0.70	48.4	48.2	51.6	51.0	77.5	82.8	90.4	88.7	79.2	62.1	46.4	48.6	64.6
	0.60	0.70	48.4	48.2	49.3	48.5	74.2	79.8	87.8	85.9	76.8	60.5	46.4	48.5	62.9
Minneapolis	0.25	0.10	51.7	50.4	46.1	70.9	84.3	81.3	106.7	92.8	80.0	44.4	49.7	51.5	67.5
	0.40	0.10	51.7	50.4	46.0	69.2	82.2	79.3	104.6	90.6	78.6	44.4	49.7	51.4	66.5
	0.60	0.10	51.9	50.6	46.2	67.1	79.3	76.7	101.7	87.5	76.6	44.6	49.9	51.6	65.3
	0.25	0.40	51.6	50.3	46.0	69.1	81.3	78.8	103.7	90.1	77.8	44.4	49.6	51.4	66.2
	0.40	0.40	51.6	50.3	46.0	67.3	79.2	76.8	101.6	87.8	76.3	44.3	49.6	51.3	65.2
	0.60	0.40	51.8	50.5	46.2	65.2	76.4	74.2	98.7	84.7	74.5	44.6	49.8	51.5	64.0
	0.25	0.70	51.5	50.2	46.0	67.0	77.9	76.0	100.3	87.2	75.3	44.3	49.5	51.2	64.7
	0.40	0.70	51.7	50.5	46.2	65.5	76.0	74.1	98.4	84.9	74.0	44.6	49.8	51.5	63.9
	0.60	0.70	51.6	50.4	46.1	63.0	73.3	71.8	95.2	81.5	72.3	44.5	48.7	51.3	62.6

Table 9. Peak demand for varying roof and exterior wall solar reflectance levels (commercial building without wall insulation and IECC 2021 roof insulation).

City	Solar Reflectance, Percent		Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	51.5	60.2	67.7	81.7	85.1	92.3	98.5	107.1	94.6	78.0	70.1	64.1	79.3
	0.40	0.10	50.2	59.3	66.7	79.7	83.2	90.3	96.2	104.7	92.6	76.8	69.4	63.4	77.7
	0.60	0.10	48.3	57.9	65.2	77.0	80.6	87.5	93.0	101.3	89.8	75.1	68.4	62.3	75.5
	0.25	0.40	50.4	59.4	66.7	79.0	82.8	89.6	95.9	104.4	92.3	76.4	69.7	63.7	77.5
	0.40	0.40	49.1	58.4	65.7	77.0	80.9	87.6	93.6	101.9	90.2	75.1	69.0	63.0	76.0
	0.60	0.40	47.6	57.3	64.5	74.4	78.5	84.9	90.5	98.7	87.6	73.5	68.3	62.2	74.0
	0.25	0.70	49.2	58.5	65.7	76.0	80.2	86.5	92.9	101.2	89.6	74.7	69.3	63.3	75.6
	0.40	0.70	47.9	57.5	64.6	74.0	78.3	84.4	90.6	98.8	87.5	73.3	68.6	62.5	74.0
	0.60	0.70	46.3	56.3	63.3	71.4	75.9	81.8	87.5	95.6	84.9	71.7	67.8	61.7	72.0
Baltimore	0.25	0.10	48.0	47.8	54.4	55.5	83.1	87.0	93.7	91.9	83.0	64.9	46.1	48.1	67.0
	0.40	0.10	47.9	47.7	52.9	53.8	80.6	84.7	91.8	89.9	81.1	63.8	46.1	48.1	65.7
	0.60	0.10	48.2	48.0	51.3	51.8	77.5	81.7	89.3	87.2	78.6	62.5	46.3	48.3	64.2
	0.25	0.40	47.9	47.7	53.5	54.2	80.7	85.0	91.8	90.0	81.6	64.1	46.1	48.1	65.9
	0.40	0.40	48.2	48.0	52.5	53.0	78.5	82.9	90.1	88.1	79.8	63.2	46.3	48.3	64.9
	0.60	0.40	48.1	47.9	50.5	49.9	75.2	79.8	87.4	85.3	77.1	61.6	46.2	48.2	63.1
	0.25	0.70	48.2	48.0	53.1	53.3	78.2	83.0	90.0	88.1	80.1	63.4	46.3	48.3	65.0
	0.40	0.70	48.1	47.9	51.6	51.5	75.9	80.7	88.0	86.0	78.2	62.3	46.2	48.2	63.7
	0.60	0.70	48.0	47.9	49.7	48.9	72.6	77.5	85.2	83.2	75.6	60.6	46.2	48.2	62.0
Minneapolis	0.25	0.10	51.7	50.4	46.1	69.8	81.5	79.1	103.6	90.3	78.2	44.5	49.7	51.5	66.4
	0.40	0.10	51.6	50.4	46.0	68.1	79.4	77.1	101.4	87.9	76.7	44.4	49.7	51.4	65.4
	0.60	0.10	51.8	50.6	46.3	65.9	76.7	74.5	98.5	84.9	74.9	44.7	49.9	51.6	64.2
	0.25	0.40	51.6	50.3	46.1	68.6	79.5	77.4	101.6	88.5	76.7	44.4	49.7	51.4	65.5
	0.40	0.40	51.6	50.3	46.0	66.8	77.4	75.4	99.4	86.1	75.2	44.4	49.6	51.3	64.5
	0.60	0.40	51.8	50.6	46.2	64.6	74.7	72.9	96.4	83.0	73.4	44.6	49.8	51.5	63.3
	0.25	0.70	51.5	50.3	46.0	67.2	77.3	75.5	99.3	86.6	75.0	44.4	49.6	51.3	64.5
	0.40	0.70	51.8	50.6	46.3	65.7	75.4	73.6	97.3	84.3	73.8	44.6	49.8	51.5	63.7
	0.60	0.70	51.7	50.5	46.2	63.2	73.1	71.7	94.1	80.9	72.2	44.6	49.7	51.4	62.4

Table 10. Peak demand for varying roof and exterior wall solar reflectance levels (commercial building with IECC 2021 wall insulation and IECC 2006 roof insulation).

