Appendix A

Roof Albedo

Albedo Retrieval Procedure

Albedo is defined as the fraction of the incident solar energy that is reflected. To determine it one has the choice of localized measurements, which are of high accuracy and resolution, but are impractical in covering the large areas we need. Or, one can take wide angle measurements from a distance, which provides suitable spatial coverage but the accuracy and resolution of the data strongly depend on many factors, such as the sensor's height (airplane or satellite), the sensor's characteristics (IFOV - Instantaneous Field Of View, bandwidth, the spectral range) and the weather conditions. Once the data is corrected for atmospheric effects, some method of calibrating the observed radiant intensity with known albedos is then needed. The albedo value at a particular point can be calculated as a weighted average of the band(s) (channel) reflectances from that surface.

The altitude of the orbits of satellites (about 100 mi) limits the ground resolution of commercial satellite photographs from approximately 1 km (AVHRR) to 30 m (Landsat-TM), down to 10 m (SPOT). Unfortunately, these values are too coarse for the analysis of individual buildings. On the other hand, photographs from aircraft (usually taken at an altitude of about 4 mi) provides spatial coverage with resolution down to 1 m. However, this source of data usually lacks spectral information. Aircraft pictures are usually taken on panchromatic black and white, or infrared film. Multi-spectral sensors originally designed for satellite use can be mounted on an airplane, thus providing the additional spectral information, but at a higher cost.

High quality aerial photographs are sometimes available from the planning, zoning, or engineering departments of city or county governments. We tried to obtain copies for analysis in our laboratory (we can scan photographs into a computer, and then use programs that can give the grayscale values of the selected roofs and their surface areas). However, the quality of such copies of photos varies widely and most are not of sufficiently accurate contrast to be useful.

Fortunately, the National Digital Orthophoto Program (NDOP) is in the process of producing digitized aerial photographs of the entire United States, which is to be completed by the year 2001. Digitization means that degrees of lightness on panchromatic black and white photographs are represented as digital data. The digitized photographs are of sufficient resolution that individual buildings can be identified. The digital value of a roof's "grayness" can be read out. This data has the advantage of having been digitized from high quality original photographs taken for the National Aerial Photography Program, but we are not certain about how much processing has been done on the data. We then calibrate the digital readings into albedo by correlating surfaces of known albedo (asphalt, concrete, grass, etc.) with their digitized "graynesses". Using this correlation, we then convert the digitized data of roofs to their corresponding albedos.

Data and Processing

The digitizations of aerial photographs of three of the cities of interest for this project; Atlanta, Philadelphia, and Washington DC, have already been completed by NDOP. These photographs are available from the U.S. Geological Survey (USGS[8]). The resolution is about one pixel per 1 m and is sufficient for our purposes. In addition, the data have been subjected to orthographic projection[9], a vertical projection like a map. This results in "Digitized Orthophotos". The area of coverage of 7.5 minutes of latitude and longitude is called a "quadrangle", so that the data is referred to as a Digital Ortho Quadrangle (DOQ). It may be divided in four into "quarter quadrangles" (DOQQ), of extent 3.75 minutes of latitude and longitude.

The original photographs are taken at the center of a particular quarter-quadrangle at a flying height of 20,000 feet above mean terrain (photography scale = 1:40,000). After the photo has been digitalized it is rectified to an orthographic projection. The rectified image is then archived on a digital medium with a header containing descriptive information inserted as the first four records of the file. A typical DOQQ file contains approximately 7500 rows by 6500 columns with 8 bits per pixel (USGS, 1993), thus the file size is about 50 megabytes. Image brightness is represented by the 8 bits to give 256 levels per pixel. A value of 0 represents black and a value of 255 white.

In our study of Atlanta we used 16 DOQQs, which when put together formed 4 DOQs covering the urbanized area and some of its surroundings. The exact extent encompassed the area from -84.25 degrees to -84.5 degrees of geographic longitude and from 33.625 degrees to 33.875 degrees of geographic latitude (approx. 780 km^2).

In the process of image manipulation we stripped off the descriptive ASCII image headers and only the raw (binary) pixel data were displayed. The size of each DOQQ caused some problems. The files were too large to be handled by our programs. However, they could resample the data displaying one in ten pixels. Once the DOQQ was visualized at this lower resolution we could select a desired neighborhood and then extract the original data for this "sub-image". Thus, we achieved images of neighborhoods at the original high resolution. Photographs of residential and commercial buildings in Atlanta are shown in **Figures A-1** and **A-2**, respectively.

The sub-image analysis provided us with details and recognizable features contained in a particular image. Therefore, we were able to identify roofs, paved surfaces, lawns, trees, etc. By point-and-click, the objects grayness value was rapidly read and directed into a file of similar

[8] U.S. Geological Survey (USGS), Earth Science Information Center, 507 National Center, Reston, VA 22092.

[9] An orthographic projection is produced from a digitized perspective aerial photograph by differential rectification so that image displacements (radial deformations) caused by camera tilt and relief of terrain are removed. This process requires, as input, ground control points and a Digital Elevation Model (DEM). Digitized Orthophotos are geo-referenced in Universal Transverse Mercator (UTM) projection, with coordinates in meters, cast on North American Datum of 1983 (NAD 83).

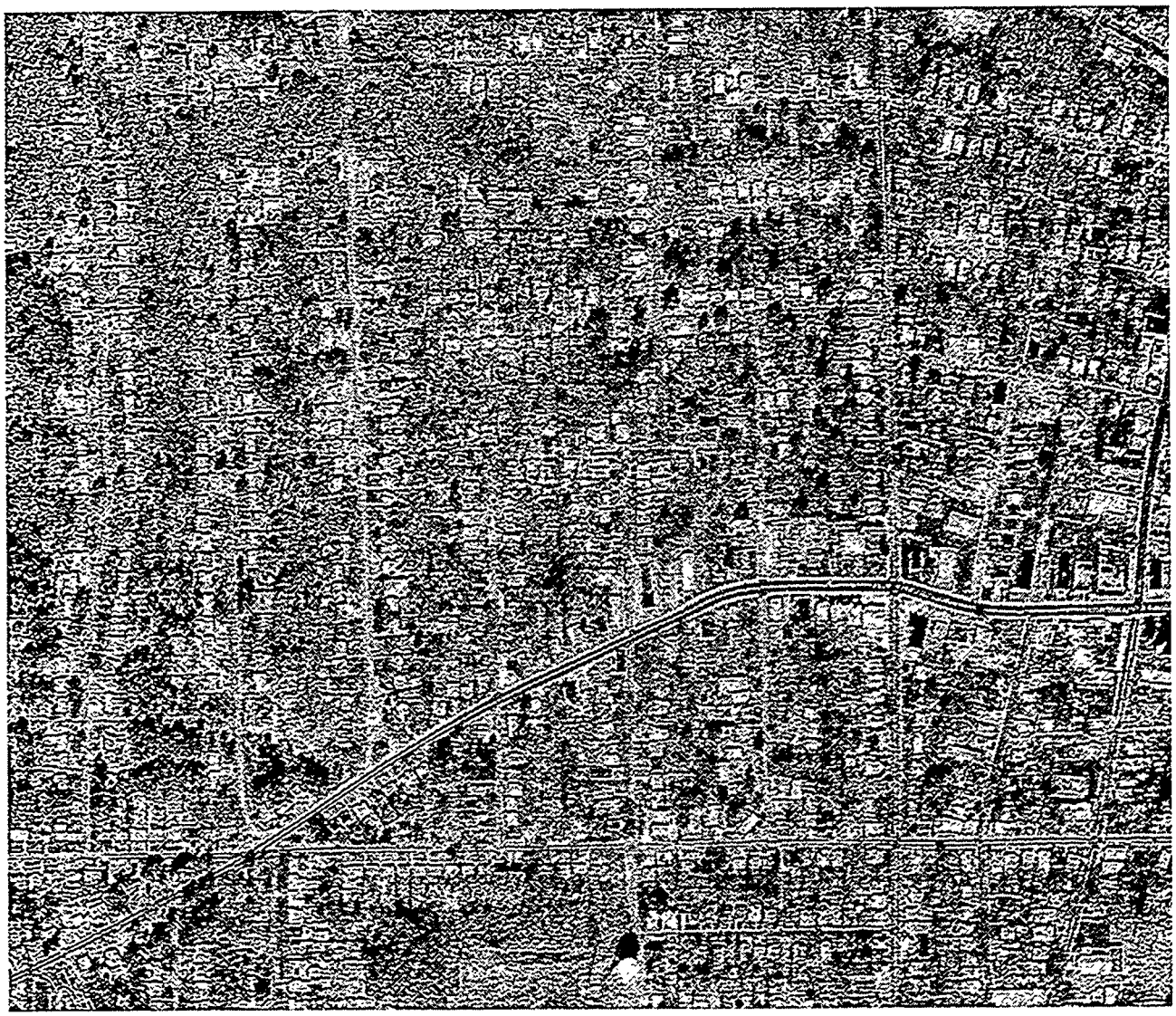

Figure A-1. Sub-image containing residential buildings in Atlanta with 1m resolution.

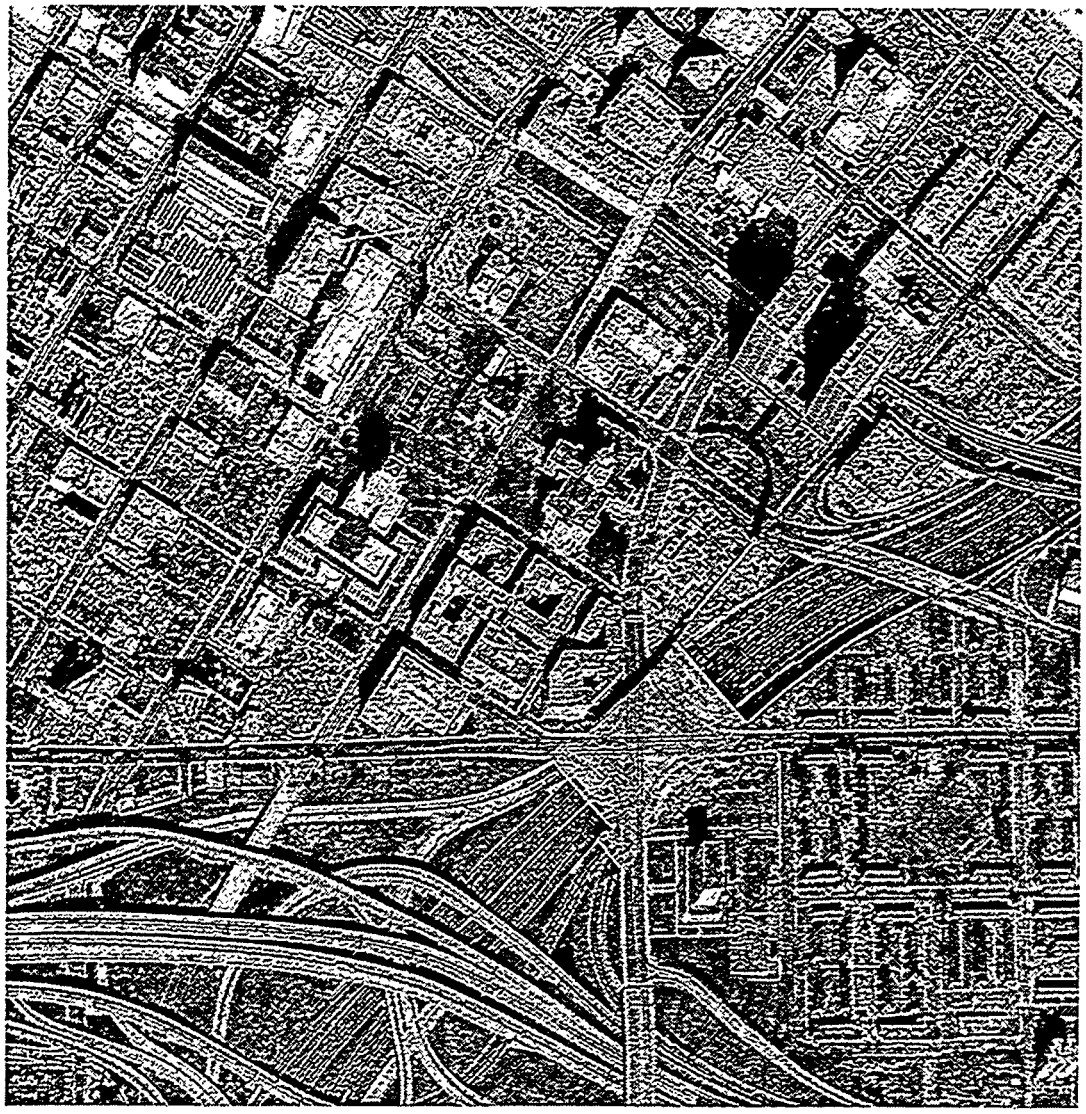

Figure A-2. Sub-image containing commercial buildings in Atlanta with 1m resolution.

objects. Sampling was performed randomly on sub-images. In going from one sub-image to the next, we checked that points that appeared in both images, where they overlapped had similar grayness values. This was to mitigate the problems that result from possible distortions of the grayness levels of the DOQQs before we received the data, which are described below.

Calibration of Grayness vs. Albedo

The grayness levels of interesting objects was converted to albedo. We did this by selecting surfaces whose albedos were known, and correlated the grayness values to these albedos. Surfaces used for the calibration of the grayness vs measured values of albedo were chosen to (a) span the range from low albedo to high, (b) be easily recognizable features on the image, and (c) be as homogeneous as possible. For example, in Atlanta, the graynesses of dark asphalt, weathered asphalt, grass, concrete surfaces and the roof of the Georgia Dome were utilized as calibration points. The roof of the Georgia Dome Stadium is very white and thus was a particularly handy reference point. These provided us with an average and range of grayness values for each surface. Next, we compared them with known (Taha, et al., 1992) albedos of the same kinds of surfaces as shown in **Table A-1**. The roof of the Georgia Dome, made of teflon coated fiberglass (Sheerfill ®), represented the high-end with albedo value of 0.72 (the value was provided by the manufacturer[10]). At the low-end dark asphalt albedo values were chosen. Since these surfaces reflect more diffusely than water, we preferred them to water as a reference point. In the choice of surfaces to measure, it was best to avoid those that were in the direction of the sun. Specular reflection can cause these areas to appear to have erroneously high albedos.

To find a mathematical relationship between grayness and albedo, we first tried a simple linear model, equation [3], where G is grayness and A is albedo.

$$G = mA + b \qquad [3]$$

The regression analysis had a high correlation ($R^2 = 0.94$), but it predicted an impossible result for the intercept value, $b = 69.7$. In other words, a surface with grayness less than the intercept would have a negative albedo, see **Figure A-3**. Therefore, a square root fitting was tested, equation [4].

$$G = mA^{1/2} + b \qquad [4]$$

It showed a similarly high correlation ($R^2 = 0.94$), but the intercept, $b = 1.8$, is close enough to zero to prevent negative albedos, see **Figure A-4**. Our goal was to determine albedo values from grayness. Equations [5] and [6] express this relation.

[10] Chemfab Corporation, 701 Daniel Webster Highway, PO Box 1137, Merrimack, NH 03054.

$$A = [(G - b)/m]^2 \quad [5]$$

$$A = [(G - 1.8) / 290.9]^2 \quad [6]$$

Table A-1. Albedo and Grayness Values for Surfaces in Atlanta.

Surface	Albedo	Grayness
Dark Asphalt	0.05 - 0.08	64 - 108
Weathered Asphalt	0.13 - 0.15	89 - 126
Grass	0.18 - 0.22	105 - 133
Concrete	0.30 - 0.36	157 - 185
Sheerfill ®	0.72	255

Our next step was to collect samples of roofs' grayness values for residential and commercial buildings. **Figures A-5** and **A-6**, respectively show histograms of the Atlanta distributions of the grayness values for residential and commercial buildings (divided into 20 levels each with bin width of 13). We randomly sampled 888 residential roofs and 129 commercial roofs in Atlanta. Converting the individual grayness values to albedos, using equation [6], then taking the average albedo, we find the average albedo of residences was 0.30 and for commercial buildings the average albedo was 0.32. These values seem rather high considering that the albedo of new "white" roof asphalt shingles was measured (Berdahl and Bretz, 1995) to be about 0.25.

A similar procedure was applied to the data available from the NDOP for Philadelphia and Washington DC. In **Table A-2** we show the cities analyzed, the number of roofs measured and the estimated average albedos for residential and commercial buildings. We note that the average albedo increased north to south, denoting lighter colored roofs in the South.

Table A-2. Estimated average roof albedos of residences and commercial buildings and sample size for Atlanta, Philadelphia, and Washington, DC.

city	residences		commercial	
	albedo	sample size	albedo	sample size
Atlanta	0.30	888	0.32	129
Washington DC	0.25	859	0.25	243
Philadelphia	0.20	1292	0.18	172

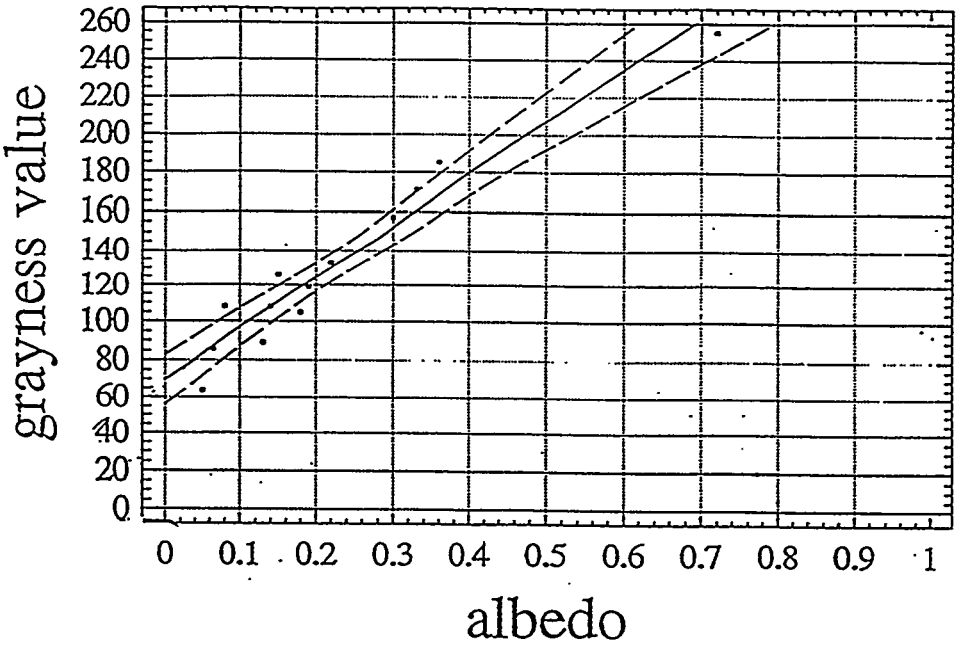

Figure A-3. Plot of fitted linear model.

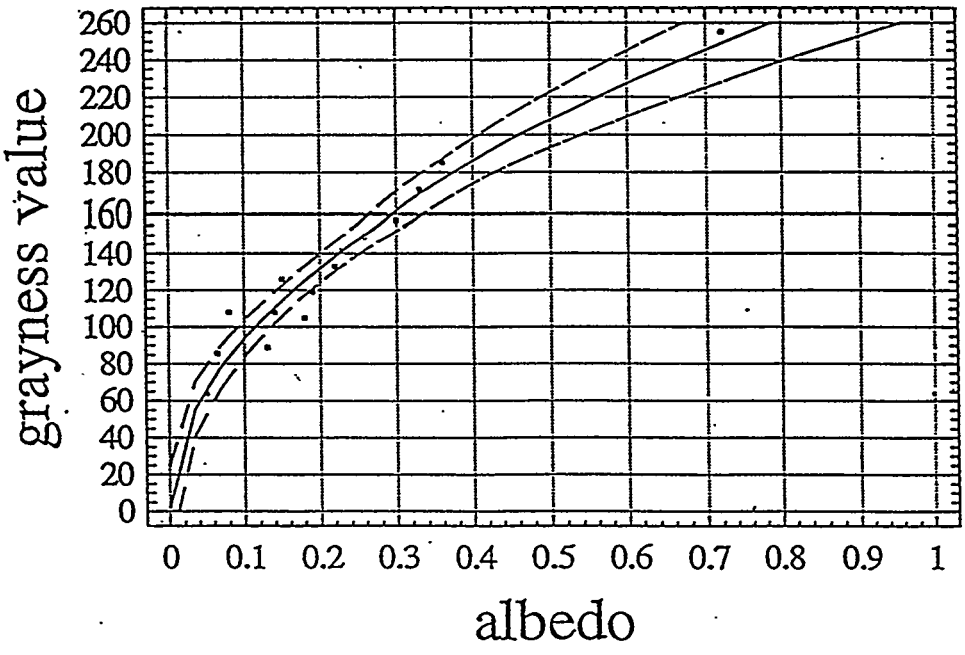

Figure A-4. Plot of fitted square root model.

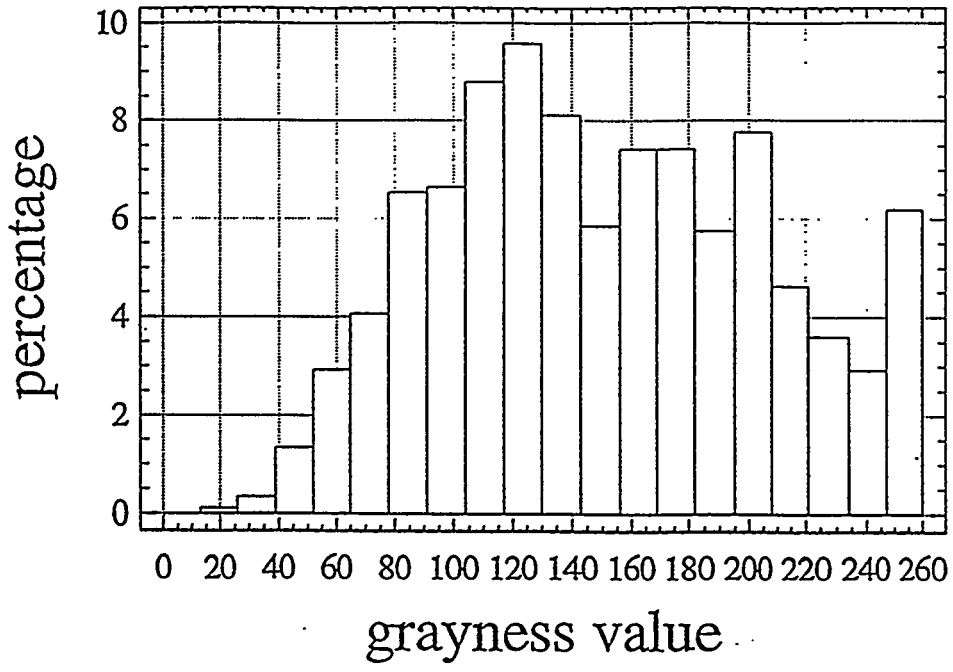

Figure A-5. Relative frequency histogram for distribution of grayness of residential building's roofs (20 bins, bin width = 13).

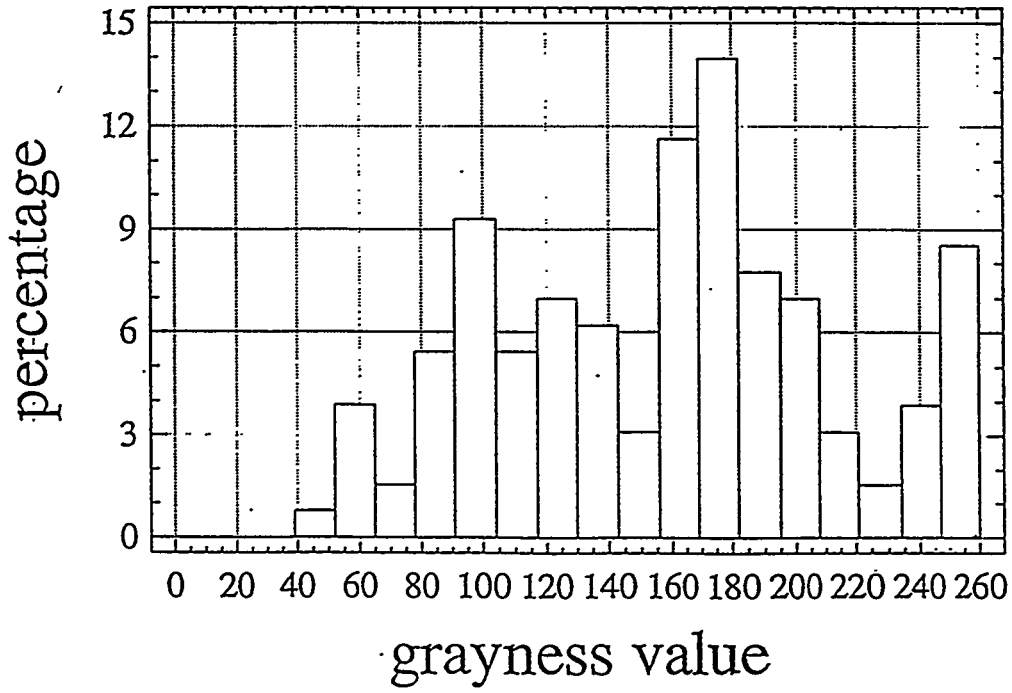

Figure A-6. Relative frequency histogram for distribution of grayness of commercial building's roofs (20 bins, bin width = 13).

Discussion

Our method, although very simple, proved the possibility of determining albedo values from digitized aerial photographs. It should be mentioned that this method is particularly valid for human-made surfaces. The explanation lies in the fact that human-made surfaces tend to have a more constant reflectivity over the visible and near IR spectral region. So, the visible reflectivity is a good approximation to the average albedo; whereas, vegetation reflects relatively more in the near infra-red part of the spectrum.

The question of consistency still remains. The same object in adjacent pictures will probably not have the same value of grayness, although similar, because of the effects of picture processing (USGS, 1993), such as "dodging" (or, shading of certain areas in picture) or "contrast stretching" (the practice of assigning the maximum (minimum) number to the brightest (darkest) pixel in a given set of data. With "stretching", the grayness is not absolute, but only relative to the particular set of pixels in that photograph. For example, if the Georgia Dome is the whitest point in its picture, it is assigned grayness is 255 and we know its albedo is 0.72. In an adjacent picture, if the brightest surface has an albedo of 0.60, its grayness will also be assigned 255. This means that an object in the overlapping region of both pictures with albedo of 0.36 will be assigned two different grayness values: 0.36/0.72*255=128 in the first picture and 0.36/0.60*255=153 in the second. These effects could also be a possible reason for a better fit of the square root model compared to the linear.

In the future, when analyzing other cities one has to check image consistency and then derive from the consistent set of pictures a new, city specific, regression. We have also recently found a method for correction of stretching.

Appendix B

Building-Scale HVAC Energy and Monetary Data

Weather and Price of Energy Data

The weather tapes used in DOE-2 building energy simulations and typical weather year (TMY) data for each location are shown in **Table B-1**; note the civic center tape represents Los Angeles. The residential and commercial average prices of energy for electricity and gas are in **Table B-2.**

Table B-1. Weather tapes used for DOE-2 simulations and typical weather year (TMY) data of 11 Metropolitan Statistical Areas (latent enthalpy hours: Btuh/lb of dry air).

metropolitan area	DOE-2 weather data					TMY weather data	
	type	latitude °N	longitude °W	degree hours / 24 at base 65 °F		latent enthalpy hours	avg sky cover
				heating	cooling		
Atlanta	wyec2	33.65	84.42	3215	1602	4931	0.495
Chicago	wyec2	41.78	92.75	6425	1105	2781	0.492
Los Angeles	tmy (civic center)	34.20	117.20	2238	1198	109	0.588
Dallas/Ft Wth	wyec2 (Ft Worth)	32.90	97.03	2604	2649	7951	0.536
Houston	tmy	29.65	95.28	1580	2883	18845	0.480
Miami/Ft Ldl	wyec2 (Miami)	25.82	80.28	283	4011	27753	0.506
New Orleans	tmy	29.88	90.25	1526	2610	17754	0.511
New York City	wyec2	40.77	73.90	5029	1076	1533	0.465
Philadelphia	tmy2	39.88	75.25	5297	1146	3168	0.461
Phoenix	wyec2	33.43	112.02	1672	4044	967	0.686
DC/Baltimore	wyec (DC)	38.95	77.45	4410	1494	3734	0.472

Table B-2. Average 1993 prices of electricity and natural gas (EIA, 1993a and 1993b).

Metropolitan Area	Electricity (cents/kWh)		Natural Gas ($/MBtu)	
	Residential	Commercial	Residential	Commercial
Atlanta	7.8	7.4	6.8	5.8
Chicago	11.2	8.4	5.5	5.1
Los Angeles	9.8	8.9	6.2	6.0
Dallas/Fort Worth	7.7	6.4	5.9	4.4
Houston	9.3	7.6	5.9	4.4
Miami/Fort Lauderdale	8.1	6.8	10.0	5.8
New Orleans	7.9	8.4	6.1	5.3
New York City	16.0	12.6	8.1	6.2
Philadelphia	12.8	11.8	6.8	6.0
Phoenix	10.7	9.2	7.2	5.1
DC/Baltimore	7.2	7.1	8.3	5.8

DOE-2 Building Prototype Characteristics and Simulation Results

DOE-2 prototypes were developed for single-family residential and commercial buildings from several sources. Residential, office, and retail store prototype characteristics were based on survey data from the California Energy Commission (CEC, 1994). Additional residential characteristics were obtained from data of a Sacramento, California white-surface study (Akbari, et al., 1992). The primary and secondary schools, hospital, nursing home, and grocery store building prototypes and additional office and retail store characteristics were obtained from mail and on-site surveys of Pacific Gas & Electric (PG&E) and Southern California Edison (SCE) service areas during previous LBNL projects (Akbari, et al., 1989, 1991, and 1993b). These are shown in **Tables B-3** through **B-18**.

The residential, office, and retail store prototypes were further sub-divided into old and new vintages and into gas furnace and electric heat pump heating types. The old style vintage represents pre-1980 construction practices and HVAC system efficiencies, and the new represents 1980 and later. In California, title-24 building energy standards were implemented starting 1978, and these were applied to the residential, office, and retail store new vintage prototypes. Construction, interior load, and HVAC system characteristics are shown for all building prototypes in Tables B-3 through B-18. The characteristics were uniform over all locations with the exception of the HVAC component sizes, which were locally dependent.

All buildings were modeled as single-story structures, with the exception of the 7 story hospital and the two-section secondary school (where the first section had 3 floors and the second 1 floor). The hospital had 14% roof area and the secondary school 57%.

The prototypes were used as input to the building energy simulation program DOE-2.1E. These simulation results for the base case and savings from modified albedo are shown in **Table B-19** for each building and location and are expressed per 1000ft^2 of flat roof area.

DOE-2 Simulated HVAC Electricity, Natural Gas, and Net Energy Savings by Climate

Figures B-1 through **B-4** are scatter plots of annual electricity, net energy, and peak demand savings in increasing order of cooling degree days, and annual natural gas deficit in increasing order of heating degree days for each building type and location.

Table B-3. Single-family residential prototype characteristics.

Characteristic	Old Vintage	New Vintage
Construction		
Floor Area (ft^2)	1500	
Number of Floors	1	
Floor Materials	Carpet w/ Pad	
	4" Heavy Weight Dried Concrete	
Roof Materials	1/4" Asphalt Shingle, 1/2" Plywood, Attic Res	
	R-11 Insulation	R-19 Insulation
	1/2" Gypsum	
Wall Materials	1" Stucco, Paper	
	R-7 Insulation	R-11 Insulation
	1/2" Gypsum	
Window Characteristics	Clear	
Number of Panes	1	2
Shading Coefficient	0.86	0.76
Interior Loads		
Occupancy	3	
Interior Lights (W/ft^2)	0.4	
Miscellaneous (W/ft^2)	0.8	
HVAC System		
Type	RESYS2	
Schedule	7 am - 11 pm	
	Weekday / Weekend	
	Jan 1 - Dec 31	
Ventilation	Supply	
Capacity (cfm)	Local	Local
Efficiency (W/cfm)	0.373	0.336
Economizer	Enthalpic	
Minimum Outside Air	0.05	
Natural Ventilation	Yes	
Cooling		
Type	Packaged Direct-Expansion / Air-Cooled	
Capacity (tons)	Local	Local
COP	2.1	2.7
Setpoint (°F)	78	
Setup (°F)	78	
Heating		
Type 1	Forced Air / Natural Gas	
Capacity (kBtu/hr)	Local	Local
Efficiency (%)	70	74
Type 2	Electric Heat Pump	
Capacity (tons)	Local	Local
COP	2.1	2.7
Setpoint (°F)	70	
Setback (°F)	64	

Table B-4. Single-family residential prototype local HVAC capacities.

Location	Old Vintage			New Vintage		
	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)
Atlanta	800	2.5	40	700	2.0	35
Chicago	1000	2.5	50	800	2.0	35
Los Angeles	1000	2.5	45	900	2.0	40
Fort Worth	1100	3.0	50	900	2.5	40
Houston	900	3.0	45	800	2.5	35
Miami	900	2.5	40	800	2.0	35
New Orleans	800	2.0	40	600	2.0	30
New York City	900	2.5	45	700	2.0	35
Philadelphia	1000	2.5	50	900	2.0	40
Phoenix	1400	3.5	65	1200	3.0	55
Washington DC	800	2.5	40	700	2.0	35

Table B-5. Office prototype characteristics.

Characteristic	Old Vintage	New Vintage
Construction		
Floor Area (ft^2)	4900	
Number of Floors	1	
Floor Materials	Carpet w/ Pad	
	4" Heavy Weight Dried Concrete	
Roof Materials	Built-up-roof, 1/2" Plywood, Attic Res	
	R-11 Insulation	R-19 Insulation
	1/2" Gypsum	
Wall Materials	1" Stucco, 1/2" Plywood, Paper	
	R-7 Insulation	R-11 Insulation
	1/2" Gypsum	
Window Characteristics	Clear	
Number of Panes	1	2
Shading Coefficient	0.86	0.76
Interior Loads		
Occupancy (ft^2/person)	200	
Interior Lights (W/ft^2)	1.4	
Miscellaneous (W/ft^2)	0.7	
HVAC System		
Type	PSZ	
Schedule	6 am - 7 pm	
	Weekdays Only	
	Jan 1 - Dec 31	
Ventilation	Supply	
Capacity (cfm)	Zonal/Local	Zonal/Local
Efficiency (W/cfm)	0.587	0.528
Economizer	Enthalpic	
Outside Air (cfm/person)	15	
Natural Ventilation	No	
Cooling		
Type	Packaged Direct-Expansion / Air-Cooled	
Capacity (tons)	Zonal/Local	Zonal/Local
COP	2.1	2.7
Setpoint (°F)	78	
Setup (°F)	99	
Heating		
Type 1	Forced Air / Natural Gas	
Capacity (kBtu/hr)	Zonal/Local	Zonal/Local
Efficiency (%)	70	74
Type 2	Electric Heat Pump	
Capacity (tons)	Zonal/Local	Zonal/Local
COP	2.1	2.7
Setpoint (°F)	70	
Setback (°F)	55	

Table B-6. Office prototype zonal and local HVAC capacities.

Location	Old Office Zone														
	Core (1600 ft^2)			North (600 ft^2)			East (1050 ft^2)			South (600 ft^2)			West (1050 ft^2)		
	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)
Atlanta	800	2.5	40	540	2.0	30	945	2.5	40	780	2.5	40	945	2.5	40
Chicago	800	2.5	40	540	2.0	30	945	2.5	45	720	2.0	35	945	2.5	45
Los Angeles	800	2.5	35	540	2.0	25	945	2.5	40	1020	3.0	45	945	2.5	40
Fort Worth	960	3.0	45	619	2.5	30	1050	3.0	45	781	2.5	40	1050	3.5	50
Houston	800	3.0	35	544	2.0	30	945	3.0	40	780	2.5	35	945	3.0	40
Miami	800	3.0	40	540	2.0	25	945	3.0	40	900	3.0	40	945	3.0	40
New Orleans	800	3.0	35	540	2.0	25	945	3.0	40	780	2.5	35	945	3.0	40
New York City	800	2.5	35	600	2.0	30	1050	3.0	45	600	2.0	30	1050	2.5	40
Philadelphia	800	2.5	40	540	1.5	30	945	2.5	40	600	2.0	30	945	2.5	40
Phoenix	968	3.0	45	731	2.5	35	1260	3.5	50	960	3.0	45	1260	3.5	55
Washington DC	800	2.5	35	540	2.0	30	945	2.5	40	660	2.5	35	945	3.0	45

Location	New Office Zone														
	Core (1600 ft^2)			North (600 ft^2)			East (1050 ft^2)			South (600 ft^2)			West (1050 ft^2)		
	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)
Atlanta	800	2.5	35	422	1.5	25	735	2.5	35	720	2.5	35	735	2.5	35
Chicago	800	2.5	35	480	1.5	25	840	2.5	40	660	2.0	35	840	2.5	40
Los Angeles	800	2.5	30	480	1.5	20	840	2.5	35	900	2.5	40	840	2.5	35
Fort Worth	960	3.0	40	540	2.0	30	945	3.0	40	720	2.5	35	945	3.0	40
Houston	800	2.5	35	480	2.0	25	840	2.5	35	660	2.5	35	840	3.0	35
Miami	800	2.5	35	480	2.0	25	840	2.5	35	780	2.5	35	840	2.5	35
New Orleans	800	2.5	35	427	2.0	25	735	2.5	35	663	2.5	35	735	2.5	35
New York City	800	2.0	35	480	1.5	25	840	2.5	40	540	1.5	25	840	2.5	35
Philadelphia	800	2.5	40	420	1.5	25	735	2.0	35	540	2.0	30	735	2.0	35
Phoenix	960	3.0	40	600	2.0	30	1050	3.0	40	840	2.5	40	1050	3.0	45
Washington DC	800	2.5	35	480	1.5	25	840	2.5	35	600	2.0	30	840	2.5	40

Table B-7. Retail store prototype characteristics.

Characteristic	Old Vintage	New Vintage
Construction		
Floor Area (ft^2)	8100	
Number of Floors	1	
Floor Materials	Carpet w/ Pad	
	4" Heavy Weight Dried Concrete	
Roof Materials	Built-up-roof, 1/2" Plywood, Attic Res	
	R-11 Insulation	R-19 Insulation
	1/2" Gypsum	
Wall Materials	1" Stucco, 1/2" Plywood, Paper	
	R-7 Insulation	R-11 Insulation
	1/2" Gypsum	
Window Characteristics	Clear	
Number of Panes	1	2
Shading Coefficient	0.86	0.76
Interior Loads		
Occupancy (ft^2/person)	500	
Interior Lights (W/ft^2)	2.0	
Miscellaneous (W/ft^2)	0.5	
HVAC System		
Type	PSZ	
Schedule	8 am - 9 pm Weekdays	
	10 am - 7 pm Weekends	
	Jan 1 - Dec 31	
Ventilation	Supply	
Capacity (cfm)	Zonal/Local	Zonal/Local
Efficiency (W/cfm)	0.587	0.528
Economizer	Enthalpic	
Outside Air (cfm/person)	15	
Natural Ventilation	No	
Cooling		
Type	Packaged Direct-Expansion / Air-Cooled	
Capacity (tons)	Zonal/Local	Zonal/Local
COP	2.1	2.7
Setpoint (°F)	78	
Setup (°F)	99	
Heating		
Type 1	Forced Air / Natural Gas	
Capacity (kBtu/hr)	Zonal/Local	Zonal/Local
Efficiency (%)	70	74
Type 2	Electric Heat Pump	
Capacity (tons)	Zonal/Local	Zonal/Local
COP	2.1	2.7
Setpoint (°F)	70	
Setback (°F)	55	

Table B-8. Retail store prototype local HVAC capacities.