City	Solar Reflectance, Percent		Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	53.6	60.8	67.2	82.4	83.7	90.7	95.2	103.2	92.7	77.4	69.1	63.6	78.3
	0.40	0.10	53.5	60.8	67.1	81.9	83.2	90.3	94.6	102.7	92.2	77.1	69.1	63.7	78.0
	0.60	0.10	52.8	60.3	66.7	81.0	82.3	89.4	93.7	101.7	91.4	76.5	68.8	63.3	77.3
	0.25	0.40	52.1	59.7	65.9	77.9	79.6	86.3	91.0	98.8	88.8	74.7	68.7	63.3	75.6
	0.40	0.40	51.5	59.4	65.6	77.3	78.9	85.7	90.3	98.1	88.1	74.3	68.5	63.0	75.1
	0.60	0.40	50.8	58.9	65.1	76.4	78.1	84.8	89.3	97.1	87.3	73.7	68.1	62.7	74.4
	0.25	0.70	50.0	58.2	64.2	72.8	75.2	81.1	86.0	93.6	84.3	71.6	68.0	62.5	72.3
	0.40	0.70	49.5	57.8	63.8	72.2	74.7	80.4	85.3	92.9	83.6	71.2	67.7	62.3	71.8
	0.60	0.70	48.8	57.3	63.2	71.3	73.9	79.6	84.3	91.8	82.8	70.6	67.3	61.9	71.1
Baltimore	0.25	0.10	47.5	47.3	56.0	57.5	83.1	84.6	92.4	90.3	81.9	65.7	45.9	47.5	66.6
	0.40	0.10	47.5	47.3	55.6	57.0	82.6	84.1	92.0	89.9	81.6	65.5	45.9	47.5	66.4
	0.60	0.10	47.4	47.2	55.1	56.4	81.8	83.4	91.4	89.3	81.2	65.1	45.8	47.4	66.0
	0.25	0.40	47.3	47.2	54.2	54.9	78.3	80.5	88.3	86.3	78.7	64.0	45.8	47.4	64.4
	0.40	0.40	47.3	47.1	53.9	54.4	77.8	80.0	87.9	85.9	78.4	63.8	45.7	47.3	64.1
	0.60	0.40	47.2	47.1	53.3	53.9	77.0	79.3	87.3	85.3	77.9	63.4	45.7	47.3	63.7
	0.25	0.70	47.1	47.0	52.3	51.9	73.0	76.0	83.7	82.0	75.4	62.0	45.6	47.2	61.9
	0.40	0.70	47.1	47.0	52.0	51.5	72.4	75.5	83.3	81.5	75.0	61.8	45.5	47.1	61.6
	0.60	0.70	47.0	46.9	51.4	50.9	71.6	74.9	82.6	80.9	74.4	61.4	45.5	47.1	61.2
Minneapolis	0.25	0.10	49.2	48.2	44.1	69.4	77.1	73.9	95.4	83.8	75.7	45.4	47.7	49.0	63.2
	0.40	0.10	49.1	48.2	44.0	69.0	76.7	73.6	95.0	83.5	75.5	45.1	47.7	48.9	63.0
	0.60	0.10	49.1	48.2	44.0	68.5	76.2	73.1	94.4	83.1	75.1	44.7	47.7	48.9	62.7
	0.25	0.40	49.4	48.5	44.4	67.6	74.3	71.6	92.3	81.2	73.5	44.4	48.0	49.2	62.0
	0.40	0.40	49.4	48.5	44.3	67.2	73.9	71.3	91.9	80.9	73.3	44.2	47.9	49.2	61.8
	0.60	0.40	49.3	48.4	44.3	66.7	73.4	70.9	91.4	80.4	72.9	43.9	47.9	49.1	61.6
	0.25	0.70	49.2	48.3	44.2	65.2	71.5	69.7	88.7	78.0	71.4	43.2	47.8	49.0	60.5
	0.40	0.70	49.2	48.3	44.2	64.8	71.2	69.4	88.3	77.7	71.2	42.9	47.7	49.0	60.3
	0.60	0.70	49.1	48.2	44.1	64.3	70.8	69.1	87.7	77.3	70.9	42.8	47.7	48.9	60.1

Table 11. Peak demand for varying roof and exterior wall solar reflectance levels (commercial building with IECC 2021 wall insulation and IECC 2021 roof insulation).

City	Solar Reflectance, Percent		Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	53.3	60.0	65.8	77.0	78.5	84.6	89.2	96.7	87.4	74.3	68.7	63.4	74.9
	0.40	0.10	53.2	60.0	65.7	76.5	78.0	84.1	88.6	96.2	86.9	74.0	68.7	63.5	74.6
	0.60	0.10	52.4	59.5	65.2	75.6	77.1	83.3	87.6	95.1	86.0	73.4	68.4	63.2	73.9
	0.25	0.40	52.5	59.4	65.1	74.4	76.1	81.9	86.6	94.1	85.1	72.7	68.6	63.3	73.3
	0.40	0.40	51.9	59.1	64.7	73.7	75.5	81.3	85.9	93.3	84.4	72.3	68.3	63.1	72.8
	0.60	0.40	51.2	58.6	64.2	72.9	74.7	80.4	84.9	92.3	83.5	71.7	68.0	62.7	72.1
	0.25	0.70	51.1	58.5	63.9	71.2	73.4	78.6	83.4	90.8	82.2	70.8	68.1	62.9	71.3
	0.40	0.70	50.6	58.1	63.6	70.6	72.9	78.0	82.7	90.0	81.6	70.4	67.8	62,6	70.7
	0.60	0.70	49.8	57.6	63.0	69.8	72.1	77.1	81.7	89.0	80.7	69.7	67.5	62.3	70.0
Baltimore	0.25	0.10	47.0	46.9	55.3	55.8	76.5	78.1	85.5	83.3	77.5	64.1	45.5	47.0	63.6
	0.40	0.10	47.0	46.9	54.9	55.4	76.0	77.6	85.0	82.8	77.1	63.9	45.5	47.0	63.3
	0.60	0.10	46.9	46.8	54.4	54.8	75.2	77.0	84.4	82.2	76.6	63.5	45.5	47.0	62.8
	0.25	0.40	46.9	46.8	54.3	54.5	74.2	76.1	83.4	81.3	76.0	63.2	45.5	47.0	62.4
	0.40	0.40	46.9	46.8	53.9	54.0	73.6	75.7	82.9	80.8	75.6	63.0	45.4	46.9	62.1
	0.60	0.40	46.9	46.7	53.4	53.3	72.8	75.0	82.3	80.2	75.1	62.6	45.4	46.9	61.7
	0.25	0.70	46.9	46.7	53.3	52.8	71.4	73.9	81.1	79.0	74.4	62.2	45.4	46.9	61.2
	0.40	0.70	46.8	46.7	52.9	52.4	70.9	73.4	80.6	78.6	74.0	62.0	45.4	46.8	60.9
	0.60	0.70	46.8	46.6	52.3	51.7	70.0	72.8	79.9	78.0	73.4	61.6	45.3	46.8	60.4
Minneapolis	0.25	0.10	48.9	48.0	43.9	68.2	74.2	71.5	91.7	81.1	73.6	45.7	47.5	48.7	61.9
	0.40	0.10	48.8	48.0	43.8	67.8	73.8	71.2	91.3	80.8	73.3	45.5	47.5	48.6	61.7
	0.60	0.10	49.2	48.3	44.2	67.7	73.5	71.1	90.9	80.5	73.1	45.4	47.8	49.0	61.7
	0.25	0.40	49.1	48.3	44.2	67.1	72.5	70.6	89.7	79.3	72.3	45.1	47.8	49.0	61.3
	0.40	0.40	49.1	48.3	44.2	66.7	72.3	70.3	89.3	79.0	72.0	44.8	47.8	48.9	61.1
	0.60	0.40	49.0	48.2	44.1	66.2	71.9	70.0	88.7	78.6	71.8	44.5	47.7	48.9	60.8
	0.25	0.70	49.0	48.2	44.1	65.4	71.1	69.3	87.2	77.2	71.1	44.2	47.7	48.8	60.3
	0.40	0.70	49.0	48.2	44.1	65.0	70.8	69.1	86.8	76.9	70.9	44.0	47.6	48.8	60.1
	0.60	0.70	48.9	48.1	44.0	64.5	70.4	68.7	86.3	76.5	70.6	43.7	47.6	48.7	59.8

Table 12. Reduction in peak demand from baseline for varying roof and exterior wall solar reflectance levels (residential building without wall insulation).