Location	Old Vintage			New Vintage		
	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)
Atlanta	5670	15.0	250	4860	15.0	220
Chicago	5670	15.0	240	4860	12.5	210
Los Angeles	5670	15.0	240	4860	12.5	210
Fort Worth	6480	20.0	270	5670	15.0	230
Houston	5670	15.0	240	4860	15.0	210
Miami	5670	15.0	240	4860	15.0	210
New Orleans	5670	15.0	240	4860	15.0	210
New York City	5670	15.0	240	4860	12.5	210
Philadelphia	5670	15.0	230	4860	12.5	200
Phoenix	7290	20.0	290	5670	20.0	250
Washington DC	5670	15.0	250	4860	15.0	220

Table B-9. Primary school prototype characteristics.

Construction	
Floor Area (ft^2)	35000
Number of Floors	1
Floor Materials	Linoleum Tile
	6" Heavy Weight Dried Concrete
Roof Materials	Built-up-roof, 1/2" Plywood, Attic Res
	R-11 Insulation
	1/2" Gypsum
Wall Materials	8" Medium Concrete Block Hollow
	R-7 Insulation
	1/2" Gypsum
Window Characteristics	Clear
Number of Panes	1
Shading Coefficient	0.86
Interior Loads	
Occupancy	Zonal
Interior Lights (W/ft^2)	Zonal
Miscellaneous (W/ft^2)	Zonal
HVAC System	
Type	PSZ
Schedule	7 am - 6 pm
	Weekday Only
	Jan 1 - Jun 13, Sep 2 - Dec 23
Ventilation	Supply
Capacity (cfm)	Zonal/Local
Efficiency (W/cfm)	0.587
Economizer	Enthalpic
Outside Air (cfm/person)	Zonal
Natural Ventilation	No
Cooling	
Type	Packaged Direct-Expansion / Air-Cooled
Capacity (tons)	Zonal/Local
COP	2.1
Setpoint (°F)	74
Setup (°F)	99
Heating	
Type	Forced Air / Natural Gas
Capacity (kBtu/hr)	Zonal/Local
Efficiency (%)	70
Setpoint (°F)	71
Setback (°F)	55

	Class	Kitchen	Library	Total
Floor Area (% of total)	77	6	17	100
Occupancy (ft^2/person)	90	210	80	-
Outside Air (cfm/person)	15	-	15	-
Outside Air (ach)	-	2.9	-	-
Interior Lights (W/ft^2)	1.8	1.4	1.2	1.7
Miscellaneous (W/ft^2)	0.5	11.7	0.5	1.2

Table B-10. Primary school prototype zonal and local HVAC capacities.

Location	Zone								
	Class			Kitchen			Library		
	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)
Atlanta	27000	75	1400	4401	15	250	4798	15	300
Chicago	27000	75	1500	4399	15	300	4437	15	300
Los Angeles	27366	75	1300	4426	15	250	4798	15	250
Fort Worth	29700	85	1500	4398	20	250	4848	20	300
Houston	27000	80	1300	4440	20	250	4311	15	250
Miami	27388	80	1300	4478	20	250	4814	20	250
New Orleans	27000	85	1300	4463	20	250	4435	20	250
New York City	24300	65	1300	4398	15	250	3895	15	250
Philadelphia	21695	55	1200	4398	15	250	3284	10	250
Phoenix	33331	85	1600	4621	20	250	5998	20	250
Washington DC	27000	75	1400	4300	15	250	4322	15	250

Table B-11. Secondary school prototype characteristics.

Construction	
Floor Area (ft^2)	100000
Number of Floors	3
Roof Area (ft^2)	57000
Floor Materials	Linoleum Tile
	6" Heavy Weight Dried Concrete
Roof Materials	Built-up-roof, 1/2" Plywood, Attic Res
	R-11 Insulation
	1/2" Gypsum
Wall Materials	8" Medium Concrete Block Hollow
	R-7 Insulation
	1/2" Gypsum
Window Characteristics	Clear
Number of Panes	1
Shading Coefficient	0.86
Interior Loads	
Occupancy	Zonal
Interior Lights (W/ft^2)	Zonal
Miscellaneous (W/ft^2)	Zonal
HVAC System	
Type	PSZ
Schedule	7 am - 9 pm, Weekday
	10 am - 3 pm, Saturday
	Jan 1 - Dec 23
Ventilation	Supply
Capacity (cfm)	Zonal/Local
Efficiency (W/cfm)	0.587
Economizer	Enthalpic
Outside Air (cfm/person)	Zonal
Natural Ventilation	No
Cooling	
Type	Packaged Direct-Expansion / Air-Cooled
Capacity (tons)	Zonal/Local
COP	2.1
Setpoint (°F)	78
Setup (°F)	99
Heating	
Type	Forced Air / Natural Gas
Capacity (kBtu/hr)	Zonal/Local
Efficiency (%)	70
Setpoint (°F)	75
Setback (°F)	55

	Library	Gym	Auditorium	Kitchen	Dining	Class	Total
Floor Area (% of total)	13	13	8	2	4	60	100
Occupancy (ft^2/person)	100	180	100	300	20	90	-
Outside Air (cfm/person)	15	15	15	-	15	15	-
Outside Air (ach)	-	-	-	3.0	-	-	-
Interior Lights (W/ft^2)	1.5	0.7	0.8	1.7	1.7	2.2	1.8
Miscellaneous (W/ft^2)	0.15	0.15	0.15	12.0	0.15	0.15	0.4

Table B-12. Secondary school prototype zonal and local HVAC capacities.

Location	Zone														
	Library			Gym			Auditorium			Kitchen			Dining		
	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)
Atlanta	5200	20	350	11700	35	500	6400	20	350	3600	15	200	4800	25	400
Chicago	5200	20	350	15600	50	650	8361	30	400	3600	15	250	4918	25	450
Los Angeles	5200	20	250	9100	30	350	3200	10	200	3600	12	200	5200	20	300
Fort Worth	5200	25	350	10400	35	450	4932	20	300	3600	15	200	4932	25	400
Houston	5200	25	300	9141	35	400	4202	20	250	3600	15	200	4827	25	350
Miami	5200	25	300	9100	35	400	3200	15	200	3600	15	200	4935	25	350
New Orleans	5200	20	300	9100	30	400	4108	20	250	3605	15	200	4868	25	350
New York City	5200	20	350	14370	40	600	8000	25	400	3476	12	200	4868	20	400
Philadelphia	4209	15	300	13000	35	550	7200	20	350	3463	12	200	4800	20	400
Phoenix	5203	25	300	15976	50	650	7200	25	350	3800	15	200	5600	25	400
Washington DC	5200	20	300	12251	40	550	6400	25	350	3458	15	200	4800	25	400

Location	Zone					
	Class Bottom Floor			Class Top Floor		
	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)
Atlanta	17999	65	1000	22182	75	1150
Chicago	18092	65	1100	21859	75	1200
Los Angeles	18529	55	850	22238	65	1000
Fort Worth	20999	75	1050	23999	80	1150
Houston	17999	75	900	22335	85	1100
Miami	19447	75	950	23999	85	1050
New Orleans	17999	70	900	23999	80	1100
New York City	18129	60	1000	21640	65	1150
Philadelphia	17999	55	1000	20999	60	1100
Phoenix	21203	75	1050	26999	90	1250
Washington DC	17999	65	950	20999	75	1100

Table B-13. Hospital prototype characteristics.

Construction	
Floor Area (ft^2)	132000
Number of Floors	7
Roof Area (ft^2)	18900
Floor Materials	Carpet and Pad
	6" Heavy Weight Dried Concrete
Roof Materials	Built-up-roof, 6" Concrete Deck, Attic Res
	R-11 Insulation
	Acoustic Tile
Wall Materials	12" Heavy Concrete Block Filled
	R-7 Insulation
	Air-Space, 1/2" Gypsum
Window Characteristics	Clear
Number of Panes	1
Shading Coefficient	0.86
Interior Loads	
Occupancy	Zonal
Interior Lights (W/ft^2)	Zonal
Miscellaneous (W/ft^2)	Zonal
HVAC System	
Type	VAVS
Schedule	24 Hour Operation
	Weekday / Weekend
	Jan 1 - Dec 31
Ventilation	Supply
Capacity (cfm)	Zonal/Local
Economizer	Enthalpic
Outside Air (cfm/person)	Zonal
Natural Ventilation	No
Cooling	
Type	Hermetic Centrifugal Chiller / Air-Cooled Cooling Tower
Capacity (tons)	Local
Setpoint (°F)	78
Heating	
Type	Hot Water Boiler / Natural Gas
Capacity (MBtu/hr)	Local
Setpoint (°F)	70

	Perimeter (Rooms)	Core/Public	Hallways	Kitchen	Clinic	Total
Floor Area (% total)	15	35	20	5	25	100
Occupancy (ft^2/person)	150	290	580	320	290	-
Outside Air (cfm/person)	15	15	15	-	15	-
Outside Air (ach)	-	-	-	1.8	-	-
Interior Lights (W/ft^2)	1.6	1.6	0.8	2.1	2.1	1.6
Miscellaneous (W/ft^2)	1.3	1.3	-	13.0	4.0	2.3

Table B-14. Hospital prototype zonal and local HVAC capacities.

Location	Zone						
	Perimeter (Rooms)	Core/Public/ Hallways	Kitchen	Clinic	All Zones		
	Fan (cfm)	Fan (cfm)	Fan (cfm)	Fan (cfm)	Chiller (tons)	Cooling Tower (tons)	Boiler (MBtu/hr)
Atlanta	43659	74327	15868	47297	450	550	1.57
Chicago	45560	75694	15891	47294	450	550	2.62
Los Angeles	47446	77303	15895	47458	450	550	0.23
Fort Worth	49657	82758	16560	50998	500	600	1.08
Houston	43995	74844	15876	47463	450	550	0.68
Miami	43509	73661	15331	47269	450	550	0.19
New Orleans	43584	73871	15350	47310	450	550	0.70
New York City	45487	75069	15422	47264	450	550	2.04
Philadelphia	45800	76290	15914	47490	450	550	1.82
Phoenix	55536	90892	17233	54537	500	600	0.41
Washington DC	45531	75548	15889	47401	450	550	1.78

Table B-15. Nursing home prototype characteristics.

Construction	
Floor Area (ft^2)	38400
Number of Floors	1
Floor Materials	Carpet and Pad
	6" Heavy Weight Dried Concrete
Roof Materials	Built-up-roof, 1/2" Plywood, Attic Res
	R-11 Insulation
	Acoustic Tile
Wall Materials	8" Medium Concrete Block Hollow
	R-7 Insulation
	1/2" Gypsum
Window Characteristics	Clear
Number of Panes	1
Shading Coefficient	0.86
Interior Loads	
Occupancy	Zonal
Interior Lights (W/ft^2)	Zonal
Miscellaneous (W/ft^2)	Zonal
HVAC System	
Type	PSZ
Schedule	24 Hour Operation
	Weekday / Weekend
	Jan 1 - Dec 31
Ventilation	Supply
Capacity (cfm)	Zonal/Local
Efficiency (W/cfm)	0.587
Economizer	Enthalpic
Outside Air (cfm/person)	Zonal
Natural Ventilation	No
Cooling	
Type	Packaged Direct-Expansion / Air-Cooled
Capacity (tons)	Zonal/Local
COP	2.1
Setpoint (°F)	78
Setup (°F)	99
Heating	
Type	Forced Air / Natural Gas
Capacity (kBtu/hr)	Zonal/Local
Efficiency (%)	70
Setpoint (°F)	70
Setback (°F)	55

	Multi-Purpose	Kitchen	Rooms	Total
Floor Area (% of total)	20	5	75	100
Occupancy (ft^2/person)	50	190	300	-
Outside Air (cfm/person)	15	-	15	-
Outside Air (ach)	-	3.9	-	-
Interior Lights (W/ft^2)	1.2	1.3	0.8	0.9
Miscellaneous (W/ft^2)	-	18.0	1.3	1.9

Table B-16. Nursing home prototype zonal and local HVAC capacities.

Location	Zone								
	Multi-Purpose			Kitchen			Rooms		
	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)
Atlanta	4603	20	350	2302	10	200	17844	50	850
Chicago	4037	15	400	2302	8	200	17113	45	850
Los Angeles	4603	20	300	2302	8	150	18401	50	800
Fort Worth	4951	20	350	2327	10	150	19709	55	900
Houston	3995	20	300	2302	10	150	16177	50	750
Miami	4603	20	300	2302	9	150	18838	55	850
New Orleans	3894	20	300	2302	9	150	16099	50	750
New York City	3980	20	350	2302	9	200	16174	50	800
Philadelphia	4603	20	350	2110	10	150	17280	45	700
Phoenix	5412	25	350	2493	9	200	22265	65	1000
Washington DC	4603	20	350	2302	9	200	18024	50	850

Table B-17. Grocery store prototype characteristics.

Construction	
Floor Area (ft^2)	4400
Number of Floors	1
Floor Materials	Linoleum Tile
	6" Heavy Weight Dried Concrete
Roof Materials	Built-up-roof, 1/2" Plywood, Attic Res
	R-11 Insulation
	1/2" Gypsum
Wall Materials	4" Brick, 8" Heavy Concrete Block Hollow
	R-7 Insulation
	1/2" Gypsum
Window Characteristics	Clear
Number of Panes	1
Shading Coefficient	0.86
Interior Loads	
Occupancy	Zonal
Interior Lights (W/ft^2)	Zonal
Miscellaneous (W/ft^2)	Zonal
HVAC System	
Type	PSZ
Schedule	6 am - 12 am
	Weekday / Weekend
	Jan 1 - Dec 31
Ventilation	Supply
Capacity (cfm)	Zonal/Local
Efficiency (W/cfm)	0.587
Economizer	Enthalpic
Outside Air (cfm/person)	Zonal
Natural Ventilation	No
Cooling	
Type	Packaged Direct-Expansion / Air-Cooled
Capacity (tons)	Zonal/Local
COP	2.1
Setpoint (°F)	75
Setup (°F)	99
Heating	
Type	Forced Air / Natural Gas
Capacity (kBtu/hr)	Zonal/Local
Efficiency (%)	70
Setpoint (°F)	70
Setback (°F)	55

	Office	Storage	Bakery	Deli	Sale	Total
Floor Area (% total)	3	20	12	5	60	100
Occupancy (ft^2/person)	130	880	220	220	325	-
Outside Air (cfm/person)	15	15	-	15	15	-
Outside Air (ach)	-	-	5.6	-	-	-
Interior Lights (W/ft^2)	1.7	1.0	1.7	1.7	1.7	1.6
Miscellaneous (W/ft^2)	0.5	0.4	7.5	3.8	0.4	0.6

Table B-18. Grocery store prototype zonal and local HVAC capacities.

Location	Zone														
	Sales			Storage			Deli			Bakery			Office		
	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)	Fan (cfm)	Cooling (tons)	Heating (kBtu/hr)
Atlanta	3457	8.0	150	356	1.5	25	288	1.0	15	1010	6.0	120	106	1.0	10
Chicago	3808	9.0	170	537	2.0	35	317	1.0	15	1010	6.0	140	106	1.0	10
Los Angeles	3723	9.0	160	303	1.5	20	253	1.0	15	1010	5.0	75	98	1.0	5
Fort Worth	4255	10.0	190	462	2.0	30	362	1.0	20	1064	6.0	100	121	1.0	10
Houston	3457	9.0	150	266	1.5	20	222	1.0	10	1010	7.0	100	109	1.0	10
Miami	3457	8.0	150	443	1.5	30	355	1.0	20	1010	6.0	90	107	1.0	10
New Orleans	3191	8.0	140	266	1.0	20	202	1.0	10	1010	6.0	100	106	1.0	10
New York City	3791	9.0	170	479	2.0	30	267	1.0	15	1010	5.0	120	99	1.0	10
Philadelphia	4057	9.0	180	1152	3.5	70	712	2.0	35	1010	5.0	110	106	1.0	10
Phoenix	5052	12.5	210	620	2.5	40	444	1.5	20	1181	6.0	110	146	1.0	10
Washington DC	3527	9.0	160	443	1.5	25	273	1.0	15	1010	6.0	110	108	1.0	10

Table B-19. DOE-2 simulated HVAC base use and savings from light-colored roofing; annual electricity and net energy, peak electricity demand, and annual natural gas estimated **per 1000ft^2 of flat roof area.**

Metropolitan Area	Old Res w/ Gas Furnace			Old Res w/ Heat Pump			New Res w/ Gas Furnace			New Res w/ Heat Pump		
	Base Case	Savings		Base Case	Savings		Base Case	Savings		Base Case	Savings	
		Δ	%		Δ	%		Δ	%		Δ	%
Atlanta												
Electricity (kWh/1000ft^2)	1994	232	12	5554	153	3	1364	125	9	3350	89	3
Gas (kBtu/1000ft^2)	27546	-697	-3	0	0	0	17351	-383	-2	0	0	0
Net Energy ($/1000ft^2)	343	14	4	433	12	3	225	8	4	261	6	2
Peak (W/1000ft^2)	2175	143	7	2175	143	7	1455	91	6	1455	91	6
Chicago												
Electricity (kWh/1000ft^2)	1380	131	9	11273	-19	0	925	72	8	7001	-12	0
Gas (kBtu/1000ft^2)	69290	-1264	-2	0	0	0	46300	-787	-2	0	0	0
Net Energy ($/1000ft^2)	536	8	1	1262	-3	0	358	4	1	784	-2	0
Peak (W/1000ft^2)	2305	117	5	2305	117	5	1481	52	4	1481	52	4
Los Angeles												
Electricity (kWh/1000ft^2)	1364	238	17	2588	177	7	846	126	15	1349	101	7
Gas (kBtu/1000ft^2)	10721	-544	-5	0	0	0	5375	-244	-5	0	0	0
Net Energy ($/1000ft^2)	200	20	10	254	18	7	116	11	9	132	10	8
Peak (W/1000ft^2)	2305	247	11	2305	247	11	1481	130	9	1481	130	9
Fort Worth												
Electricity (kWh/1000ft^2)	3457	244	7	6232	185	3	2364	133	6	3842	106	3
Gas (kBtu/1000ft^2)	21955	-501	-2	0	0	0	13294	-277	-2	0	0	0
Net Energy ($/1000ft^2)	395	16	4	480	14	3	260	8	3	296	8	3
Peak (W/1000ft^2)	3221	175	5	3221	175	5	2097	97	5	2097	97	5
Houston												
Electricity (kWh/1000ft^2)	2986	279	9	4505	238	5	1990	151	8	2759	129	5
Gas (kBtu/1000ft^2)	12542	-352	-3	0	0	0	7338	-204	-3	0	0	0
Net Energy ($/1000ft^2)	352	24	7	419	22	5	229	13	6	256	12	5
Peak (W/1000ft^2)	2981	130	4	2981	130	4	1981	110	6	1981	110	6
Miami												
Electricity (kWh/1000ft^2)	5150	376	7	5277	374	7	3689	205	6	3734	205	5
Gas (kBtu/1000ft^2)	1086	-20	-2	0	0	0	457	-1	0	0	0	0
Net Energy ($/1000ft^2)	428	30	7	427	30	7	303	16	5	303	17	6
Peak (W/1000ft^2)	2409	208	9	2409	208	9	1545	84	5	1545	84	5

Table B-19(Cont). DOE-2 simulated HVAC base use and savings from light-colored roofing; annual electricity and net energy, peak electricity demand, and annual natural gas estimated **per 1000ft^2 of flat roof area.**