City	Solar Reflectance, Percent		Reduction in Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	**Baseline**												
	0.40	0.10	0.27	0.27	0.28	0.28	0.25	0.27	0.29	0.31	0.30	0.22	0.31	0.27	0.28
	0.60	0.10	0.62	0.61	0.66	0.61	0.53	0.66	0.69	0.72	0.58	0.55	0.68	0.64	0.63
	0.25	0.25	0.01	0.02	0.02	0.02	0.03	0.05	0.02	0.02	0.02	0.01	0.02	0.01	0.02
	0.40	0.25	0.28	0.28	0.30	0.30	0.26	0.29	0.31	0.33	0.32	0.24	0.32	0.28	0.29
	0.60	0.25	0.62	0.62	0.68	0.63	0.54	0.68	0.71	0.74	0.60	0.57	0.69	0.65	0.65
	0.25	0.40	0.02	0.03	0.04	0.04	0.06	0.08	0.04	0.04	0.04	0.02	0.03	0.02	0.04
	0.40	0.40	0.29	0.29	0.32	0.32	0.27	0.32	0.33	0.35	0.34	0.25	0.34	0.29	0.31
	0.60	0.40	0.63	0.62	0.69	0.65	0.56	0.71	0.73	0.77	0.62	0.59	0.70	0.66	0.66
Baltimore	0.25	0.10	**Baseline**												
	0.40	0.10	0.04	0.04	0.16	0.27	0.25	0.24	0.25	0.25	0.22	0.28	0.30	0.07	0.20
	0.60	0.10	0.09	0.09	0.37	0.65	0.58	0.54	0.57	0.58	0.44	0.62	0.54	0.12	0.44
	0.25	0.25	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.40	0.25	0.04	0.04	0.17	0.29	0.25	0.25	0.25	0.25	0.22	0.29	0.31	0.07	0.20
	0.60	0.25	0.09	0.09	0.38	0.66	0.58	0.55	0.58	0.59	0.45	0.63	0.54	0.12	0.44
	0.25	0.40	0.00	0.00	0.01	0.03	0.02	0.01	0.02	0.01	0.02	0.03	0.02	0.01	0.02
	0.40	0.40	0.04	0.04	0.17	0.30	0.26	0.25	0.26	0.26	0.22	0.30	0.31	0.07	0.21
	0.60	0.40	0.09	0.09	0.38	0.67	0.59	0.56	0.59	0.59	0.46	0.64	0.54	0.13	0.45
Minneapolis	0.25	0.10	**Baseline**												
	0.40	0.10	0.02	0.01	0.16	0.19	0.13	0.26	0.08	0.09	0.14	0.29	0.01	0.02	0.11
	0.60	0.10	0.02	0.01	0.16	0.43	0.24	0.55	0.06	0.07	0.55	0.67	0.01	0.02	0.23
	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	0.40	0.25	0.02	0.01	0.16	0.19	0.16	0.27	0.08	0.09	0.15	0.29	0.01	0.02	0.12
	0.60	0.25	0.02	0.01	0.16	0.44	0.24	0.55	0.06	0.07	0.56	0.68	0.01	0.02	0.23
	0.25	0.40	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00
	0.40	0.40	0.02	0.01	0.16	0.19	0.18	0.28	0.08	0.09	0.15	0.30	0.01	0.02	0.12
	0.60	0.40	0.02	0.01	0.16	0.45	0.24	0.56	0.06	0.07	0.58	0.68	0.01	0.02	0.24

Table 13. Reduction in peak demand from baseline for varying roof and exterior wall solar reflectance levels (residential building with IECC 2021 wall insulation).

City	Solar Reflectance, Percent		Reduction in Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	**Baseline**												
	0.40	0.10	0.04	0.03	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.02	0.05	0.04
	0.60	0.10	0.09	0.06	0.11	0.11	0.10	0.12	0.12	0.12	0.12	0.06	0.04	0.08	0.10
	0.25	0.25	0.01	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.01
	0.40	0.25	0.04	0.03	0.06	0.06	0.06	0.07	0.07	0.07	0.05	0.03	0.02	0.05	0.05
	0.60	0.25	0.09	0.07	0.13	0.13	0.12	0.14	0.14	0.14	0.12	0.06	0.04	0.08	0.11
	0.25	0.40	0.01	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.02	0.00	0.00	0.01	0.02
	0.40	0.40	0.05	0.04	0.07	0.08	0.07	0.09	0.09	0.09	0.07	0.03	0.02	0.05	0.06
	0.60	0.40	0.10	0.07	0.14	0.14	0.14	0.16	0.16	0.17	0.14	0.05	0.05	0.09	0.12
Baltimore	0.25	0.10	**Baseline**												
	0.40	0.10	0.00	0.00	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.00	0.02
	0.60	0.10	0.01	0.00	0.05	0.06	0.05	0.06	0.06	0.05	0.06	0.06	0.06	0.00	0.04
	0.25	0.25	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00
	0.40	0.25	0.01	0.00	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.02
	0.60	0.25	0.01	0.00	0.06	0.07	0.06	0.07	0.06	0.06	0.06	0.07	0.06	0.00	0.05
	0.25	0.40	0.01	0.00	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.00	0.01
	0.40	0.40	0.01	0.00	0.03	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.00	0.03
	0.60	0.40	0.01	0.00	0.06	0.08	0.09	0.08	0.07	0.07	0.05	0.07	0.06	0.00	0.05
Minneapolis	0.25	0.10	**Baseline**												
	0.40	0.10	0.01	0.00	0.01	0.02	0.02	0.04	0.03	0.03	0.04	0.02	0.00	0.01	0.02
	0.60	0.10	0.01	0.00	0.04	0.06	0.06	0.08	0.07	0.07	0.09	0.05	0.00	0.01	0.04
	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.02	0.01	0.00	0.00	0.00
	0.40	0.25	0.01	0.00	0.02	0.03	0.03	0.04	0.04	0.04	0.06	0.03	0.00	0.01	0.02
	0.60	0.25	0.02	0.00	0.04	0.07	0.07	0.08	0.07	0.07	0.12	0.05	0.01	0.02	0.05
	0.25	0.40	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.05	0.01	0.00	0.00	0.01
	0.40	0.40	0.01	0.00	0.02	0.03	0.04	0.05	0.04	0.04	0.09	0.04	0.00	0.01	0.03
	0.60	0.40	0.02	0.00	0.04	0.07	0.08	0.09	0.08	0.08	0.14	0.05	0.01	0.02	0.05

Table 14. Reduction in peak demand from baseline for varying roof and exterior wall solar reflectance levels (commercial building without wall insulation and IECC 2006 roof insulation).

City	Solar Reflectance, Percent		Reduction in Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	**Baseline**												
	0.40	0.10	1.3	1.0	1.0	2.1	1.8	2.0	2.3	2.5	2.1	1.3	0.7	0.7	1.5
	0.60	0.10	3.1	2.3	2.4	4.9	4.3	4.7	5.5	5.9	4.8	3.0	1.7	1.8	3.7
	0.25	0.25	1.7	1.3	1.4	4.5	3.6	4.4	4.2	4.5	3.8	2.8	0.6	0.7	2.8
	0.40	0.25	3.0	2.3	2.4	6.5	5.5	6.4	6.5	6.9	5.9	4.0	1.3	1.4	4.3
	0.60	0.25	4.5	3.4	3.6	9.1	7.8	9.0	9.5	10.1	8.5	5.6	2.0	2.2	6.3
	0.25	0.40	3.6	2.9	3.1	9.5	7.8	9.4	8.9	9.5	8.2	5.7	1.4	1.4	5.9
	0.40	0.40	4.6	3.6	3.9	11.3	9.4	11.3	11.1	11.8	10.0	6.9	1.8	1.9	7.3
	0.60	0.40	6.4	5.1	5.5	14.0	12.0	14.0	14.3	15.1	12.8	8.6	2.8	3.0	9.4
Baltimore	0.25	0.10	**Baseline**												
	0.40	0.10	0.1	0.1	1.5	1.7	2.5	2.3	1.9	2.0	1.7	1.2	0.1	0.2	1.2
	0.60	0.10	-0.1	-0.2	3.1	3.6	5.7	5.2	4.3	4.6	3.5	2.5	-0.1	0.0	2.6
	0.25	0.25	0.2	0.1	1.6	2.5	4.7	3.8	3.9	3.5	2.7	1.6	0.2	0.2	2.0
	0.40	0.25	-0.1	-0.1	2.7	3.6	6.9	5.9	5.5	5.4	4.6	2.6	-0.1	0.0	3.0
	0.60	0.25	0.0	-0.1	4.6	6.0	10.3	9.0	8.2	8.2	6.6	4.1	0.0	0.1	4.7
	0.25	0.40	0.1	-0.1	3.0	4.6	9.8	8.0	7.9	7.5	5.8	3.2	0.0	0.1	4.1
	0.40	0.40	0.1	0.0	3.9	6.4	12.2	10.3	9.8	9.5	7.6	4.4	0.1	0.1	5.3
	0.60	0.40	0.1	0.0	6.2	8.9	15.5	13.3	12.4	12.3	10.0	6.0	0.1	0.2	7.0
Minneapolis	0.25	0.10	**Baseline**												
	0.40	0.10	0.0	0.0	0.1	1.7	2.1	2.0	2.1	2.2	1.4	0.0	0.0	0.1	1.0
	0.60	0.10	-0.2	-0.2	-0.1	3.8	5.0	4.6	5.0	5.3	3.4	-0.2	-0.2	-0.1	2.2
	0.25	0.25	0.1	0.1	0.1	1.8	3.0	2.5	3.0	2.7	2.2	0.0	0.1	0.1	1.3
	0.40	0.25	0.1	0.1	0.1	3.6	5.1	4.5	5.1	5.0	3.7	0.1	0.1	0.2	2.3
	0.60	0.25	-0.1	-0.1	-0.1	5.7	7.9	7.1	8.0	8.1	5.5	-0.2	-0.1	0.0	3.5
	0.25	0.40	0.2	0.2	0.1	3.9	6.4	5.3	6.4	5.6	4.7	0.1	0.2	0.3	2.8
	0.40	0.40	0.0	-0.1	-0.1	5.4	8.3	7.2	8.3	7.9	6.0	-0.2	-0.1	0.0	3.6
	0.60	0.40	0.1	0.0	0.0	7.9	11.0	9.5	11.5	11.3	7.7	-0.1	1.0	0.2	4.9

Table 15. Reduction in peak demand from baseline for varying roof and exterior wall solar reflectance levels (commercial building without wall insulation and IECC 2021 roof insulation).

City	Solar Reflectance, Percent		Reduction in Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	**Baseline**												
	0.40	0.10	1.3	0.9	1.0	2.0	1.9	2.0	2.3	2.4	2.0	1.2	0.7	0.7	1.6
	0.60	0.10	3.2	2.3	2.5	4.7	4.5	4.8	5.5	5.8	4.8	2.9	1.7	1.8	3.8
	0.25	0.25	1.1	0.8	1.0	2.7	2.3	2.7	2.6	2.7	2.3	1.6	0.4	0.4	1.8
	0.40	0.25	2.4	1.8	2.0	4.7	4.2	4.7	4.9	5.2	4.4	2.9	1.1	1.1	3.3
	0.60	0.25	3.9	2.9	3.2	7.3	6.6	7.4	8.0	8.4	7.0	4.5	1.8	1.9	5.3
	0.25	0.40	2.3	1.7	2.0	5.7	4.9	5.8	5.6	5.9	5.0	3.3	0.8	0.8	3.7
	0.40	0.40	3.6	2.7	3.1	7.7	6.8	7.9	7.9	8.3	7.1	4.7	1.5	1.6	5.3
	0.60	0.40	5.2	3.9	4.4	10.3	9.2	10.5	11.0	11.5	9.7	6.3	2.3	2.4	7.3
Baltimore	0.25	0.10	**Baseline**												
	0.40	0.10	0.1	0.1	1.5	1.7	2.5	2.3	1.9	2.0	1.9	1.1	0.0	0.0	1.3
	0.60	0.10	-0.2	-0.2	3.1	3.7	5.6	5.3	4.4	4.7	4.4	2.4	-0.2	-0.2	2.8
	0.25	0.25	0.1	0.1	0.9	1.3	2.4	2.0	1.9	1.9	1.4	0.8	0.0	0.0	1.1
	0.40	0.25	-0.2	-0.2	1.9	2.5	4.6	4.1	3.6	3.8	3.2	1.7	-0.2	-0.2	2.1
	0.60	0.25	-0.1	-0.1	3.9	5.6	7.9	7.2	6.3	6.6	5.9	3.3	-0.1	-0.1	3.9
	0.25	0.40	-0.2	-0.2	1.3	2.2	4.9	4.0	3.7	3.8	2.9	1.5	-0.2	-0.2	2.0
	0.40	0.40	-0.1	-0.1	2.8	4.0	7.2	6.3	5.7	5.9	4.8	2.6	-0.1	-0.1	3.3
	0.60	0.40	0.0	-0.1	4.7	6.6	10.5	9.5	8.5	8.7	7.4	4.3	-0.1	-0.1	5.0
Minneapolis	0.25	0.10	**Baseline**												
	0.40	0.10	0.1	0.0	0.1	1.7	2.1	2.0	2.2	2.4	1.5	0.1	0.0	0.1	1.0
	0.60	0.10	-0.1	-0.2	-0.2	3.9	4.8	4.6	5.1	5.4	3.3	-0.2	-0.2	-0.1	2.2
	0.25	0.25	0.1	0.1	0.0	1.2	2.0	1.7	2.0	1.8	1.5	0.1	0.0	0.1	0.9
	0.40	0.25	0.1	0.1	0.1	3.0	4.1	3.7	4.2	4.2	3.0	0.1	0.1	0.2	1.9
	0.60	0.25	-0.1	-0.2	-0.1	5.2	6.8	6.2	7.2	7.3	4.8	-0.1	-0.1	0.0	3.1
	0.25	0.40	0.2	0.1	0.1	2.6	4.2	3.6	4.3	3.7	3.2	0.1	0.1	0.2	1.9
	0.40	0.40	-0.1	-0.2	-0.2	4.1	6.1	5.5	6.3	6.0	4.4	-0.1	-0.1	0.0	2.7
	0.60	0.40	0.0	-0.1	-0.1	6.6	8.4	7.4	9.5	9.4	6.0	-0.1	0.0	0.1	4.0