Metropolitan Area	Old Res w/ Gas Furnace			Old Res w/ Heat Pump			New Res w/ Gas Furnace			New Res w/ Heat Pump		
	Base Case	Savings Δ	Savings %	Base Case	Savings Δ	Savings %	Base Case	Savings Δ	Savings %	Base Case	Savings Δ	Savings %
New Orleans												
Electricity (kWh/1000ft^2)	2584	283	11	3813	241	6	1766	171	10	2386	149	6
Gas (kBtu/1000ft^2)	10877	-384	-4	0	0	0	6101	-226	-4	0	0	0
Net Energy ($/1000ft^2)	271	20	7	301	19	6	177	12	7	188	12	6
Peak (W/1000ft^2)	2130	71	3	2130	71	3	1494	84	6	1494	84	6
New York City												
Electricity (kWh/1000ft^2)	1229	106	9	8729	1	0	836	57	7	5315	4	0
Gas (kBtu/1000ft^2)	58363	-967	-2	0	0	0	39334	-587	-1	0	0	0
Net Energy ($/1000ft^2)	669	9	1	1397	0	0	453	5	1	851	1	0
Peak (W/1000ft^2)	2292	169	7	2292	169	7	1448	84	6	1448	84	6
Philadelphia												
Electricity (kWh/1000ft^2)	736	103	14	10923	-96	-1	431	42	10	7353	-78	-1
Gas (kBtu/1000ft^2)	78118	-1823	-2	0	0	0	59284	-1302	-2	0	0	0
Net Energy ($/1000ft^2)	625	1	0	1398	-12	-1	458	-3	-1	941	-10	-1
Peak (W/1000ft^2)	1545	201	13	1545	201	13	922	91	10	922	91	10
Phoenix												
Electricity (kWh/1000ft^2)	5495	484	9	6643	459	7	3590	256	7	4102	247	6
Gas (kBtu/1000ft^2)	9388	-211	-2	0	0	0	4816	-90	-2	0	0	0
Net Energy ($/1000ft^2)	656	51	8	711	49	7	419	27	6	439	27	6
Peak (W/1000ft^2)	4123	162	4	4123	162	4	2656	97	4	2656	97	4
Washington DC												
Electricity (kWh/1000ft^2)	1794	186	10	7283	82	1	1210	101	8	4382	45	1
Gas (kBtu/1000ft^2)	42818	-966	-2	0	0	0	28171	-605	-2	0	0	0
Net Energy ($/1000ft^2)	484	5	1	525	6	1	321	2	1	316	3	1
Peak (W/1000ft^2)	2584	162	6	2584	162	6	1649	84	5	1649	84	5

Table B-19(Cont). DOE-2 simulated HVAC base use and savings from light-colored roofing; annual electricity and net energy, peak electricity demand, and annual natural gas estimated **per 1000ft^2 of flat roof area.**

Metropolitan Area	Old Office w/ Gas Furnace			Old Office w/ Heat Pump			New Office w/ Gas Furnace			New Office w/ Heat Pump		
	Base Case	Savings		Base Case	Savings		Base Case	Savings		Base Case	Savings	
		Δ	%		Δ	%		Δ	%		Δ	%
Atlanta												
Electricity (kWh/1000ft^2)	4521	293	6	5866	203	3	3402	168	5	4120	120	3
Natural Gas (kBtu/1000ft^2)	9571	-776	-8	0	0	0	5531	-388	-7	0	0	0
Net Energy ($/1000ft^2)	390	17	4	434	15	3	284	10	4	305	9	3
Peak (W/1000ft^2)	3922	247	6	3922	247	6	2822	118	4	2822	118	4
Chicago												
Electricity (kWh/1000ft^2)	3396	191	6	8347	12	0	2679	108	4	5782	6	0
Natural Gas (kBtu/1000ft^2)	32041	-1367	-4	0	0	0	21388	-816	-4	0	0	0
Net Energy ($/1000ft^2)	449	9	2	701	1	0	334	5	1	486	0	0
Peak (W/1000ft^2)	4047	198	5	4047	198	5	3004	129	4	3004	129	4
Los Angeles												
Electricity (kWh/1000ft^2)	4174	377	9	4293	341	8	3271	221	7	3301	215	7
Natural Gas (kBtu/1000ft^2)	878	-306	-35	0	0	0	224	-82	-37	0	0	0
Net Energy ($/1000ft^2)	377	32	8	382	30	8	292	19	7	294	19	6
Peak (W/1000ft^2)	3914	292	7	3914	292	7	2886	173	6	2886	173	6
Fort Worth												
Electricity (kWh/1000ft^2)	6105	305	5	7038	221	3	4670	161	3	5119	126	2
Natural Gas (kBtu/1000ft^2)	6735	-571	-8	0	0	0	3449	-306	-9	0	0	0
Net Energy ($/1000ft^2)	420	17	4	450	14	3	314	9	3	328	8	2
Peak (W/1000ft^2)	5167	155	3	5167	155	3	3792	100	3	3792	100	3
Houston												
Electricity (kWh/1000ft^2)	6087	335	6	6464	299	5	4604	185	4	4772	167	3
Natural Gas (kBtu/1000ft^2)	2837	-327	-12	0	0	0	1367	-143	-10	0	0	0
Net Energy ($/1000ft^2)	475	24	5	491	23	5	356	13	4	363	13	4
Peak (W/1000ft^2)	4620	243	5	4620	243	5	3298	141	4	3298	141	4
Miami												
Electricity (kWh/1000ft^2)	8664	424	5	8670	418	5	6536	239	4	6536	233	4
Natural Gas (kBtu/1000ft^2)	61	0	0	0	0	0	0	0	0	0	0	0
Net Energy ($/1000ft^2)	590	29	5	590	28	5	444	16	4	444	16	4
Peak (W/1000ft^2)	4482	153	3	4482	153	3	3208	57	2	3208	57	2

Table B-19(Cont). DOE-2 simulated HVAC base use and savings from light-colored roofing; annual electricity and net energy, peak electricity demand, and annual natural gas estimated **per 1000ft^2 of flat roof area.**

Metropolitan Area	Old Office w/ Gas Furnace			Old Office w/ Heat Pump			New Office w/ Gas Furnace			New Office w/ Heat Pump		
	Base Case	Savings		Base Case	Savings		Base Case	Savings		Base Case	Savings	
		Δ	%		Δ	%		Δ	%		Δ	%
New Orleans												
Electricity (kWh/1000ft^2)	5902	383	6	6261	341	5	4341	209	5	4503	191	4
Natural Gas (kBtu/1000ft^2)	2673	-367	-14	0	0	0	1347	-163	-12	0	0	0
Net Energy ($/1000ft^2)	510	30	6	526	29	6	372	17	5	378	16	4
Peak (W/1000ft^2)	4508	314	7	4508	314	7	3106	143	5	3106	143	5
New York City												
Electricity (kWh/1000ft^2)	3361	168	5	7062	54	1	2553	96	4	4820	36	1
Natural Gas (kBtu/1000ft^2)	26673	-939	-4	0	0	0	18061	-551	-3	0	0	0
Net Energy ($/1000ft^2)	589	15	3	890	7	1	434	9	2	607	4	1
Peak (W/1000ft^2)	4098	163	4	4098	163	4	2859	63	2	2859	63	2
Philadelphia												
Electricity (kWh/1000ft^2)	2792	221	8	7845	6	0	2033	120	6	5549	0	0
Natural Gas (kBtu/1000ft^2)	34714	-1796	-5	0	0	0	26347	-1163	-4	0	0	0
Net Energy ($/1000ft^2)	538	15	3	926	1	0	398	7	2	655	0	0
Peak (W/1000ft^2)	3335	247	7	3335	247	7	2306	131	6	2306	131	6
Phoenix												
Electricity (kWh/1000ft^2)	8030	562	7	8192	538	7	5848	305	5	5890	293	5
Natural Gas (kBtu/1000ft^2)	1000	-265	-26	0	0	0	286	-82	-29	0	0	0
Net Energy ($/1000ft^2)	744	50	7	754	50	7	539	28	5	542	27	5
Peak (W/1000ft^2)	5857	196	3	5857	196	3	4065	96	2	4065	96	2
Washington DC												
Electricity (kWh/1000ft^2)	4132	251	6	6691	119	2	3205	138	4	4634	66	1
Natural Gas (kBtu/1000ft^2)	18102	-1082	-6	0	0	0	10980	-633	-6	0	0	0
Net Energy ($/1000ft^2)	398	12	3	475	9	2	291	6	2	329	5	2
Peak (W/1000ft^2)	4106	233	6	4106	233	6	2953	124	4	2953	124	4

Table B-19(Cont). DOE-2 simulated HVAC base use and savings from light-colored roofing; annual electricity and net energy, peak electricity demand, and annual natural gas estimated **per 1000ft^2 of flat roof area.**

Metropolitan Area	Old Retail w/ Gas Furnace			Old Retail w/ Heat Pump			New Retail w/ Gas Furnace			New Retail w/ Heat Pump		
	Base Case	Savings		Base Case	Savings		Base Case	Savings		Base Case	Savings	
		Δ	%		Δ	%		Δ	%		Δ	%
Atlanta												
Electricity (kWh/1000ft^2)	6211	412	7	6442	372	6	4760	213	4	4804	213	4
Natural Gas (kBtu/1000ft^2)	2235	-272	-12	0	0	0	1074	-37	-3	0	0	0
Net Energy ($/1000ft^2)	473	29	6	477	28	6	359	16	4	355	16	5
Peak (W/1000ft^2)	3193	148	5	3193	148	5	2299	69	3	2299	69	3
Chicago												
Electricity (kWh/1000ft^2)	4779	250	5	6569	108	2	3646	145	4	4247	90	2
Natural Gas (kBtu/1000ft^2)	11321	-914	-8	0	0	0	4531	-333	-7	0	0	0
Net Energy ($/1000ft^2)	459	16	3	552	9	2	329	10	3	357	8	2
Peak (W/1000ft^2)	3236	116	4	3236	116	4	2230	37	2	2230	37	2
Los Angeles												
Electricity (kWh/1000ft^2)	6026	593	10	6026	593	10	4760	344	7	4760	344	7
Natural Gas (kBtu/1000ft^2)	864	0	0	0	0	0	864	0	0	0	0	0
Net Energy ($/1000ft^2)	541	53	10	536	53	10	429	31	7	424	31	7
Peak (W/1000ft^2)	3352	193	6	3352	193	6	2264	38	2	2264	38	2
Fort Worth												
Electricity (kWh/1000ft^2)	7850	358	5	7933	336	4	5856	177	3	5867	181	3
Natural Gas (kBtu/1000ft^2)	1296	-123	-9	0	0	0	889	-12	-1	0	0	0
Net Energy ($/1000ft^2)	508	22	4	508	21	4	379	11	3	376	12	3
Peak (W/1000ft^2)	4188	204	5	4188	204	5	2789	73	3	2789	73	3
Houston												
Electricity (kWh/1000ft^2)	7926	376	5	7936	373	5	6012	217	4	6012	217	4
Natural Gas (kBtu/1000ft^2)	914	-25	-3	0	0	0	864	0	0	0	0	0
Net Energy ($/1000ft^2)	606	29	5	603	28	5	461	17	4	457	17	4
Peak (W/1000ft^2)	3452	32	1	3452	32	1	2563	44	2	2563	44	2
Miami												
Electricity (kWh/1000ft^2)	10443	477	5	10443	477	5	7839	260	3	7839	260	3
Natural Gas (kBtu/1000ft^2)	864	0	0	0	0	0	864	0	0	0	0	0
Net Energy ($/1000ft^2)	715	32	4	710	32	5	538	18	3	533	18	3
Peak (W/1000ft^2)	3270	131	4	3270	131	4	2374	70	3	2374	70	3

Table B-19(Cont). DOE-2 simulated HVAC base use and savings from light-colored roofing; annual electricity and net energy, peak electricity demand, and annual natural gas estimated **per 1000ft^2 of flat roof area.**

Metropolitan Area	Old Retail w/ Gas Furnace			Old Retail w/ Heat Pump			New Retail w/ Gas Furnace			New Retail w/ Heat Pump		
	Base Case	Savings		Base Case	Savings		Base Case	Savings		Base Case	Savings	
		Δ	%		Δ	%		Δ	%		Δ	%
New Orleans												
Electricity (kWh/1000ft^2)	7748	434	6	7756	430	6	5864	253	4	5864	253	4
Natural Gas (kBtu/1000ft^2)	889	-25	-3	0	0	0	864	0	0	0	0	0
Net Energy ($/1000ft^2)	656	36	5	651	36	6	497	21	4	493	21	4
Peak (W/1000ft^2)	3302	136	4	3302	136	4	2407	85	4	2407	85	4
New York City												
Electricity (kWh/1000ft^2)	4684	242	5	5903	155	3	3624	130	4	3979	101	3
Natural Gas (kBtu/1000ft^2)	8617	-605	-7	0	0	0	3272	-210	-6	0	0	0
Net Energy ($/1000ft^2)	644	27	4	744	20	3	477	15	3	501	13	3
Peak (W/1000ft^2)	3286	149	5	3286	149	5	2235	44	2	2235	44	2
Philadelphia												
Electricity (kWh/1000ft^2)	4532	282	6	6139	152	2	3426	145	4	4120	94	2
Natural Gas (kBtu/1000ft^2)	11383	-926	-8	0	0	0	5802	-383	-7	0	0	0
Net Energy ($/1000ft^2)	603	28	5	724	18	2	439	15	3	486	11	2
Peak (W/1000ft^2)	3121	215	7	3121	215	7	2141	102	5	2141	102	5
Phoenix												
Electricity (kWh/1000ft^2)	10497	716	7	10497	716	7	7567	416	5	7567	416	5
Natural Gas (kBtu/1000ft^2)	864	0	0	0	0	0	864	0	0	0	0	0
Net Energy ($/1000ft^2)	970	66	7	966	66	7	701	38	5	696	38	5
Peak (W/1000ft^2)	4748	112	2	4748	112	2	3219	91	3	3219	91	3
Washington DC												
Electricity (kWh/1000ft^2)	5665	307	5	6150	235	4	4308	174	4	4391	163	4
Natural Gas (kBtu/1000ft^2)	3815	-457	-12	0	0	0	1346	-74	-5	0	0	0
Net Energy ($/1000ft^2)	424	19	4	437	17	4	314	12	4	312	11	4
Peak (W/1000ft^2)	3354	69	2	3354	69	2	2477	59	2	2477	59	2

Table B-19(Cont). DOE-2 simulated HVAC base use and savings from light-colored roofing; annual electricity and net energy, peak electricity demand, and annual natural gas estimated **per 1000ft^2 of flat roof area.**

Metropolitan Area	Primary School			Secondary School			Hospital			Nursing Home		
	Base Case	Savings		Base Case	Savings		Base Case	Savings		Base Case	Savings	
		Δ	%		Δ	%		Δ	%		Δ	%
Atlanta												
Electricity (kWh/1000ft^2)	3231	151	5	3547	240	7	16240	938	6	7388	495	7
Natural Gas (kBtu/1000ft^2)	12246	-674	-6	19318	-1314	-7	13603	-5131	-38	7020	-602	-9
Net Energy ($/1000ft^2)	310	7	2	375	10	3	1281	42	3	587	33	6
Peak (W/1000ft^2)	5131	100	2	4064	217	5	3938	427	11	3277	259	8
Chicago												
Electricity (kWh/1000ft^2)	2269	76	3	2748	145	5	13789	455	3	5394	557	10
Natural Gas (kBtu/1000ft^2)	34386	-1037	-3	46462	-1608	-3	49872	-8701	-17	29607	-1670	-6
Net Energy ($/1000ft^2)	366	1	0	468	4	1	1413	-7	0	604	38	6
Peak (W/1000ft^2)	5290	42	1	4212	133	3	3920	231	6	3003	246	8
Los Angeles												
Electricity (kWh/1000ft^2)	3438	257	7	3173	299	9	16106	1211	8	6259	677	11
Natural Gas (kBtu/1000ft^2)	2649	-417	-16	6688	-1402	-21	404	-2632	-651	1495	-224	-15
Net Energy ($/1000ft^2)	322	20	6	322	18	6	1436	91	6	566	59	10
Peak (W/1000ft^2)	5259	133	3	3769	200	5	3886	427	11	3286	283	9
Fort Worth												
Electricity (kWh/1000ft^2)	4164	135	3	4506	168	4	18575	1057	6	9539	750	8
Natural Gas (kBtu/1000ft^2)	8140	-457	-6	14700	-962	-7	7709	-4361	-57	4512	-391	-9
Net Energy ($/1000ft^2)	302	7	2	353	7	2	1223	49	4	630	46	7
Peak (W/1000ft^2)	6339	39	1	4997	47	1	4363	462	11	4072	277	7
Houston												
Electricity (kWh/1000ft^2)	4886	186	4	5201	290	6	18460	1057	6	8795	756	9
Natural Gas (kBtu/1000ft^2)	4246	-277	-7	7989	-693	-9	2593	-2275	-88	2563	-216	-8
Net Energy ($/1000ft^2)	390	13	3	430	19	4	1414	70	5	680	57	8
Peak (W/1000ft^2)	5845	50	1	4796	175	4	4158	399	10	3528	324	9
Miami												
Electricity (kWh/1000ft^2)	7451	239	3	7691	317	4	21092	1316	6	13827	878	6
Natural Gas (kBtu/1000ft^2)	669	-6	-1	1158	-161	-14	38	-273	-718	573	-5	-1
Net Energy ($/1000ft^2)	511	16	3	530	21	4	1435	91	6	944	60	6
Peak (W/1000ft^2)	5778	100	2	4713	79	2	3995	336	8	3552	258	7

Table B-19(Cont). DOE-2 simulated HVAC base use and savings from light-colored roofing; annual electricity and net energy, peak electricity demand, and annual natural gas estimated **per 1000ft^2 of flat roof area.**

Metropolitan Area	Primary School			Secondary School			Hospital			Nursing Home		
	Base Case	Savings		Base Case	Savings		Base Case	Savings		Base Case	Savings	
		Δ	%		Δ	%		Δ	%		Δ	%
New Orleans												
Electricity (kWh/1000ft^2)	4747	223	5	4999	247	5	18238	1190	7	8563	805	9
Natural Gas (kBtu/1000ft^2)	4374	-357	-8	8492	-830	-10	2115	-2464	-117	2378	-255	-11
Net Energy ($/1000ft^2)	422	17	4	465	16	3	1543	84	5	732	66	9
Peak (W/1000ft^2)	6079	127	2	4528	102	2	3933	294	7	3289	306	9
New York City												
Electricity (kWh/1000ft^2)	2120	80	4	2616	126	5	13787	525	4	5286	434	8
Natural Gas (kBtu/1000ft^2)	27526	-766	-3	38728	-1176	-3	37274	-5439	-15	20617	-1068	-5
Net Energy ($/1000ft^2)	438	5	1	570	9	2	1968	35	2	794	48	6
Peak (W/1000ft^2)	4461	65	1	3645	121	3	3835	308	8	3115	325	10
Philadelphia												
Electricity (kWh/1000ft^2)	1848	78	4	2558	133	5	13951	672	5	3570	183	5
Natural Gas (kBtu/1000ft^2)	35474	-1254	-4	40483	-1547	-4	27508	-6930	-25	58859	-2834	-5
Net Energy ($/1000ft^2)	431	2	0	545	7	1	1811	35	2	774	5	1
Peak (W/1000ft^2)	3809	187	5	3302	214	6	4027	420	10	2158	278	13
Phoenix												
Electricity (kWh/1000ft^2)	5639	329	6	5852	362	6	21042	1687	8	11934	1071	9
Natural Gas (kBtu/1000ft^2)	2477	-300	-12	5748	-947	-16	972	-3164	-326	1271	-162	-13
Net Energy ($/1000ft^2)	531	29	5	568	28	5	1941	140	7	1104	98	9
Peak (W/1000ft^2)	6521	76	1	5315	243	5	4630	483	10	4540	332	7
Washington DC												
Electricity (kWh/1000ft^2)	2706	111	4	3119	145	5	14764	756	5	6738	443	7
Natural Gas (kBtu/1000ft^2)	20429	-837	-4	29929	-1283	-4	24395	-6384	-26	14097	-951	-7
Net Energy ($/1000ft^2)	311	3	1	395	4	1	1190	14	1	560	26	5
Peak (W/1000ft^2)	5155	88	2	4205	140	3	4128	448	11	3519	225	6