Table 16. Reduction in peak demand from baseline for varying roof and exterior wall solar reflectance levels (commercial building with IECC 2021 wall insulation and IECC 2006 roof insulation).

City	Solar Reflectance, Percent		Reduction in Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	**Baseline**												
	0.40	0.10	0.1	0.0	0.1	0.5	0.5	0.4	0.6	0.5	0.5	0.3	0.0	-0.1	0.3
	0.60	0.10	0.8	0.5	0.5	1.4	1.4	1.3	1.5	1.5	1.3	0.9	0.3	0.3	1.0
	0.25	0.25	1.5	1.1	1.3	4.5	4.1	4.4	4.2	4.4	3.9	2.7	0.4	0.3	2.7
	0.40	0.25	2.1	1.4	1.6	5.1	4.8	5.0	4.9	5.1	4.6	3.1	0.6	0.6	3.2
	0.60	0.25	2.8	1.9	2.1	6.0	5.6	5.9	5.9	6.1	5.4	3.7	1.0	0.9	3.9
	0.25	0.40	3.6	2.6	3.0	9.6	8.5	9.6	9.2	9.6	8.4	5.8	1.1	1.1	6.0
	0.40	0.40	4.1	3.0	3.4	10.2	9.0	10.3	9.9	10.3	9.1	6.2	1.4	1.3	6.5
	0.60	0.40	4.8	3.5	4.0	11.1	9.8	11.1	10.9	11.4	9.9	6.8	1.8	1.7	7.2
Baltimore	0.25	0.10	**Baseline**												
	0.40	0.10	0.0	0.0	0.4	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.0	0.0	0.2
	0.60	0.10	0.1	0.1	0.9	1.1	1.3	1.2	1.0	1.0	0.7	0.6	0.1	0.1	0.6
	0.25	0.25	0.2	0.1	1.8	2.6	4.8	4.1	4.1	4.0	3.2	1.7	0.1	0.1	2.2
	0.40	0.25	0.2	0.2	2.1	3.1	5.3	4.6	4.5	4.4	3.5	1.9	0.2	0.2	2.5
	0.60	0.25	0.3	0.2	2.7	3.6	6.1	5.3	5.1	5.0	4.0	2.3	0.2	0.2	2.9
	0.25	0.40	0.4	0.3	3.7	5.6	10.1	8.6	8.7	8.3	6.5	3.7	0.3	0.3	4.7
	0.40	0.40	0.4	0.3	4.0	6.0	10.7	9.1	9.1	8.8	6.9	3.9	0.4	0.4	5.0
	0.60	0.40	0.5	0.4	4.6	6.6	11.5	9.7	9.8	9.4	7.5	4.3	0.4	0.4	5.4
Minneapolis	0.25	0.10	**Baseline**												
	0.40	0.10	0.1	0.0	0.1	0.4	0.4	0.3	0.4	0.3	0.2	0.3	0.0	0.1	0.2
	0.60	0.10	0.1	0.0	0.1	0.9	0.9	0.8	1.0	0.7	0.6	0.7	0.0	0.1	0.5
	0.25	0.25	-0.2	-0.3	-0.3	1.8	2.8	2.3	3.1	2.6	2.2	1.0	-0.3	-0.2	1.2
	0.40	0.25	-0.2	-0.3	-0.2	2.2	3.2	2.6	3.5	2.9	2.4	1.2	-0.2	-0.2	1.4
	0.60	0.25	-0.1	-0.2	-0.2	2.7	3.7	3.0	4.0	3.4	2.8	1.5	-0.2	-0.1	1.6
	0.25	0.40	0.0	-0.1	-0.1	4.2	5.6	4.2	6.7	5.8	4.3	2.2	-0.1	0.0	2.7
	0.40	0.40	0.0	-0.1	-0.1	4.6	5.9	4.5	7.1	6.1	4.5	2.5	0.0	0.0	2.9
	0.60	0.40	0.1	0.0	0.0	5.1	6.3	4.8	7.7	6.5	4.8	2.6	0.0	0.1	3.1

Table 17. Reduction in peak demand from baseline for varying roof and exterior wall solar reflectance levels (commercial building with IECC 2021 wall insulation and IECC 2021 roof insulation).

City	Solar Reflectance, Percent		Reduction in Monthly Peak, kW												
	Wall	Roof	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Houston	0.25	0.10	**Baseline**												
	0.40	0.10	0.1	0.0	0.1	0.5	0.5	0.5	0.6	0.5	0.5	0.3	0.0	-0.1	0.3
	0.60	0.10	0.9	0.5	0.6	1.4	1.4	1.3	1.6	1.6	1.4	0.9	0.3	0.2	1.0
	0.25	0.25	0.8	0.6	0.7	2.6	2.4	2.7	2.6	2.6	2.3	1.6	0.1	0.1	1.6
	0.40	0.25	1.4	0.9	1.1	3.3	3.0	3.3	3.3	3.4	3.0	2.0	0.4	0.3	2.1
	0.60	0.25	2.1	1.4	1.6	4.1	3.8	4.2	4.3	4.4	3.9	2.6	0.7	0.7	2.8
	0.25	0.40	2.2	1.5	1.9	5.8	5.1	6.0	5.8	5.9	5.2	3.5	0.6	0.5	3.6
	0.40	0.40	2.7	1.9	2.2	6.4	5.6	6.6	6.5	6.7	5.8	3.9	0.9	0.8	4.2
	0.60	0.40	3.5	2.4	2.8	7.2	6.4	7.5	7.5	7.7	6.7	4.6	1.2	1.1	4.9
Baltimore	0.25	0.10	**Baseline**												
	0.40	0.10	0.0	0.0	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.2	0.0	0.0	0.3
	0.60	0.10	0.1	0.1	0.9	1.0	1.3	1.1	1.1	1.1	0.9	0.6	0.0	0.0	0.8
	0.25	0.25	0.1	0.1	1.0	1.3	2.3	2.0	2.1	2.0	1.5	0.9	0.0	0.0	1.2
	0.40	0.25	0.1	0.1	1.4	1.8	2.9	2.4	2.6	2.5	1.9	1.1	0.1	0.1	1.5
	0.60	0.25	0.1	0.2	1.9	2.5	3.7	3.1	3.2	3.1	2.4	1.5	0.1	0.1	1.9
	0.25	0.40	0.1	0.2	2.0	3.0	5.1	4.2	4.4	4.3	3.1	1.9	0.1	0.1	2.4
	0.40	0.40	0.2	0.2	2.4	3.4	5.6	4.7	4.9	4.7	3.5	2.1	0.1	0.2	2.7
	0.60	0.40	0.2	0.3	3.0	4.1	6.5	5.3	5.6	5.3	4.1	2.5	0.2	0.2	3.2
Minneapolis	0.25	0.10	**Baseline**												
	0.40	0.10	0.1	0.0	0.1	0.4	0.4	0.3	0.4	0.3	0.3	0.2	0.0	0.1	0.2
	0.60	0.10	-0.3	-0.3	-0.3	0.5	0.7	0.4	0.8	0.6	0.5	0.3	-0.3	-0.3	0.2
	0.25	0.25	-0.2	-0.3	-0.3	1.1	1.7	0.9	2.0	1.8	1.3	0.6	-0.3	-0.3	0.6
	0.40	0.25	-0.2	-0.3	-0.3	1.5	1.9	1.2	2.4	2.1	1.6	0.9	-0.3	-0.2	0.8
	0.60	0.25	-0.1	-0.2	-0.2	2.0	2.3	1.5	3.0	2.5	1.8	1.2	-0.2	-0.2	1.1
	0.25	0.40	-0.1	-0.2	-0.2	2.8	3.1	2.2	4.5	3.9	2.5	1.5	-0.2	-0.1	1.6
	0.40	0.40	-0.1	-0.2	-0.2	3.2	3.4	2.4	4.9	4.2	2.7	1.7	-0.1	-0.1	1.8
	0.60	0.40	0.0	-0.1	-0.1	3.7	3.8	2.8	5.4	4.6	3.0	2.0	-0.1	0.0	2.1

5.2 COST SAVINGS

The results for the cost savings are shown in Tables 18 through 23. The tables include results for the average monthly peak and energy savings, demand savings, and total savings for high and low demand charges. The total savings is the summation of energy and demand savings. In these tables, for the average monthly peak, the cell color varies from white to red for higher peak load values and from white to blue for lower peak load values. For cost savings, the cell color varies from yellow to green for higher cost savings and from yellow to red for lower cost savings.

Houston and Baltimore's residential buildings have cost savings overall in exterior walls without insulation (Table 18). The highest potential annual total cost savings in Houston was $308 with a high demand charge and $268 with a low demand charge. For Baltimore, the highest annual total cost savings were $83 and $57 for high and low demand charges, respectively. In the case of Minneapolis, there was a $21 increase in total cost for the case with the highest roof and exterior wall solar reflectance levels. This is due to the increase in the cost of heating energy consumption exceeding the combined savings from cooling energy and peak demand reductions. For the buildings with IECC 2021 wall insulation (Table 19), the cost savings in Houston and Baltimore, and the cost increase in Minneapolis are reduced significantly compared to the buildings without wall insulation (Table 18). This demonstrates that the impact of solar reflectance is higher in exterior walls with low insulation levels. Similar to energy savings and peak demand, the overall cost savings for residential buildings are more greatly influenced by the change in the exterior wall solar reflectance compared to the change in roof solar reflectance due to the attic R-value levels used in the simulations.

Houston and Baltimore's commercial buildings achieved the most cost savings with the highest values for roof and exterior wall reflectances. For commercial buildings without exterior wall insulation, the highest total annual cost savings were $3810 in Houston and $1472 in Baltimore for IECC 2006 roof insulation (Table 20). However, in Minneapolis, cost increases of up to $296 were observed for the low peak demand rate with IECC 2021 roof insulation (Table 21).

For commercial buildings with IECC 2021 wall level insulation (Tables 22 and 23), the total cost savings decreased for Houston compared to corresponding savings with no exterior wall insulation. For Baltimore, the cost savings increased for buildings with IECC 2021 wall level insulation and IECC 2006 roof level insulation which is mainly due to a reduction in heating energy consumption. For Minneapolis, the penalty for heating energy costs decreases with increases in exterior wall insulation; however, the peak electric demand reduction also decreases and thus the highest savings achieved in Minneapolis with IECC 2021 wall level insulation is $294 with the highest roof and exterior wall solar reflectances, which is due to the peak electric demand reductions. For IECC 2021 wall level insulation, the total cost savings for Minneapolis was higher for IECC 2006 roof insulation compared with IECC 2021 exterior wall insulation.

Table 18. Residential building without exterior wall insulation: average monthly peak, energy savings, demand savings, and total cost savings.

City	Solar Reflectance		Average Monthly Peak (kW)	Energy Savings ($)	Demand Savings ($)		Total Savings ($)	
	Wall	Roof			High Demand Charge	Low Demand Charge	High Demand Charge	Low Demand Charge
Houston	0.25	0.1	4.17	Baseline				
	0.4	0.1	3.89	80	50	33	130	113
	0.6	0.1	3.54	180	113	76	293	255
	0.25	0.25	4.15	5	4	2	9	8
	0.4	0.25	3.88	85	53	35	138	120
	0.6	0.25	3.52	184	116	77	301	262
	0.25	0.4	4.13	10	7	5	17	15
	0.4	0.4	3.86	90	56	37	146	127
	0.6	0.4	3.51	189	119	79	308	268
Baltimore	0.25	0.1	3.4	Baseline				
	0.4	0.1	3.2	9	35	23	44	32
	0.6	0.1	2.96	3	78	53	81	55
	0.25	0.25	3.39	1	1	1	2	2
	0.4	0.25	3.2	10	36	24	46	34
	0.6	0.25	2.96	3	79	52	82	56
	0.25	0.4	3.38	1	3	2	4	3
	0.4	0.4	3.19	10	37	25	47	35
	0.6	0.4	2.95	4	80	53	83	57
Minneapolis	0.25	0.1	3.43	Baseline				
	0.4	0.1	3.32	-10	14	7	4	-3
	0.6	0.1	3.2	-34	28	14	-6	-20
	0.25	0.25	3.43	0	0	0	0	0
	0.4	0.25	3.31	-10	15	7	4	-3
	0.6	0.25	3.2	-35	28	14	-6	-21
	0.25	0.4	3.43	-1	1	0	0	0
	0.4	0.4	3.31	-11	15	8	4	-3
	0.6	0.4	3.19	-35	29	14	-7	-21

Table 19. Residential building with IECC 2021 exterior wall insulation: average monthly peak, energy savings, demand savings, and total cost savings.