Table B-19(Cont). DOE-2 simulated HVAC base use and savings from light-colored roofing; annual electricity and net energy, peak electricity demand, and annual natural gas estimated **per 1000ft^2 of flat roof area.**

Metropolitan Area	Grocery Store		
	Base Case	Savings	
		Δ	%
Atlanta			
Electricity (kWh/1000ft^2)	9189	245	3
Natural Gas (kBtu/1000ft^2)	31024	-451	-1
Net Energy ($/1000ft^2)	860	15	2
Peak (W/1000ft^2)	5675	262	5
Chicago			
Electricity (kWh/1000ft^2)	8092	152	2
Natural Gas (kBtu/1000ft^2)	85447	-970	-1
Net Energy ($/1000ft^2)	1116	8	1
Peak (W/1000ft^2)	5690	129	2
Los Angeles			
Electricity (kWh/1000ft^2)	8561	337	4
Natural Gas (kBtu/1000ft^2)	12613	-203	-2
Net Energy ($/1000ft^2)	838	29	3
Peak (W/1000ft^2)	5296	162	3
Fort Worth			
Electricity (kWh/1000ft^2)	13394	297	2
Natural Gas (kBtu/1000ft^2)	23985	-316	-1
Net Energy ($/1000ft^2)	963	18	2
Peak (W/1000ft^2)	7331	203	3
Houston			
Electricity (kWh/1000ft^2)	11027	258	2
Natural Gas (kBtu/1000ft^2)	15704	-181	-1
Net Energy ($/1000ft^2)	907	19	2
Peak (W/1000ft^2)	6241	158	3
Miami			
Electricity (kWh/1000ft^2)	16263	397	2
Natural Gas (kBtu/1000ft^2)	8258	-23	0
Net Energy ($/1000ft^2)	1154	27	2
Peak (W/1000ft^2)	5959	165	3

Metropolitan Area	Grocery Store		
	Base Case	Savings	
		Δ	%
New Orleans			
Electricity (kWh/1000ft^2)	10518	291	3
Natural Gas (kBtu/1000ft^2)	14621	-181	-1
Net Energy ($/1000ft^2)	961	23	2
Peak (W/1000ft^2)	5388	169	3
New York City			
Electricity (kWh/1000ft^2)	7768	132	2
Natural Gas (kBtu/1000ft^2)	65501	-654	-1
Net Energy ($/1000ft^2)	1385	13	1
Peak (W/1000ft^2)	5456	140	3
Philadelphia			
Electricity (kWh/1000ft^2)	7669	139	2
Natural Gas (kBtu/1000ft^2)	127911	-1895	-1
Net Energy ($/1000ft^2)	1672	5	0
Peak (W/1000ft^2)	4713	187	4
Phoenix			
Electricity (kWh/1000ft^2)	18954	555	3
Natural Gas (kBtu/1000ft^2)	12432	-135	-1
Net Energy ($/1000ft^2)	1807	50	3
Peak (W/1000ft^2)	8802	203	2
Washington DC			
Electricity (kWh/1000ft^2)	8780	278	3
Natural Gas (kBtu/1000ft^2)	49774	-722	-1
Net Energy ($/1000ft^2)	912	16	2
Peak (W/1000ft^2)	5722	269	5

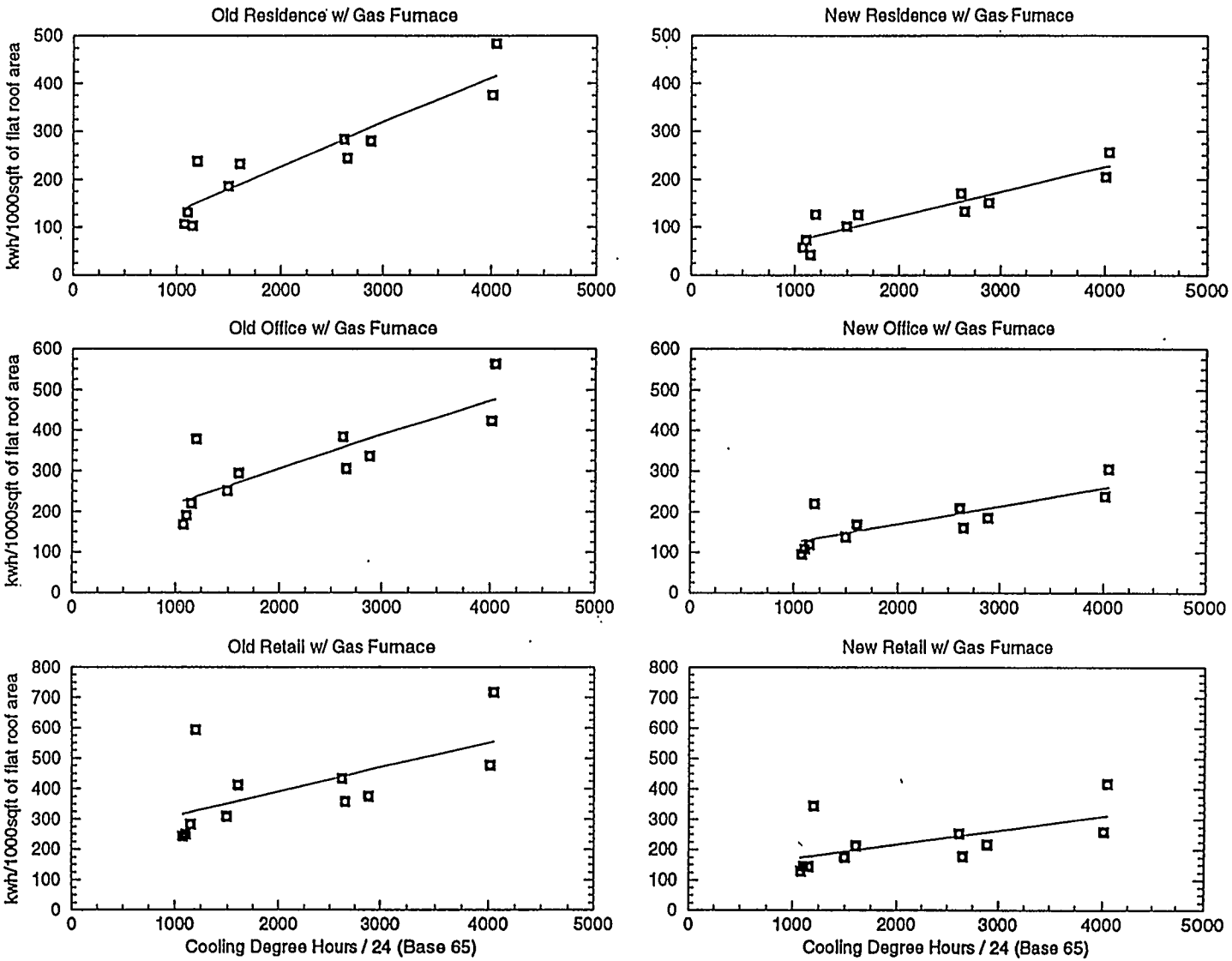

Figure B-1(a). DOE-2 simulated HVAC annual electricity savings from light-colored roofing shown versus cooling degree days.

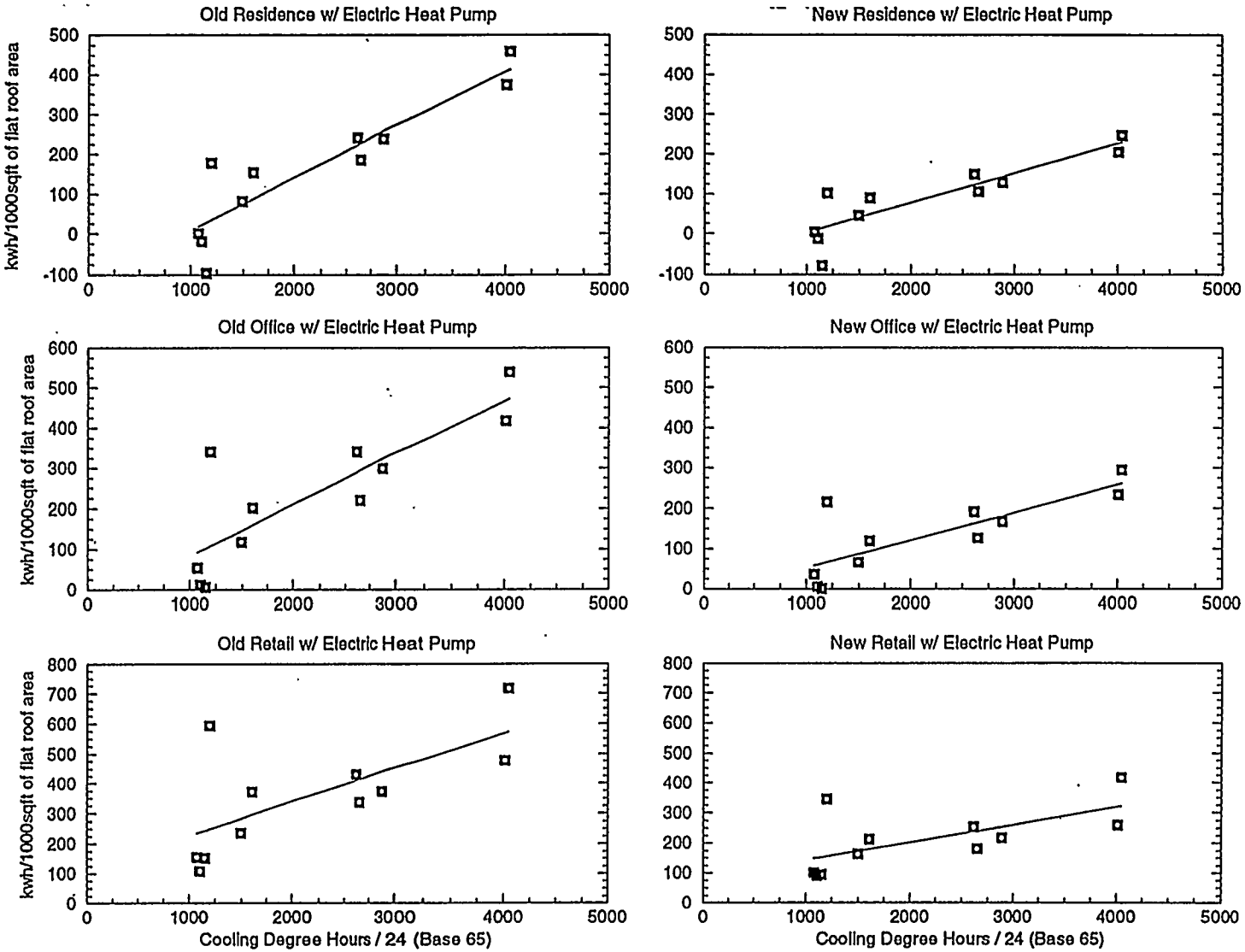

Figure B-1(b). DOE-2 simulated HVAC annual electricity savings from light-colored roofing shown versus cooling degree days.

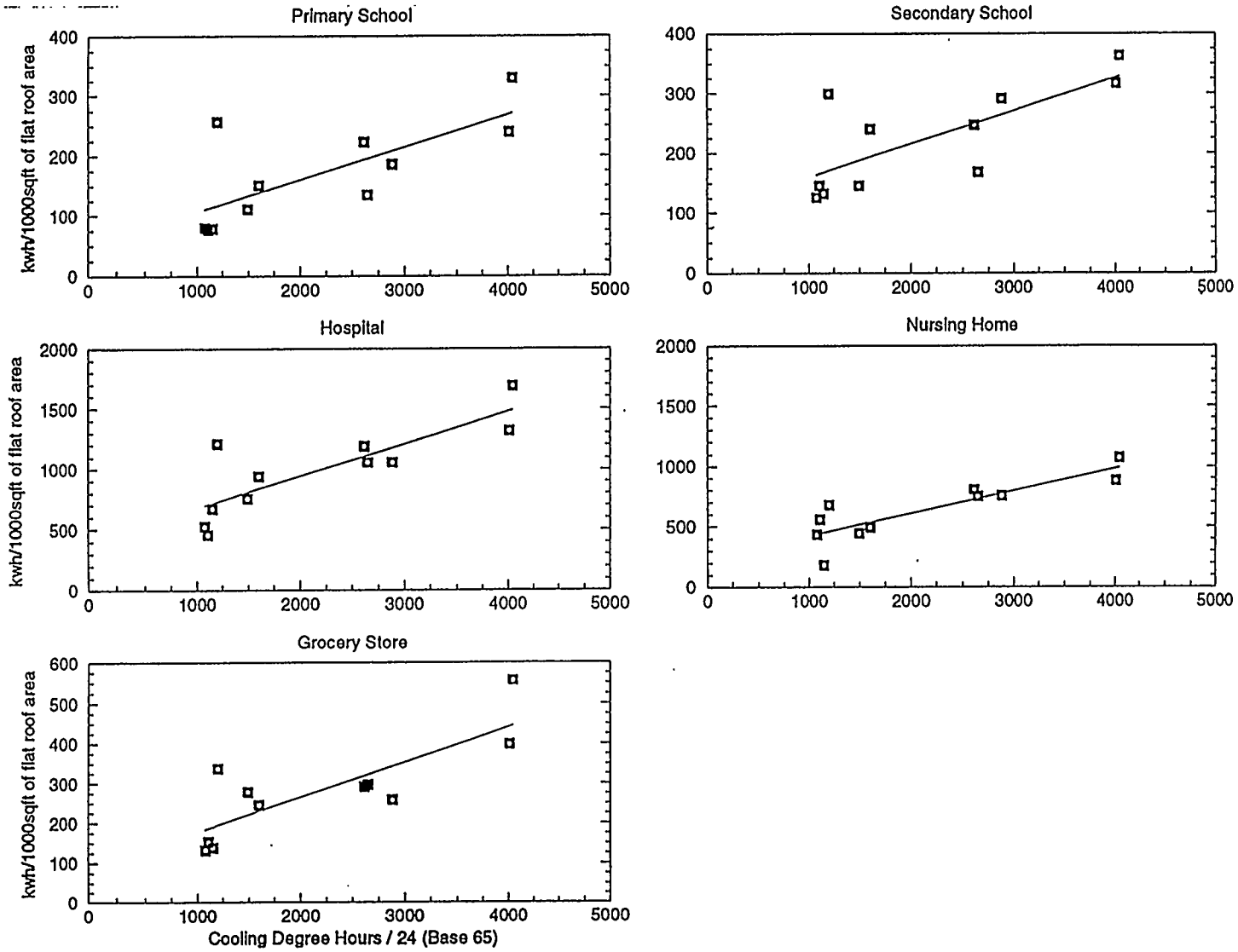

Figure B-1(c). DOE-2 simulated HVAC annual electricity savings from light-colored roofing shown versus cooling degree days.

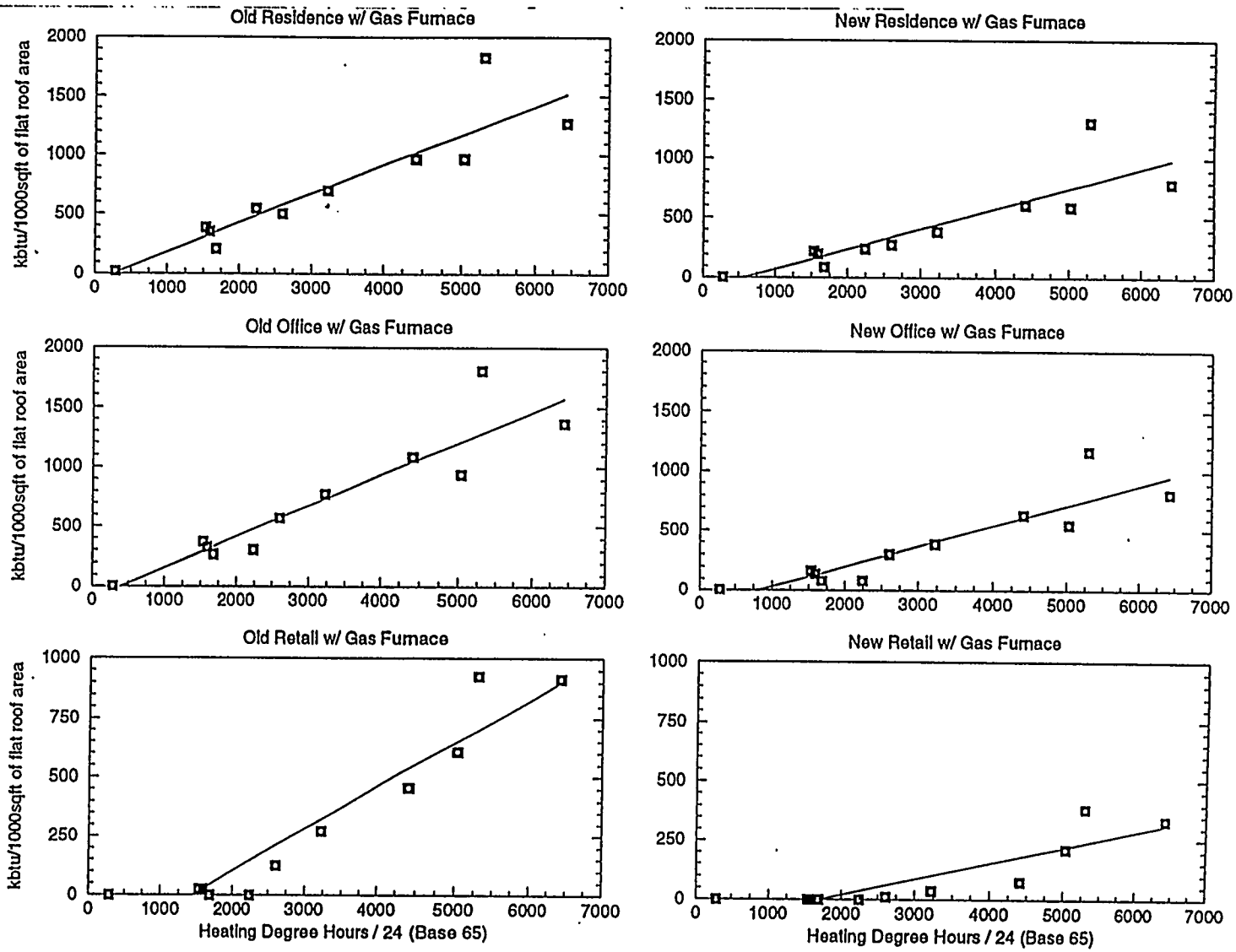

Figure B-2(a). DOE-2 simulated HVAC annual natural gas deficit from light-colored roofing shown versus heating degree days.