City	Solar Reflectance		Average Monthly Peak (kW)	Energy Savings ($)	Demand Savings ($)		Total Savings ($)	
	Wall	Roof			High Demand Charge	Low Demand Charge	High Demand Charge	Low Demand Charge
Houston	0.25	0.1	2.9	Baseline				
	0.4	0.1	2.86	12	8	5	20	17
	0.6	0.1	2.8	28	17	12	45	40
	0.25	0.25	2.89	5	2	1	7	7
	0.4	0.25	2.85	17	10	6	27	24
	0.6	0.25	2.79	33	19	13	52	46
	0.25	0.4	2.88	10	4	3	14	13
	0.4	0.4	2.84	23	12	8	34	30
	0.6	0.4	2.78	38	21	14	60	53
Baltimore	0.25	0.1	2.48	Baseline				
	0.4	0.1	2.46	-3	3	2	1	-1
	0.6	0.1	2.44	-7	8	5	0	-2
	0.25	0.25	2.48	1	1	1	3	2
	0.4	0.25	2.46	-1	4	3	3	2
	0.6	0.25	2.43	-6	9	6	3	0
	0.25	0.4	2.47	3	2	1	5	4
	0.4	0.4	2.45	0	5	4	5	3
	0.6	0.4	2.43	-5	10	6	5	2
Minneapolis	0.25	0.1	2.55	Baseline				
	0.4	0.1	2.53	-4	2	1	-2	-3
	0.6	0.1	2.51	-10	6	3	-5	-8
	0.25	0.25	2.55	0	1	0	1	1
	0.4	0.25	2.53	-4	3	2	-1	-2
	0.6	0.25	2.5	-10	6	3	-4	-7
	0.25	0.4	2.54	1	1	1	2	1
	0.4	0.4	2.52	-4	4	2	0	-2
	0.6	0.4	2.5	-10	7	3	-3	-7

Table 20. Commercial building without exterior wall insulation and IECC 2006 roof insulation: average monthly peak, energy savings, demand savings, and total cost savings.

City	Solar Reflectance		Average Monthly Peak (kW)	Energy Savings ($)	Demand Savings ($)		Total Savings ($)	
	Wall	Roof			High Demand Charge	Low Demand Charge	High Demand Charge	Low Demand Charge
Houston	0.25	0.1	82.5	Baseline				
	0.4	0.1	81	446	280	187	726	633
	0.6	0.1	78.8	1,037	665	443	1,702	1,480
	0.25	0.4	79.7	627	504	336	1,131	963
	0.4	0.4	78.2	1,051	784	522	1,834	1,573
	0.6	0.4	76.2	1,493	1,132	755	2,625	2,248
	0.25	0.7	76.6	1,289	1,069	713	2,358	2,001
	0.4	0.7	75.2	1,564	1,312	875	2,877	2,439
	0.6	0.7	73.1	2,106	1,704	1,136	3,810	3,242
Baltimore	0.25	0.1	69.9	Baseline				
	0.4	0.1	68.7	81	225	150	305	230
	0.6	0.1	67.3	1	476	318	477	318
	0.25	0.4	67.9	198	373	249	571	447
	0.4	0.4	66.9	118	552	368	670	486
	0.6	0.4	65.2	114	850	567	964	681
	0.25	0.7	65.8	241	744	496	985	737
	0.4	0.7	64.6	239	959	640	1,198	879
	0.6	0.7	62.9	200	1,272	848	1,472	1,048
Minneapolis	0.25	0.1	67.5	Baseline				
	0.4	0.1	66.5	-127	119	59	-9	-68
	0.6	0.1	65.3	-418	260	130	-159	-289
	0.25	0.4	66.2	-20	158	79	138	59
	0.4	0.4	65.2	-153	278	139	125	-14
	0.6	0.4	64	-467	418	209	-49	-258
	0.25	0.7	64.7	-49	334	167	285	118
	0.4	0.7	63.9	-299	428	214	128	-85
	0.6	0.7	62.6	-532	589	295	57	-237

Table 21. Commercial building without exterior wall insulation and IECC 2021 roof insulation: average monthly peak, energy savings, demand savings, and total cost savings.

City	Solar Reflectance		Average Monthly Peak (kW)	Energy Savings ($)	Demand Savings ($)		Total Savings ($)	
	Wall	Roof			High Demand Charge	Low Demand Charge	High Demand Charge	Low Demand Charge
Houston	0.25	0.1	79.3	Baseline				
	0.4	0.1	77.7	455	280	187	735	642
	0.6	0.1	75.5	1,050	670	447	1,720	1,496
	0.25	0.4	77.5	381	311	208	692	588
	0.4	0.4	76	823	593	396	1,416	1,218
	0.6	0.4	74	1,279	945	630	2,224	1,909
	0.25	0.7	75.6	806	662	441	1,468	1,247
	0.4	0.7	74	1,229	949	632	2,178	1,861
	0.6	0.7	72	1,666	1,303	868	2,969	2,535
Baltimore	0.25	0.1	67	Baseline				
	0.4	0.1	65.7	62	229	152	291	215
	0.6	0.1	64.2	-23	495	330	471	307
	0.25	0.4	65.9	99	192	128	290	227
	0.4	0.4	64.9	13	372	248	385	261
	0.6	0.4	63.1	28	692	461	720	489
	0.25	0.7	65	48	354	236	402	284
	0.4	0.7	63.7	86	584	390	669	475
	0.6	0.7	62	75	899	599	974	675
Minneapolis	0.25	0.1	66.4	Baseline				
	0.4	0.1	65.4	-124	120	60	-3	-63
	0.6	0.1	64.2	-427	262	131	-165	-296
	0.25	0.4	65.5	-10	105	52	95	43
	0.4	0.4	64.5	-147	227	113	80	-33
	0.6	0.4	63.3	-450	367	184	-82	-266
	0.25	0.7	64.5	-29	223	112	194	83
	0.4	0.7	63.7	-273	316	158	43	-115
	0.6	0.7	62.4	-493	470	235	-22	-258

Table 22. Commercial building with IECC 2021 exterior wall insulation and IECC 2006 roof insulation: average monthly peak, energy savings, demand savings, and total cost savings.