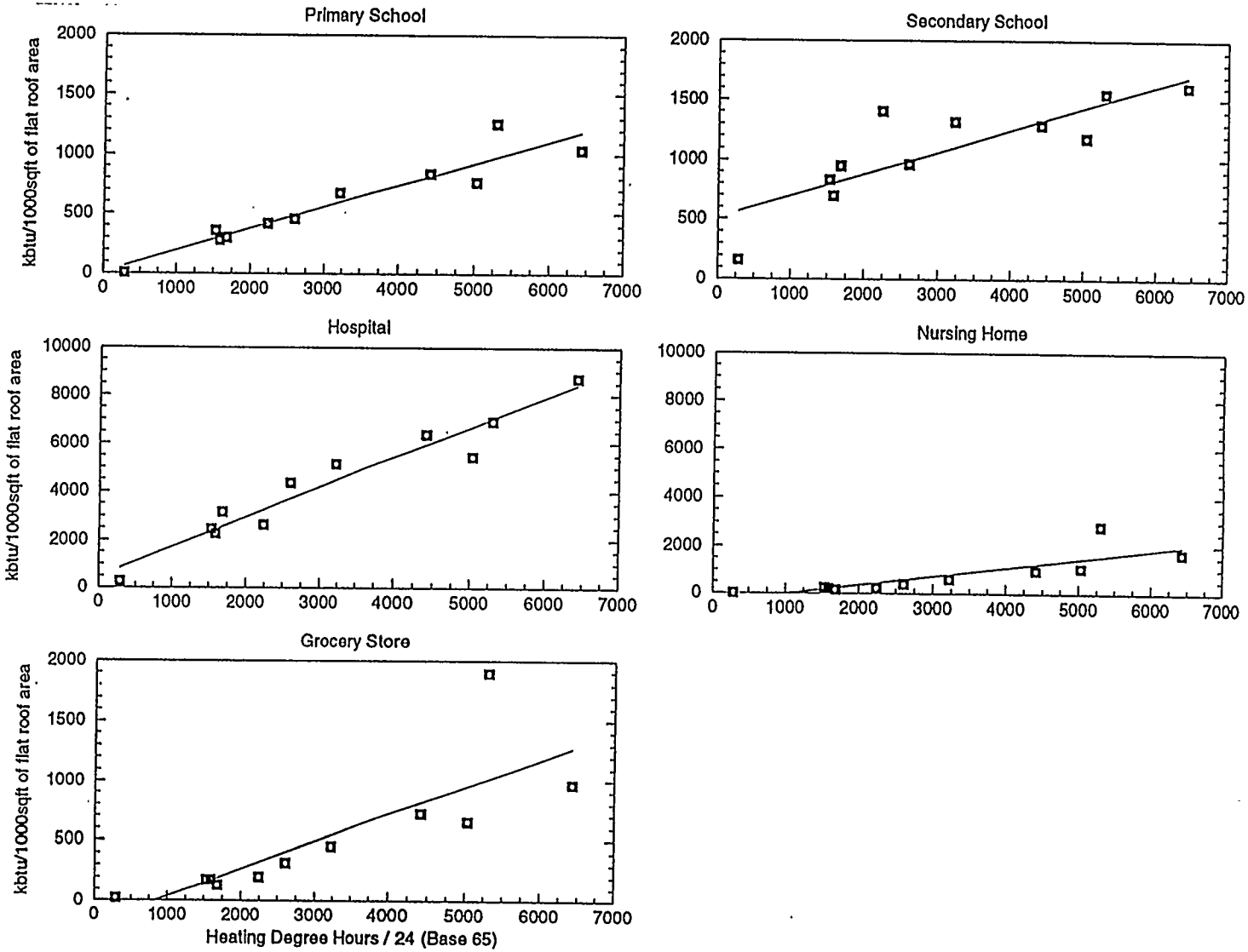

Figure B-2(b). DOE-2 simulated HVAC annual natural gas deficit from light-colored roofing shown versus heating degree days.

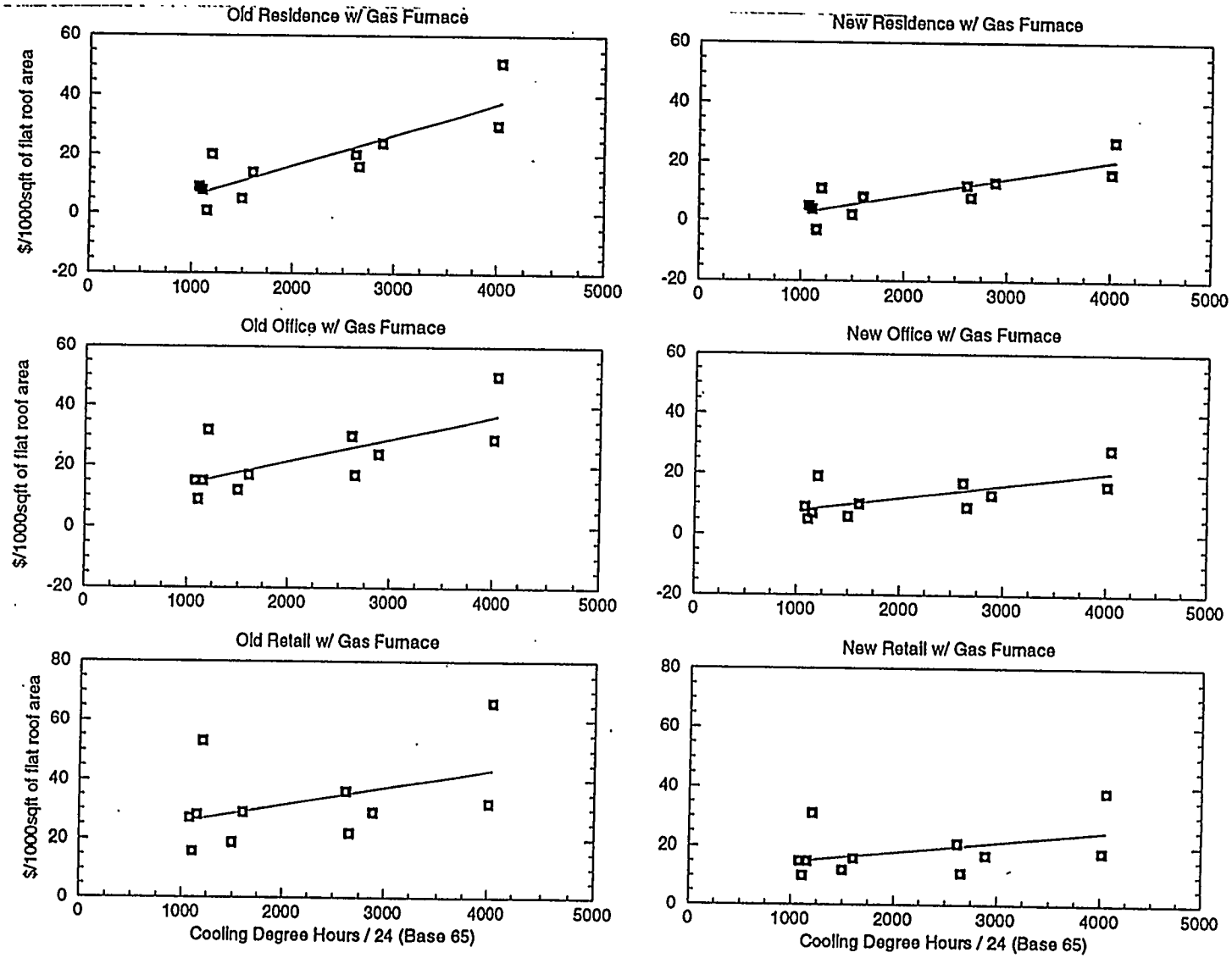

Figure B-3(a). DOE-2 simulated HVAC annual net energy savings from light-colored roofing shown versus cooling degree days.

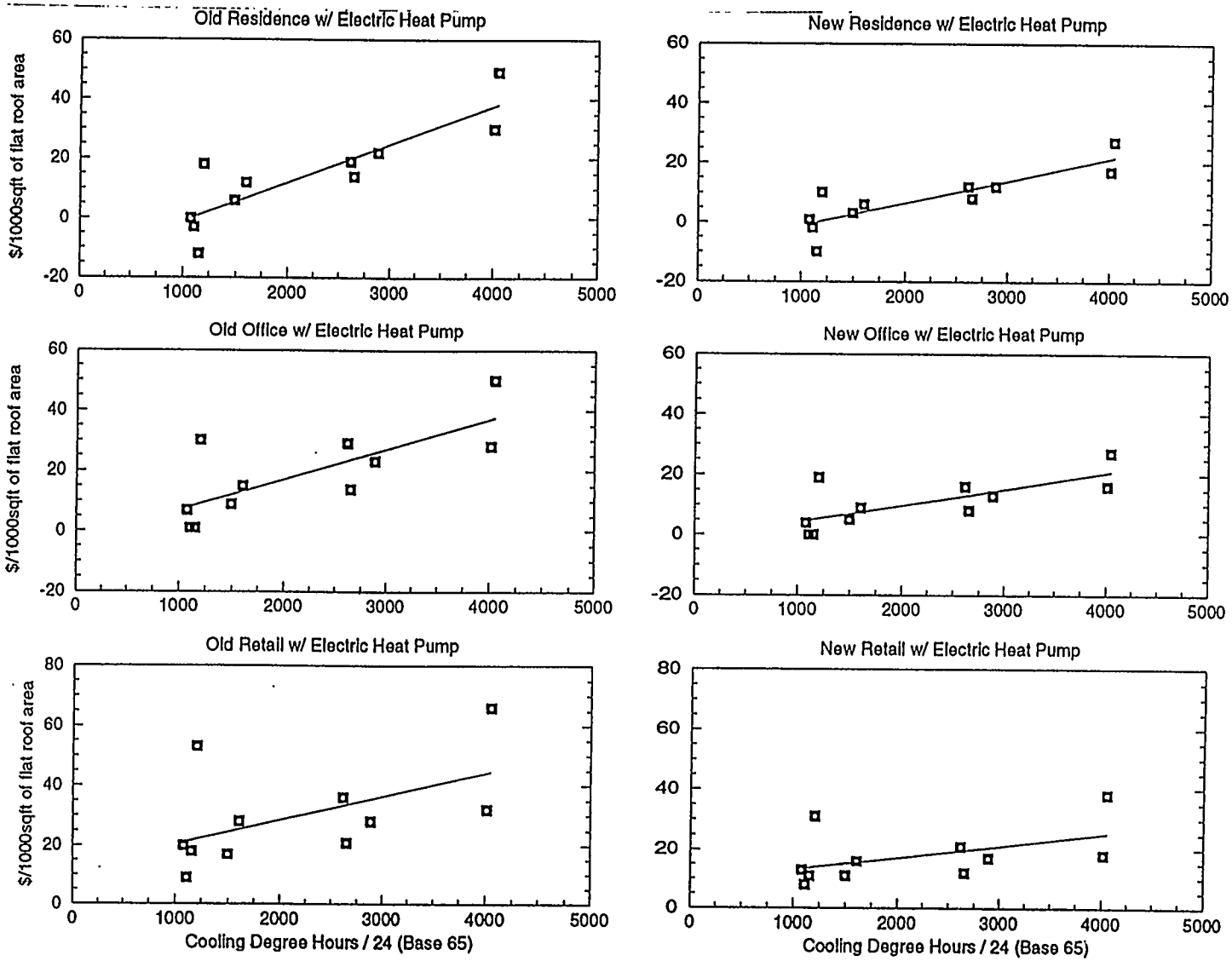

Figure B-3(b). DOE-2 simulated HVAC annual net energy savings from light-colored roofing shown versus cooling degree days.

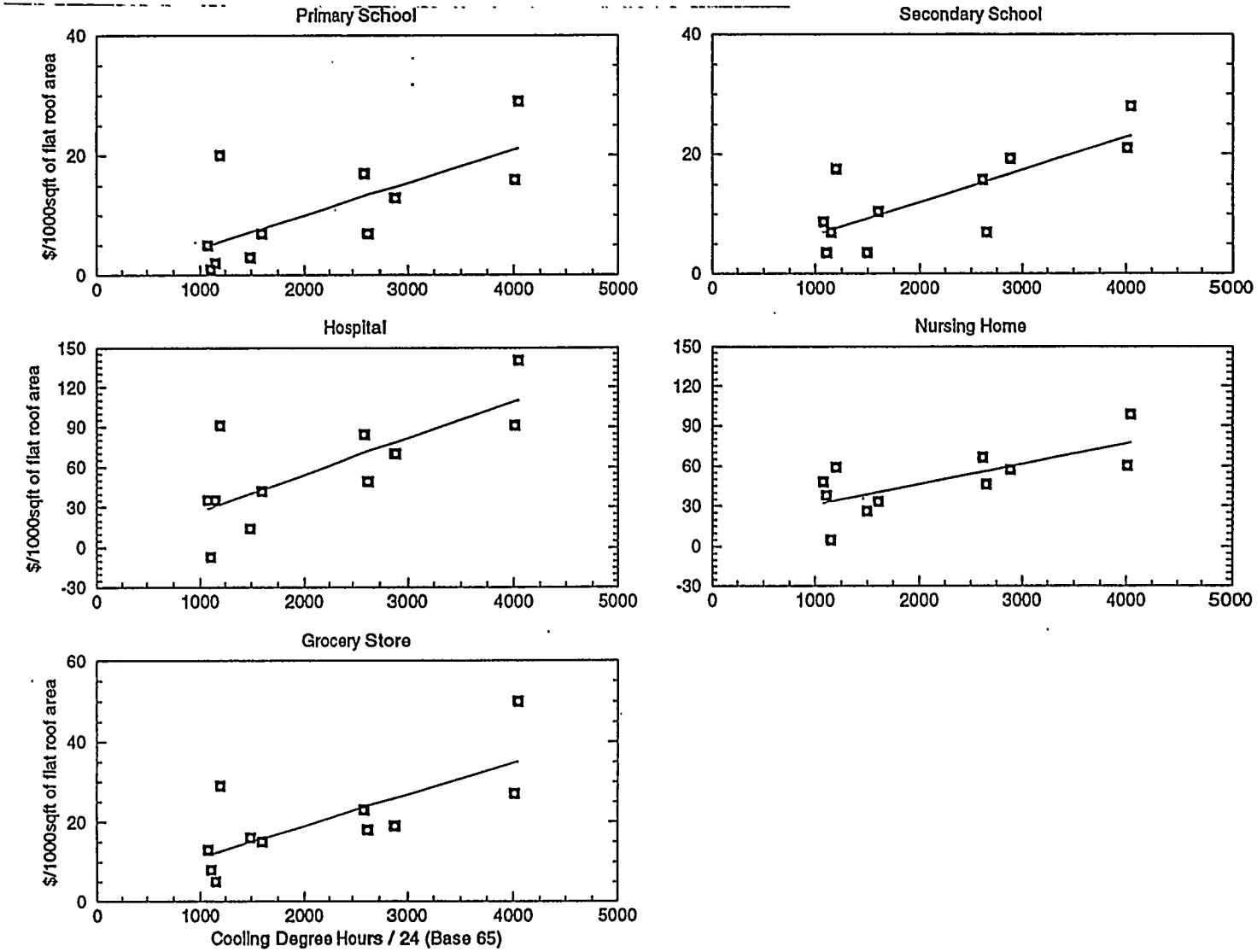

Figure B-3(c). DOE-2 simulated HVAC annual net energy savings from light-colored roofing shown versus cooling degree days.

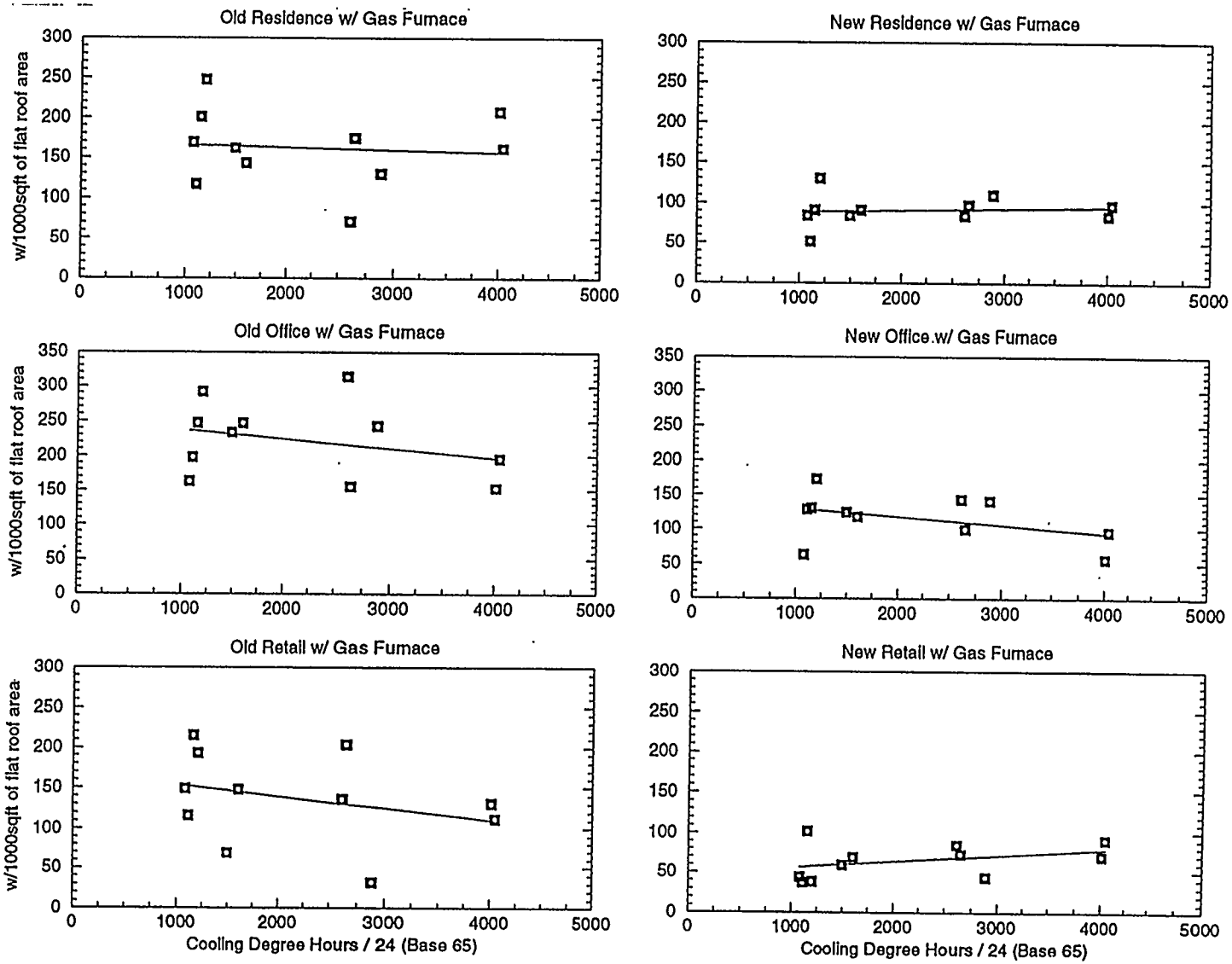

Figure B-4(a). DOE-2 simulated HVAC peak electricity demand savings from light-colored roofing shown versus cooling degree days.

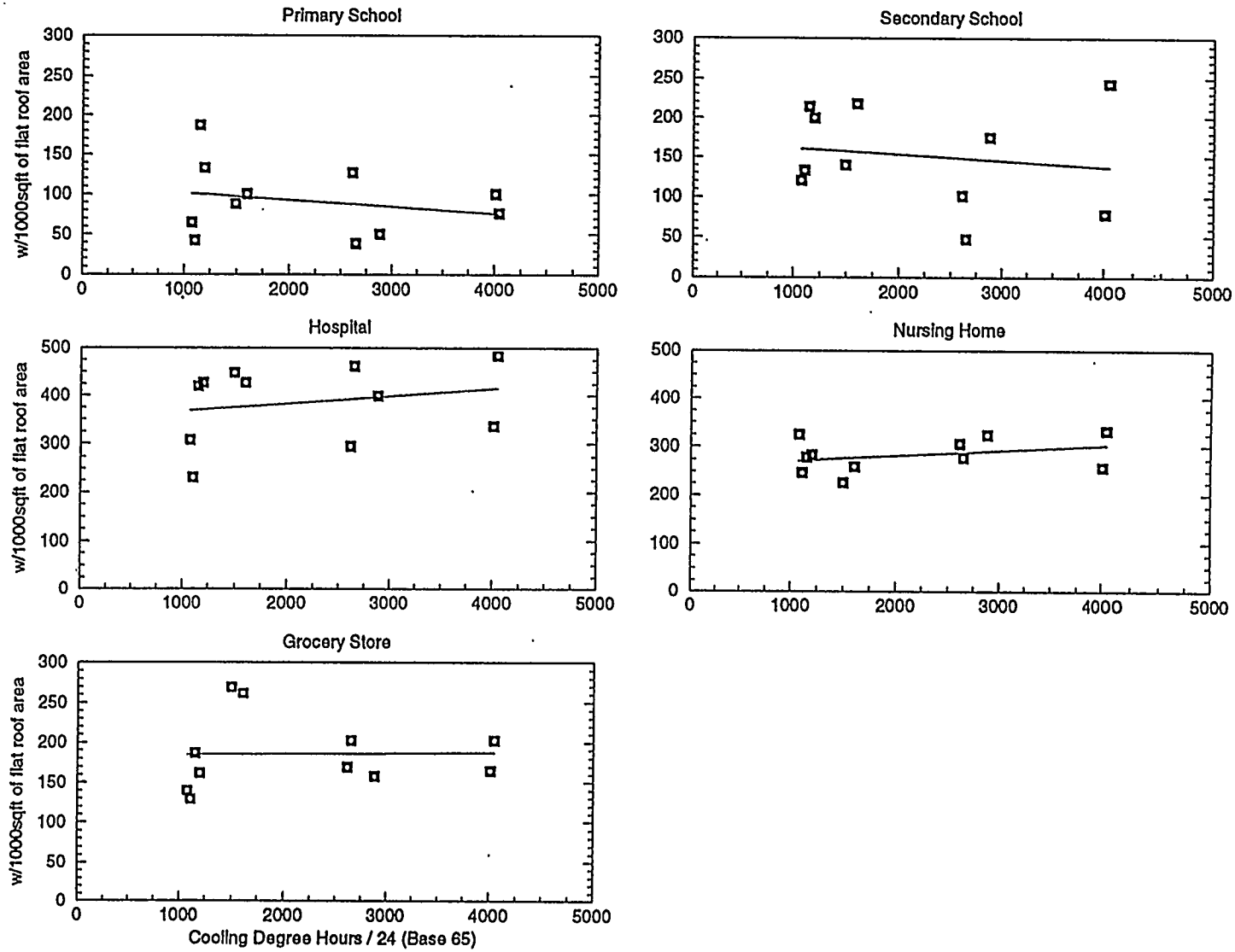

Figure B-4(b). DOE-2 simulated HVAC peak electricity demand savings from light-colored roofing shown versus cooling degree days.