City	Solar Reflectance		Average Monthly Peak (kW)	Energy Savings ($)	Demand Savings ($)		Total Savings ($)	
	Wall	Roof			High Demand Charge	Low Demand Charge	High Demand Charge	Low Demand Charge
Houston	0.25	0.1	78.3	Baseline				
	0.4	0.1	78	34	50	34	84	67
	0.6	0.1	77.3	257	177	118	434	375
	0.25	0.4	75.6	530	492	328	1,022	858
	0.4	0.4	75.1	688	583	389	1,271	1,077
	0.6	0.4	74.4	900	708	472	1,608	1,372
	0.25	0.7	72.3	1,244	1,083	722	2,327	1,966
	0.4	0.7	71.8	1,394	1,173	782	2,567	2,176
	0.6	0.7	71.1	1,597	1,302	868	2,899	2,465
Baltimore	0.25	0.1	66.6	Baseline				
	0.4	0.1	66.4	34	53	35	86	69
	0.6	0.1	66	77	124	83	201	160
	0.25	0.4	64.4	247	402	268	649	515
	0.4	0.4	64.1	276	454	303	730	579
	0.6	0.4	63.7	314	527	351	841	665
	0.25	0.7	61.9	483	848	565	1,330	1,048
	0.4	0.7	61.6	506	901	601	1,407	1,107
	0.6	0.7	61.2	532	978	652	1,510	1,184
Minneapolis	0.25	0.1	63.2	Baseline				
	0.4	0.1	63	-7	25	12	18	5
	0.6	0.1	62.7	-17	59	30	43	13
	0.25	0.4	62	-92	145	73	53	-19
	0.4	0.4	61.8	-101	170	85	69	-16
	0.6	0.4	61.6	-113	203	102	90	-11
	0.25	0.7	60.5	-57	328	164	271	107
	0.4	0.7	60.3	-70	350	175	281	105
	0.6	0.7	60.1	-86	380	190	294	104

Table 23. Commercial building with IECC 2021 exterior wall insulation and IECC 2021 roof insulation: average monthly peak, energy savings, demand savings, and total cost savings.

City	Solar Reflectance		Average Monthly Peak (kW)	Energy Savings ($)	Demand Savings ($)		Total Savings ($)	
	Wall	Roof			High Demand Charge	Low Demand Charge	High Demand Charge	Low Demand Charge
Houston	0.25	0.1	74.9	Baseline				
	0.4	0.1	74.6	34	50	33	84	67
	0.6	0.1	73.9	267	178	118	445	385
	0.25	0.4	73.3	279	287	191	566	470
	0.4	0.4	72.8	447	379	253	826	700
	0.6	0.4	72.1	670	506	337	1,176	1,007
	0.25	0.7	71.3	734	656	437	1,390	1,171
	0.4	0.7	70.7	896	749	499	1,645	1,395
	0.6	0.7	70	1,110	875	583	1,985	1,693
Baltimore	0.25	0.1	63.6	Baseline				
	0.4	0.1	63.3	35	54	36	88	70
	0.6	0.1	62.8	91	128	85	219	176
	0.25	0.4	62.4	132	201	134	333	266
	0.4	0.4	62.1	171	255	170	425	341
	0.6	0.4	61.7	220	331	221	551	440
	0.25	0.7	61.2	274	431	287	705	561
	0.4	0.7	60.9	305	484	323	789	628
	0.6	0.7	60.4	351	561	374	912	725
Minneapolis	0.25	0.1	61.9	Baseline				
	0.4	0.1	61.7	-4	25	13	21	8
	0.6	0.1	61.7	-149	22	11	-126	-137
	0.25	0.4	61.3	-106	78	39	-27	-66
	0.4	0.4	61.1	-111	101	51	-10	-61
	0.6	0.4	60.8	-120	133	67	13	-54
	0.25	0.7	60.3	-76	194	97	118	21
	0.4	0.7	60.1	-85	217	108	132	23
	0.6	0.7	59.8	-98	248	124	150	26

6. CONCLUSIONS

Energy simulations were performed on residential and commercial prototype building models at three geographic locations to evaluate the impact of roof/wall solar reflectance on energy consumption, peak demand, and cost savings. The evaluation was performed for different roof and exterior wall insulation levels, and roof and exterior wall solar reflectances. Note that the cost savings compiled in this report are based on energy and demand savings exclusively and needs to be combined with the cost differences between the baseline and simulated roofs and exterior wall surfaces. If there are no material cost differences, then the energy and demand savings would be your actual cost savings.

The following conclusions can be drawn from the results of this simulation study:

Cool surfaces can reduce the peak demand in all climate zones in the continental US. If the building owner is paying demand charges, the economic benefit of cool surfaces can be extended to more northern climate zones than those using just energy savings. Utilities offer a wide variety of demand charge programs and the benefits vary even within the jurisdiction of a single utility.

Residential Buildings:

- Results from the simulations show that buildings with high solar reflectance can reduce cooling energy consumption by up to 25% while increasing the heating energy consumption.
- The highest peak load reduction was shown using the highest roof and exterior wall solar reflectance levels in all locations.
- The impact on energy savings was higher from the change in exterior wall solar reflectance compared to the change in roof solar reflectance when the exterior wall had no insulation compared to IECC 2021 wall insulation.
- Cost savings were highest in the hottest climate and lowest (with some penalties) in the coldest climate.
- For the residential cases that were simulated, the annual demand savings compared to the baseline for Houston, Baltimore, and Minneapolis ranged from $1 - $119, $1 - $80, and $0 - $29, respectively, while the annual total savings (energy plus demand) compared to the baseline for Houston, Baltimore, and Minneapolis ranged from $7 - $308, -$2 - $83, and -$21 - $4, respectively. See Tables 18 and 19 for more complete details.

Commercial Buildings:

- Commercial buildings with the highest roof and exterior wall solar reflectance levels saved up to 17% on cooling energy.
- The highest peak electric load reduction was seen with buildings having the highest roof and exterior wall solar reflectance in all locations.
- The cost savings was highest in the hot climate of Houston and lowest (with some penalties) in the cold climate of Minneapolis. The reduction in cooling energy consumption and increase in heating energy consumption from reflective roofs and exterior walls was also higher for building envelopes with lower insulation levels.
- In commercial buildings, the effect of roof solar reflectance was similar or higher than the exterior wall solar reflectance. This is due to the greater amount of roof surface area in commercial buildings relative to exterior wall surface area, and the lower insulation levels for commercial roofs compared to residential attics.
- For the commercial cases that were simulated, the annual demand savings compared to the baseline for Houston, Baltimore, and Minneapolis ranged from $33 - $1,704, $35 - $1,272, and $11 - $589, respectively, while the annual total savings (energy plus demand) compared to the

baseline for Houston, Baltimore, and Minneapolis ranged from $67 - $3,810, $69 - $1,510, and -$296 - $294, respectively. See Tables 20 through 23 for more complete details.

7. REFERENCES

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