Appendix C

Building Stock and Roof Area Data

This appendix contains data used in the calculation of residential and commercial conditioned flat roof area described within *Chapter 4*. **Table C-1** shows data extracted from the American Housing Survey (AHS); i.e., number of housing units, average number of floors, and median floor area, for the calculation of residential conditioned flat roof area for old and new vintages. **Table C-2** displays the population of each each census division, which supplement the CBECS data for the estimation of commercial conditioned flat roof area. Air-conditioning (heat pump) and gas furnace saturations for each building and location are in **Table C-3** with the total and conditioned flat roof area.

Table C-1. Residential building stock data for determination of conditioned flat roof area (Source: AHS).

Metropolitan Area	# Housing Units (1000s)			Average # Floors		Median Floor Area (ft^2)		Total Roof Area (Mft^2)	
	total	pre-1980	1980-1990	pre-1980	1980-1990	pre-1980	1980-1990	pre-1980	1980-1990
Atlanta	1172.6	784.1	388.5	1.9	2.3	1642	2078	677.6	351.0
Chicago	2815.9	2547.1	268.8	3.1	3.0	1736	2770	1426.4	248.2
Los Angeles	5293.1	4850.9	442.2	1.6	2.2	1258	1596	3814.0	320.8
Dallas/Ft Worth	1696.3	1202.0	494.3	1.5	1.8	1463	2065	1172.4	567.1
Houston	1430.6	1090.8	339.8	1.5	2.1	1568	2373	1140.2	384.0
Miami/Ft Lauderdale	1502.1	1181.6	320.5	2.3	2.2	1436	2266	737.7	330.1
New Orleans	583.9	460.4	123.5	1.5	1.5	1437	2071	441.1	170.5
New York	7096.7	6757.4	339.3	4.5	4.0	1728	2856	2594.8	242.3
Philadelphia	1937.1	1753.5	183.6	3.0	2.8	2343	2721	1369.5	178.4
Phoenix	985.3	603.4	381.9	1.3	1.7	1355	1915	628.9	430.2
DC/Baltimore	2498.4	2029.9	468.5	3.0	3.1	1911	2784	1293.0	420.7

Table C-2. Metropolitan area and census division population for calculation of commercial conditioned flat roof area (CBECS, 1994).

Metropolitan Area	Population (Millions)	Census Division	Population (Millions)	Percent of Division Population
Atlanta	2.8	South Atlantic	41.3	6.9
Chicago	8.1	East North Central	41.7	19.3
Los Angeles	14.5	Pacific	39.2	37.1
Dallas/Ft Worth	3.9	West South Central	25.8	15.1
Houston	3.7	West South Central	25.8	14.4
Miami/Ft Lauderdale	3.2	South Atlantic	41.3	7.7
New Orleans	1.2	West South Central	25.8	4.8
New York	18.1	Middle Atlantic	39.6	45.7
Philadelphia	5.9	Middle Atlantic	39.6	14.9
Phoenix	2.1	Mountain	13.2	16.1
DC/Baltimore	6.3	South Atlantic	41.3	15.3

Table C-3. Total and conditioned flat roof area of residential and commercial building stock.

metropolitan area	total flat roof area [Mft^2]	HVAC saturation [%]			conditioned flat roof area [Mft^2]	
		ac	gas	hp	ac & gas	ac / hp
Residence Old						
Atlanta	677.6	72	93	7	453.7	34.2
Chicago	1426.4	39	98	2	545.2	11.1
Los Angeles	3814.0	25	100	0	953.5	0.0
Dallas/Ft Worth	1172.4	76	96	4	855.4	35.6
Houston	1140.2	76	91	9	788.6	78.0
Miami/Ft Lauderdale	737.7	72	48	52	254.9	276.2
New Orleans	441.1	59	97	3	252.4	7.8
New York	2594.8	9	99	1	231.2	2.3
Philadelphia	1369.5	29	95	5	377.3	19.9
Phoenix	628.9	85	65	35	347.5	187.1
DC/Baltimore	1293.0	71	78	22	716.1	202.0
Residence New						
Atlanta	351.0	94	81	19	267.3	62.7
Chicago	248.2	84	96	4	200.1	8.3
Los Angeles	320.8	62	97	3	192.9	6.0
Dallas/Ft Worth	567.1	99	94	6	527.7	33.7
Houston	384.0	94	86	14	310.4	50.5
Miami/Ft Lauderdale	330.1	98	32	68	103.5	220.0
New Orleans	170.5	95	86	14	139.3	22.7
New York	242.3	43	99	1	103.1	1.0
Philadelphia	178.4	81	69	31	99.7	44.8
Phoenix	430.2	97	42	58	175.3	242.0
DC/Baltimore	420.7	97	62	38	253.0	155.1
Office Old						
Atlanta	27.5	100	69	31	19.0	8.5
Chicago	93.5	95	94	6	83.5	5.3
Los Angeles	168.2	93	92	8	143.9	12.5
Dallas/Ft Worth	53.1	100	95	5	50.4	2.7
Houston	50.8	100	95	5	48.3	2.5
Miami/Ft Lauderdale	31.0	100	69	31	21.4	9.6
New Orleans	19.3	100	95	5	18.3	1.0
New York	111.9	92	88	12	90.6	12.4
Philadelphia	36.6	92	88	12	29.6	4.0
Phoenix	12.1	100	86	14	10.4	1.7
DC/Baltimore	61.5	100	69	31	42.4	19.1
Office New						
Atlanta	8.7	100	45	55	3.9	4.8
Chicago	31.6	100	95	5	30.0	1.6
Los Angeles	100.0	100	72	28	72.0	28.0
Dallas/Ft Worth	33.5	100	85	15	28.5	5.0
Houston	32.1	100	85	15	27.3	4.8
Miami/Ft Lauderdale	9.7	100	45	55	4.4	5.3
New Orleans	12.2	100	85	15	10.4	1.8
New York	48.4	100	72	28	34.8	13.6
Philadelphia	15.8	100	72	28	11.4	4.4
Phoenix	22.9	100	72	28	16.5	6.4
DC/Baltimore	18.9	100	45	55	8.5	10.4

Table C-3(Cont). Total and conditioned flat roof area of residential and commercial building stock.

metropolitan area	total flat roof area [Mft^2]	HVAC saturation [%]			conditioned flat roof area [Mft^2]	
		ac	gas	hp	ac & gas	ac / hp
Retail Store Old						
Atlanta	22.3	79	82	18	14.4	3.2
Chicago	132.2	63	100	0	83.3	0.0
Los Angeles	228.1	64	94	6	137.2	8.8
Dallas/Ft Worth	117.2	85	95	5	94.6	5.0
Houston	111.9	85	95	5	90.4	4.8
Miami/Ft Lauderdale	25.2	79	82	18	16.3	3.6
New Orleans	42.5	85	95	5	34.3	1.8
New York	333.7	70	97	3	226.6	7.0
Philadelphia	109.3	70	97	3	74.2	2.3
Phoenix	15.4	78	99	1	11.9	0.1
DC/Baltimore	50.2	79	82	18	32.5	7.1
Retail Store New						
Atlanta	13.1	71	75	25	7.0	2.3
Chicago	58.5	69	99	1	40.0	0.4
Los Angeles	70.8	85	86	14	51.8	8.4
Dallas/Ft Worth	25.2	79	100	0	19.9	0.0
Houston	24.0	79	100	0	19.0	0.0
Miami/Ft Lauderdale	14.6	71	75	25	7.8	2.6
New Orleans	9.1	79	100	0	7.2	0.0
New York	72.4	69	99	1	49.5	0.5
Philadelphia	23.8	69	99	1	16.3	0.2
Phoenix	56.5	69	65	35	25.3	13.6
DC/Baltimore	28.4	71	75	25	15.1	5.0
School						
Atlanta	32.7	99	72		23.3	
Chicago	118.8	74	99		87.0	
Los Angeles	142.0	63	90		80.5	
Dallas/Ft Worth	101.6	95	94		90.7	
Houston	96.9	95	94		86.5	
Miami/Ft Lauderdale	36.8	99	72		26.2	
New Orleans	36.9	95	94		33.0	
New York	179.3	85	95		144.8	
Philadelphia	58.8	85	95		47.5	
Phoenix	41.3	98	89		36.0	
DC/Baltimore	72.9	99	72		52.0	
Hospital						
Atlanta	4.4	100	98		4.3	
Chicago	10.1	86	98		8.5	
Los Angeles	24.5	100	84		20.6	
Dallas/Ft Worth	9.3	40	100		3.7	
Houston	8.8	40	100		3.5	
Miami/Ft Lauderdale	4.7	100	98		4.6	
New Orleans	3.4	40	100		1.4	
New York	16.3	51	85		7.1	
Philadelphia	5.3	51	85		2.3	
Phoenix	2.5	100	100		2.5	
DC/Baltimore	9.5	100	98		9.3	

Table C-3(Cont). Total and conditioned flat roof area of residential and commercial building stock.

metropolitan area	total flat roof area [Mft^2]	HVAC saturation [%]			conditioned flat roof area [Mft^2]	
		ac	gas	hp	ac & gas	ac / hp
Nursing Home						
Atlanta	2.2	24	89		0.5	
Chicago	22.4	97	90		19.6	
Los Angeles	13.0	100	100		13.0	
Dallas/Ft Worth	7.3	100	92		6.7	
Houston	7.1	100	92		6.5	
Miami/Ft Lauderdale	2.5	24	89		0.5	
New Orleans	4.5	100	55		2.5	
New York	24.9	100	90		22.4	
Philadelphia	7.6	100	89		6.8	
Phoenix	9.6	100	100		9.6	
DC/Baltimore	4.7	24	89		1.0	
Grocery Store						
Atlanta	2.2	98	44		0.9	
Chicago	10.6	87	100		9.2	
Los Angeles	33.5	77	81		20.9	
Dallas/Ft Worth	9.6	100	98		9.4	
Houston	9.2	100	98		9.0	
Miami/Ft Lauderdale	2.4	98	44		1.0	
New Orleans	3.4	100	98		3.3	
New York	11.9	100	100		11.9	
Philadelphia	3.9	100	100		3.9	
Phoenix	12.7	100	59		7.5	
DC/Baltimore	4.7	98	44		2.0	

Appendix D

Metropolitan-Scale HVAC Energy and Monetary Data

Metropolitan-scale HVAC annual electricity and net energy savings, peak electricity demand savings, and annual natural gas deficit were estimated by taking the product of the building-scale energy and monetary savings (**Table B-19**), the conditioned flat roof area (**Table C-3**), and the ratio of the local change in albedo to the change our simulations are based on. These are displayed in **Table D-1**.

Table D-1. Metropolitan-scale HVAC annual electricity and net energy savings, peak electricity demand savings, and annual natural gas deficit estimates from light-colored roofing for residential and commercial buildings in 11 U.S. Metropolitan Statistical Areas.

metropolitan area	gas furnace				heat pump			
	electricity (MWh)	gas (MBtu)	net (k$)	peak (kW)	electricity (MWh)	gas (MBtu)	net (k$)	peak (kW)
Residence Old								
Atlanta	87715	263524	5293	54066	4361	0	342	4076
Chicago	83324	803988	5089	74419	-246	0	-38	1516
Los Angeles	189111	432253	15892	196262	0	0	0	0
Dallas/Ft Worth	173932	357129	11405	124746	5488	0	415	5192
Houston	183349	231322	15772	85432	15470	0	1430	8450
Miami/Ft Lauderdale	79868	4248	6372	44182	86082	0	6905	47875
New Orleans	59524	80768	4207	14933	1567	0	123	462
New York	28592	260832	2428	45585	2	0	0	454
Philadelphia	45339	802454	440	88476	-2228	0	-279	4667
Phoenix	140158	61102	14768	46912	71566	0	7640	25258
DC/Baltimore	133195	691753	3580	116008	16564	0	1212	32724
Residence New								
Atlanta	27843	85313	1782	20270	4650	0	313	4755
Chicago	16808	183726	933	12139	-117	0	-20	504
Los Angeles	20254	39223	1768	20898	505	0	50	650
Dallas/Ft Worth	58487	121811	3518	42656	2977	0	225	2724
Houston	39058	52768	3362	28453	5428	0	505	4629
Miami/Ft Lauderdale	17682	87	1380	7245	37583	0	3117	15400
New Orleans	19850	26235	1393	9751	2818	0	227	1589
New York	6856	70607	602	10103	5	0	1	98
Philadelphia	4885	151444	-349	10585	-4076	0	-523	4756
Phoenix	37398	13148	3944	14170	49812	0	5445	19562
DC/Baltimore	25553	153065	506	21252	6980	0	465	13028
Office Old								
Atlanta	4639	12287	269	3911	1438	0	107	1750
Chicago	18606	133168	877	19288	75	0	6	1224
Los Angeles	45208	36694	3838	35016	3552	0	312	3042
Dallas/Ft Worth	12810	23982	714	6510	498	0	32	348
Houston	13483	13162	966	9781	623	0	48	507
Miami/Ft Lauderdale	7562	0	518	2728	3344	0	224	1224
New Orleans	5841	5597	458	4788	284	0	24	262
New York	17758	99252	1586	17229	782	0	102	2358
Philadelphia	7632	62022	518	8530	28	0	5	1153
Phoenix	4871	2297	433	1698	762	0	71	278
DC/Baltimore	10642	45877	509	9879	2273	0	172	4450
Office New								
Atlanta	546	1261	32	383	480	0	36	472
Chicago	3780	28560	175	4515	12	0	0	240
Los Angeles	13260	4920	1140	10380	5017	0	443	4037
Dallas/Ft Worth	3823	7268	213	2375	525	0	33	417
Houston	4208	3253	296	3208	668	0	52	564
Miami/Ft Lauderdale	877	0	58	209	1029	0	71	252
New Orleans	1812	1412	148	1239	287	0	24	214
New York	3898	22371	365	2557	572	0	63	1000
Philadelphia	1596	15468	93	1742	0	0	0	672
Phoenix	4193	1128	385	1320	1562	0	144	512
DC/Baltimore	1173	5380	51	1054	686	0	52	1290

Table D-1(Cont). Metropolitan-scale HVAC annual electricity and net energy savings, peak electricity demand savings, and annual natural gas deficit estimates from light-colored roofing for residential and commercial buildings in 11 U.S. Metropolitan Statistical Areas.

metropolitan area	gas furnace				heat pump			
	electricity (MWh)	gas (MBtu)	net (k$)	peak (kW)	electricity (MWh)	gas (MBtu)	net (k$)	peak (kW)
Retail Store Old								
Atlanta	4944	3264	348	1776	992	0	75	395
Chicago	24296	88825	1555	11274	0	0	0	0
Los Angeles	67800	0	6060	22067	4348	0	388	1415
Dallas/Ft Worth	28222	9697	1734	16082	1400	0	88	850
Houston	28325	1883	2185	2411	1492	0	112	128
Miami/Ft Lauderdale	6479	0	435	1779	1431	0	96	393
New Orleans	12405	714	1029	3888	645	0	54	204
New York	63977	159942	7138	39390	1266	0	163	1217
Philadelphia	24411	80160	2424	18612	408	0	48	576
Phoenix	7100	0	654	1111	60	0	6	9
DC/Baltimore	9978	14852	618	2242	1668	0	121	490
Retail Store New								
Atlanta	1242	216	93	402	408	0	31	132
Chicago	6767	15540	467	1727	42	0	4	18
Los Angeles	14849	0	1338	1640	2408	0	217	266
Dallas/Ft Worth	2935	199	182	1211	0	0	0	0
Houston	3436	0	269	697	0	0	0	0
Miami/Ft Lauderdale	1690	0	117	455	563	0	39	152
New Orleans	1518	0	126	510	0	0	0	0
New York	7508	12128	866	2541	58	0	7	26
Philadelphia	2758	7284	285	1940	22	0	2	23
Phoenix	8771	0	801	1918	4715	0	431	1032
DC/Baltimore	2627	1117	181	891	815	0	55	295

metropolitan Area	primary				secondary			
	electricity (MWh)	gas (MBtu)	net (k$)	peak (kW)	electricity (MWh)	gas (MBtu)	net (k$)	peak (kW)
School								
Atlanta	1466	6543	68	971	2328	12759	102	2107
Chicago	3857	52628	51	2132	7371	81619	177	6750
Los Angeles	8620	13987	671	4461	10038	47017	587	6692
Dallas/Ft Worth	5102	17271	264	1474	6349	36374	264	1786
Houston	6703	9983	468	1802	10470	24977	694	6308
Miami/Ft Lauderdale	2609	66	175	1092	3458	1758	229	860
New Orleans	3067	4908	233	1747	3392	11406	217	1396
New York	6757	64701	422	5490	10642	99332	740	10199
Philadelphia	2161	34746	56	5181	3686	42864	194	5916
Phoenix	4935	4500	435	1140	5433	14202	420	3648
DC/Baltimore	2886	21762	78	2288	3776	33352	91	3640

Table D-1(Cont). Metropolitan-scale HVAC annual electricity and net energy savings, peak electricity demand savings, and annual natural gas deficit estimates from light-colored roofing for residential and commercial buildings in 11 U.S. Metropolitan Statistical Areas.

metropolitan Area	hospital				nursing home			
	electricity (MWh)	gas (MBtu)	net (k$)	peak (kW)	electricity (MWh)	gas (MBtu)	net (k$)	peak (kW)
Health								
Atlanta	3361	18386	151	1530	207	251	13	108
Chicago	4513	86284	-70	2291	12736	38187	869	5626
Los Angeles	20789	45182	1562	7330	7334	2427	639	3066
Dallas/Ft Worth	3259	13447	151	1424	4188	2183	257	1547
Houston	3083	6635	204	1163	4095	1170	308	1755
Miami/Ft Lauderdale	5045	1047	349	1288	366	2	25	108
New Orleans	1388	2875	98	343	1677	532	138	638
New York	4349	45053	289	2552	11342	27910	1254	8493
Philadelphia	1804	18596	93	1127	1451	22483	40	2205
Phoenix	3515	6592	292	1007	8568	1296	784	2656
DC/Baltimore	7031	59371	130	4166	443	951	26	225

metropolitan Area	grocery store			
	electricity (MWh)	gas (MBtu)	net (k$)	peak (kW)
Grocery Store				
Atlanta	183	338	12	197
Chicago	1631	10411	86	1385
Los Angeles	5869	3536	505	2822
Dallas/Ft Worth	2327	2475	141	1590
Houston	1935	1358	142	1185
Miami/Ft Lauderdale	331	19	22	138
New Orleans	800	498	63	465
New York	1833	9080	181	1944
Philadelphia	632	8622	23	850
Phoenix	3468	843	312	1268
DC/Baltimore	556	1444	32	538

National Estimates of HVAC Energy and Monetary Savings

The results for the 11 MSAs were extrapolated to estimate the savings in the entire United States. This extrapolation was done by two methods, first by accounting for the climatic variations of the savings and second by scaling to the national population.

Extrapolation by Climate Zone

The MSAs were located in three climatically distinct zones as defined in the Residential Energy Consumption Survey (RECS, 1995), where the hottest zone (5) contained the following MSAs: Phoenix, New Orleans, Houston, Dallas/Fort Worth, and Miami/Fort Lauderdale; zone (4): Atlanta and Los Angeles; and zone 3: Chicago, New York City, Philadelphia, and DC/Baltimore. Starting with the residential sector, for each zone we summed the savings and roof area (conditioned and non-conditioned) from the 11 MSAs. From RECS we obtained residential floorspace and the ratio of roof-to-floor area in each climate zone. The residential savings in each climate zone were calculated as the product of the zonal savings [A], floorspace [C], and ratio of roof-to-floor area [D], divided by the MSA roof area [B] as presented in **Table E-1**.

- *Example of residential calculation*: For the five MSAs in zone 5 we estimated residential dollar savings at \$93M and roof area at 6 Bft^2. RECS floor space was 34 Bft^2 with a 0.80 ratio of roof-to-floor area in zone 5. The dollars saved in that climate zone were \$435M, and additionally, the savings from zone 4 and zone 3 were \$107M and \$52M, respectively. The dollar savings in these three zones were estimated at \$594M.

A similar analysis was not applied to the commercial sector because the Commercial Energy Consumption Survey (CBECS, 1994) did not sub-divide the building stock by climate zone. Therefore, we took the zonal-level savings from the residential sector and scaled these by the ratio of MSA-sum-total (residential and commercial) to MSA-sum-residential savings to obtain total zonal-level savings. This is presented in detail in **Table E-2**.

- *Example of residential and commercial calculation*: For the five MSAs in zone 5 we estimated residential dollar savings at \$93M and total (residential and commercial) at \$113M; also, zone 5 residential savings were \$435M. The total dollars saved in climate zone 5 were calculated as the ratio of 113-to-93, multiplied by \$435M, which resulted in \$530M.

Naturally, most of the savings were found in the hottest zone (5). This resulted in annual electricity savings of 11.1 TWh, (56% in zone 5, 22% in zone 3, and 22% in zone 3), annual net energy savings of \$850M, (63% in zone 5, 21% in zone 3, and 16% in zone 3), an annual gas deficit of 28.2 TBtu, and peak electricity demand savings of 7.2 GW.

Table E-1. Climate zone extrapolated estimates of annual **national** energy (M$), electricity (GWh), gas (GBtu), and peak electricity (MW) savings potentials of reflective roofs in the **residential** sector.

Climate Zone[a]	[A][b] Savings in MSA				[B][c] Roof Area in MSA	[C][d] Floorspace in Climate Zone	[D][e] Ratio of Roof to Floor Area	[E=A*C*D/B] Savings in Climate Zone			
	(M$)	(GWh)	(GBtu)	(MW)	(Bft^2)	(Bft^2)		(M$)	(GWh)	(GBtu)	(MW)
Zone 5											
Phoenix	32	299	-74	106	1.059						
New Orleans	6	84	-107	27	0.612						
Houston	21	243	-284	127	1.524						
Dallas	16	241	-479	175	1.739						
Miami	18	221	-4	115	1.068						
Total	*93*	*1088*	*-948*	*550*	*6.002*	*34*	*0.80*	*435*	*4920*	*-5280*	*2490*
Zone 4											
Atlanta	8	125	-349	83	1.029						
Los Angeles	18	210	-471	218	4.135						
Total	*26*	*335*	*-820*	*301*	*5.164*	*29*	*0.74*	*107*	*1390*	*-3410*	*1250*
Zone 3											
Chicago[f]	6	100	-988	89	1.674						
New York	3	35	-331	56	2.837						
Philadelphia	-1	44	-954	108	1.548						
Washington DC	6	182	-845	183	1.714						
Total	*14*	*361*	*-3118*	*436*	*7.773*	*44*	*0.66*	*52*	*1340*	*-11650*	*1630*
Zone 2 (Ignored in these calculations)						*52*		*0*	*0*	*0*	*0*
Zone 1 (Ignored in these calculations)						*19*		*0*	*0*	*0*	*0*
Total					**18.939**	**178**		**594**	**7,650**	**-20,340**	**5,370**

Notes:

a. Climate zones as defined in Residential Energy Consumption Survey (RECS, 1995).

b. This report, Table 5-1.

c. This report, Table C-3, includes non-conditioned and conditioned.

d. Residential Energy Consumption Survey, Table 3.5 (RECS, 1995).

e. Residential Energy Consumption Survey, Tables 3.1a, 3.4 (RECS, 1995).

f. Base on RECS climate zone definitions Chicago was classified as in zone 2. However, we included it in zone 3 because its climate is strongly influenced by Lake Michigan and is unlike the zone-2 continental climate type. In fact, the savings in Chicago were much like those of other MSAs in zone 3.

Table E-2. Climate zone extrapolated estimates of annual **national** energy (M$), electricity (GWh), gas (GBtu), and peak electricity (MW) savings potentials of reflective roofs in **residential and commercial** sectors.

Climate Zone[a]	Row	Savings (M$)	Savings (GWh)	Savings (GBtu)	Savings (MW)
Zone 5 Savings[b]	A				
Residential in MSA[c]	A1	93	1088	-948	550
Residential and Commercial in MSA[c]	A2	113	1382	-1201	665
Residential in Climate Zone[c]	A3	435	4920	-5280	2490
Residential and Commercial in Climate Zone	A4= A2*A3/A1	531	6250	-6690	3010
Zone 4 Savings[b]	B				
Residential in MSA[c]	B1	26	335	-820	301
Residential and Commercial in MSA[c]	B2	46	581	-1044	425
Residential Savings in Climate Zone[c]	B3	107	1390	-3410	1250
Residential and Commercial in Climate Zone	B4= B2*B3/B1	180	2470	-4340	1770
Zone 3 Savings[b]	C				
Residential in MSA[c]	C1	14	361	-3118	436
Residential and Commercial in MSA[c]	C2	37	654	-4586	658
Residential in Climate Zone[c]	C3	52	1340	-11650	1630
Residential and Commercial in Climate Zone	C4= C2*C3/C1	137	2420	-17200	2460
National Savings	D				
Residential	**D1=** A3+B3+C3	**594**	**7650**	**-20,340**	**5,370**
Residential and Commercial	**D2=** A4+B4+C4	**848**	**11,140**	**-28,230**	**7,239**

Notes:

a. Climate zones as defined in Residential Energy Consumption Survey (RECS, 1995).

b. Metropolitan areas in Climate Zone 5 include: Phoenix, New Orleans, Houston, Dallas, and Miami; in Climate Zone 4 include: Atlanta and Los Angeles; and in Climate Zone 3 include: Chicago, New York, Philadelphia, and Washington DC.

c. This report, Tables 5-1 and E-1.

Extrapolation by Population

National estimates were also derived from scaling by population, where the 1990 population of the 11 MSA was 70 million and the entire United States was 249 million. The savings estimates from the 11 MSA were increased by the ratio of 249 to 70 (3.56) and are shown in **Table E-4**. This resulted in a reduction of 9.3 TWh in annual electricity use, $680M in annual net energy payments, and 6.2 GW in peak electricity demand. The associated heating penalty was 24.5 TBtu. The reduction in peak electricity demand is the equivalent of 12 to 14 power plants each of 0.5 GW capacity.

Metropolitan-Scale and National HVAC Energy and Monetary Base Use

The energy use for dark-colored roofs (base case) was estimated in order to understand the relative savings from light-colored roofs, and was calculated as the product of DOE-2 estimates and conditioned flat-roof area. Metropolitan-scale base energy use and monetary expenditures for single-story buildings are presented for groups of buildings: residences, offices, retail stores, and other buildings (primary and secondary schools, hospital, nursing home, and grocery store grouped together) in **Table E-3**. The base use was then grouped into residential and commercial buildings to scale the single-story estimates to multi-story by the average number of floors as shown in Table E-4. The average number of floors for residences was 2.3 for 11 MSA (Source: AHS), 1.5 nationally (RECS, 1995), and 3.0 for commercial buildings nationally (CBECS, 1994). Note, the absolute savings estimated for single-story buildings are applicable to multi-story buildings.

The relative savings that reflect actual building stocks, those with multiple floors, are shown in the final column of Table E-4. In the 11 MSAs with the population extrapolation method we estimated a total electricity savings of 2.4%, a gas deficit of 1.2%, a net energy savings of 1.4%, and a peak demand savings of 2.0%, and nationally 2.9%, 1.6%, 1.8%, and 2.5%, respectively.

A comparison of our base use estimates with those of the EIA serves as a reality check. The annual national cooling electricity consumption in the residential sector was 0.51 QBtu (150 TWh) and in the commercial sector was 0.73 QBtu (210 TWh) in the early 1990s (EIA, 1993c). We estimated a base cooling electricity consumption of 144 TWh (within 4% of EIA) for the residential sector and 172 TWh (within 18% of EIA) for the commercial sector. Note, the commercial buildings we selected contained fewer building types than the EIA database.

Table E-3. Metropolitan-scale HVAC annual electricity, natural gas, and net energy and peak electricity demand base use (dark roof) estimates for residential, office, retail store, and other (schools, health, and grocery store) buildings in 11 U.S. Metropolitan Statistical Areas.

Metropolitan Area	Base Use	Residential	Office	Retail Store	Other	Total
Atlanta	Elec (GWh)	1669	169	154	161	2153
	Gas (GBtu)	17136	203	40	458	17836
	Net (M$)	247	14	12	15	287
	Peak (MW)	1541	132	78	131	1882
Chicago	Elec (GWh)	1121	417	546	516	2599
	Gas (GBtu)	47042	3317	1124	5307	56790
	Net (M$)	384	52	52	70	558
	Peak (MW)	1591	454	360	558	2963
Los Angeles	Elec (GWh)	1472	982	1166	858	4479
	Gas (GBtu)	11259	142	163	667	12232
	Net (M$)	214	88	105	80	487
	Peak (MW)	2492	901	626	597	4616
Dallas/Fort Worth	Elec (GWh)	4556	485	899	652	6592
	Gas (GBtu)	25796	438	140	1320	27694
	Net (M$)	502	33	58	48	641
	Peak (MW)	4047	401	473	626	5548
Houston	Elec (GWh)	3463	459	869	657	5448
	Gas (GBtu)	12168	174	99	696	13138
	Net (M$)	394	36	66	53	549
	Peak (MW)	3298	341	377	554	4570
Miami/Fort Lauderdale	Elec (GWh)	3974	332	289	319	4913
	Gas (GBtu)	324	1	21	33	379
	Net (M$)	325	23	20	22	389
	Peak (MW)	1779	170	90	164	2203
New Orleans	Elec (GWh)	982	168	322	242	1714
	Gas (GBtu)	3595	63	37	269	3964
	Net (M$)	100	14	27	22	163
	Peak (MW)	796	125	137	207	1264
New York City	Elec (GWh)	396	546	1284	652	2878
	Gas (GBtu)	17549	3045	2115	6303	29011
	Net (M$)	205	88	175	121	589
	Peak (MW)	686	560	879	749	2875
Philadelphia	Elec (GWh)	867	162	407	191	1627
	Gas (GBtu)	35384	1328	939	2766	40418
	Net (M$)	351	27	54	39	471
	Peak (MW)	747	148	274	211	1381
Phoenix	Elec (GWh)	4774	232	420	516	5943
	Gas (GBtu)	4107	15	32	256	4410
	Net (M$)	541	21	39	49	650
	Peak (MW)	3312	164	182	334	3993
DC/Baltimore	Elec (GWh)	3742	378	315	313	4748
	Gas (GBtu)	37789	861	144	1650	40444
	Net (M$)	583	32	23	32	670
	Peak (MW)	3045	308	183	297	3833
Total	Elec (GWh)	27016	4330	6672	5076	43094
	Gas (GBtu)	212149	9588	4854	19725	246317
	Net (M$)	3847	428	630	550	5455
	Peak (MW)	23336	3706	3657	4427	35126

Table E-4. Eleven metropolitan area sum total and population extrapolated **national** estimates of HVAC energy base use and savings resulting from light-colored roofs on residential and commercial buildings.

Eleven Metropolitan Area Sum Total							
Building Type	Savings	HVAC Base Single-Story	# of Floors	HVAC Base Multi-Story	HVAC Savings		
					Δ	% Single	% Multi
Residential	TWh	27.0	2.3	62.1	1.78	6.6	2.9
Commercial	TWh	16.1	3.0	48.3	0.81	5.0	1.7
Total	TWh	43.1	-	110.4	2.60	6.0	2.4
Residential	TBtu	212.1	2.3	487.9	-4.89	-2.3	-1.0
Commercial	TBtu	34.2	3.0	102.6	-2.00	-5.8	-1.9
Total	TBtu	246.3	-	590.5	-6.89	-2.8	-1.2
Residential	$B	3.8	2.3	8.8	0.13	3.4	1.5
Commercial	$B	1.6	3.0	4.8	0.06	3.8	1.2
Total	$B	5.5	-	13.6	0.19	3.5	1.4
Residential	GW	23.3	2.3	53.7	1.29	5.5	2.4
Commercial	GW	11.8	3.0	35.4	0.46	3.9	1.3
Total	GW	35.1	-	89.1	1.74	5.0	2.0

National Extrapolation by Population							
Building Type	Savings	HVAC Base Single-Story	# of Floors	HVAC Base Multi-Story	HVAC Savings		
					Δ	% Single	% Multi
Residential	TWh	96.1	1.5	144.1	6.33	6.6	4.4
Commercial	TWh	57.3	3.0	171.9	2.88	5.0	1.7
Total	TWh	153.4	-	316.0	9.25	6.0	2.9
Residential	TBtu	755.1	1.5	1132.7	-17.39	-2.3	-1.5
Commercial	TBtu	121.8	3.0	365.4	-7.11	-5.8	-1.9
Total	TBtu	876.8	-	1498.1	-24.51	-2.8	-1.6
Residential	$B	13.5	1.5	20.2	0.46	3.4	2.3
Commercial	$B	5.7	3.0	17.1	0.21	3.7	1.2
Total	$B	19.6	-	37.3	0.68	3.5	1.8
Residential	GW	82.9	1.5	124.4	4.59	5.5	3.7
Commercial	GW	42.0	3.0	126.0	1.64	3.9	1.3
Total	GW	125.0	-	250.4	6.19	5.0	2.5

Attachment 1

Residential White Roofing Shingles

Source: Akbari, H., "Memo to Millard Carr, Attachment 2 - July 12, 1995," Heat Island Group, LBNL, 510-486-4287

Shingle	Albedo	Availability
Brown	0.10	Commonly used
Typical white	0.26	Several manufacturers
Premium white algaecide	0.36	Several manufacturers
Typical 1960's white	0.36	Manufacturers can produce upon request
Premium 1960's white	0.40	Manufacturers can produce upon request
ISP prototype two-coat TiO white	0.46	ISP has the process in place, it can be produced within 3-6 months
ISP prototype three-coat TiO white	0.51	ISP has the process in place, it can be produced within 3-6 months
ISP prototype six-coat TiO white	0.58	ISP needs to make modification to their process line, it can be produced within 1-2 years

Two major manufacturers of granules for roofing shingles are ISP Minerals and 3M Industrial Minerals. The list of shingle companies can be obtained from either ISP or 3M.

ISP Minerals Products Inc.
34 Charles Street
Hagerstown, MD 21740
310-733-4000

3M
3M Center, Building 209-1W-14
St. Paul, MN 55144
612-737-5536

Attachment 2

Linearity Property

DOE-2 Simulated HVAC Annual Electricity and Net Energy and Peak Demand Savings from Light-Colored Roofs for a Base Case of 0.10 and Modified of 0.25, 0.40, 0.55, and 0.70. These prototypes and savings estimates were from a separate research task and were not identical to those described in this report, these results are presented only to highlight the linear relationship between savings and step-wise changes in roof albedo (Source: Konopacki, S., Heat Island Group, LBNL, 510-486-6966).

Building & Location	Electricity Savings (kWh/1000ft^2)				Net Energy Savings ($/1000ft^2)				Peak Demand Savings (W/1000ft^2)			
	0.25	0.40	0.55	0.70	0.25	0.40	0.55	0.70	0.25	0.40	0.55	0.70
Residence Old w/ Gas Furnace												
San Bernardino	249	512	788	1079	27	56	86	116	1456	3112	5008	7101
LAX Airport	149	300	440	588	12	25	36	47	1257	2043	3546	4918
Santa Ana	169	338	505	668	18	36	53	69	1466	2863	4461	6092
LA Civic Center	195	397	601	808	16	34	50	66	1408	2810	4231	5689
Sacramento	187	384	590	798	10	21	32	42	1361	2864	4432	6069
Residence New w/ Gas Furnace												
San Bernardino	84	171	259	355	9	19	29	38	607	1253	1840	2573
LAX Airport	46	93	141	190	4	8	12	16	449	879	1335	1755
Santa Ana	54	106	162	219	6	12	18	23	495	1002	1548	2099
LA Civic Center	60	125	189	256	5	11	16	22	389	860	1345	1844
Sacramento	62	127	193	263	3	7	10	14	511	1035	1576	2136
Office Old w/ Gas Furnace												
San Bernardino	156	305	455	616	17	32	48	65	1078	2168	3181	4335
LAX Airport	120	233	347	460	10	20	29	39	983	1750	2741	3407
Santa Ana	120	251	371	484	13	27	40	52	900	1788	2642	3623
LA Civic Center	120	239	359	478	10	20	30	40	771	1562	2473	3210
Sacramento	102	215	329	442	7	14	22	30	741	1734	2639	3564
Office New w/ Gas Furnace												
San Bernardino	78	149	233	317	9	16	25	34	541	1093	1656	2304
LAX Airport	60	120	185	251	5	10	16	22	410	939	1407	1861
Santa Ana	66	132	197	275	7	14	21	30	483	856	1521	1980
LA Civic Center	60	131	197	269	5	12	17	23	403	806	1263	1692
Sacramento	54	120	185	245	4	9	13	17	415	908	1396	1880
Residence Old w/ Electric Heat Pump												
San Bernardino	192	394	595	790	23	48	72	95				
LAX Airport	103	196	267	333	10	19	27	33				
Santa Ana	118	230	330	405	14	27	40	49				
LA Civic Center	143	279	407	521	14	28	40	52				
Sacramento	116	229	341	441	9	18	27	34				
Residence New w/ Electric Heat Pump												
San Bernardino	68	136	204	276	8	17	25	34				
LAX Airport	35	69	103	136	4	7	10	14				
Santa Ana	42	81	122	160	5	10	15	19				
LA Civic Center	49	96	145	192	5	10	14	19				
Sacramento	38	78	116	156	3	6	9	12				
Office Old w/ Electric Heat Pump												
San Bernardino	144	275	401	532	16	31	44	59				
LAX Airport	108	209	311	413	10	19	28	37				
Santa Ana	114	227	329	431	13	25	37	48				
LA Civic Center	108	215	323	424	10	19	29	38				
Sacramento	78	162	245	323	6	13	20	26				
Office New w/ Electric Heat Pump												
San Bernardino	78	143	221	299	9	16	25	33				
LAX Airport	54	113	173	233	5	10	15	21				
Santa Ana	66	120	191	251	7	13	21	28				
LA Civic Center	60	125	191	263	5	11	17	23				
Sacramento	54	102	155	197	4	8	12	16				