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Executive
Summary

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Executive Summary

The U.S. Environmental Protection Agency (EPA) sponsored this project to estimate potential energy and monetary savings resulting from the implementation of light-colored roofs on residential and commercial buildings in major U.S. metropolitan areas. Light-colored roofs reflect more sunlight than dark roofs, so they keep buildings cooler and reduce air-conditioning demand. Typically, rooftops in the United States are dark, and thus there is a potential for saving energy and money by changing to reflective roofs. Naturally, the expected savings are higher in southern, sunny, and cloudless climates. In this study, we make quantitative estimates of reduction in peak power demand and annual cooling electricity use that would result from increasing the reflectivity of the roofs. Since light-colored roofs also reflect heat in the winter, the estimates of annual electricity savings are a net value corrected for the increased wintertime energy use. Savings estimates only include **direct** reduction in building energy use and do not account for the **indirect** benefit that would also occur from the reduction in ambient temperature, i.e. a reduction in the heat island effect.

This analysis is based on simulations of building energy use, using the DOE-2 building energy simulation program. Our methodology starts with specifying 11 prototypical buildings:† single-family residential (old and new), office (old and new), retail store (old and new), school (primary and secondary), health (hospital and nursing home), and grocery store. Most prototypes are simulated with two heating systems: gas furnace and heat pumps. We then perform DOE-2 simulations of the prototypical buildings, with light and dark roofs, in a variety of climates and obtain estimates of the energy use for air conditioning and heating. Weather data for 11 U.S. Metropolitan Statistical Areas (MSAs) are used: Atlanta, Chicago, Los Angeles, Dallas/Fort Worth, Houston, Miami/Fort Lauderdale, New Orleans, New York City, Philadelphia, Phoenix, and Washington, DC/Baltimore. Cooling energy savings and heating energy penalties are then obtained by calculating the difference between the simulated energy use of the prototype buildings with light- and dark-colored roofs.

We proceed from the estimates of savings in individual buildings to the entire MSA, by calculating how much energy and money could be saved if the current building stock had its roofs changed from dark to light. This is done by scaling the simulated energy savings of the prototype buildings by the amount of air-conditioned space immediately beneath roofs in an entire MSA. For this, we use data in each MSA on the stock of commercial and residential buildings, the saturation of heating and cooling systems, the current roof reflectivities, and the local costs of electricity and gas.

The estimates of the direct savings are shown in **Table EX-1**. The largest potential for net annual dollar savings was found in Phoenix, \$37 million (\$37M), followed by Los Angeles (\$35M), Houston (\$27M), Miami/Fort Lauderdale (\$20M), Dallas/Fort Worth (\$20M), New York

† In a multi-story building, only the top floor which is directly affected by the roof color is included.

City ($16M), Chicago ($10M), New Orleans ($9M), Atlanta ($9M), Washington, DC/Baltimore ($8M), and Philadelphia ($3M). The same quantities per $1000ft^2$ of roof area of air-conditioned buildings for each MSA are shown in **Table EX-2**. To illustrate the climate effect, the results are plotted in **Figures EX-1** to **EX-4**, superimposed on a map of the United States with contours of annual cooling hours for a typical residential building. The data per $1000ft^2$ of roof area reflect the effects of climate, whereas the MSA savings are strongly affected by the sizes of the populations.

The sum total for all 11 MSAs are: electricity savings, 2.6 terawatt hours (TWh) (200 kilowatt hours per $1000ft^2$ of roof area of air-conditioned buildings); natural gas deficit, 6.9 TBtu (5 therms per $1000ft^2$); net savings in energy bills, $194M ($15 per $1000ft^2$); and savings in peak demand 1.7 gigawatt (GW) (135 W per $1000ft^2$). Six building types account for over 90% of the annual electricity and net dollar savings: old residences more than 55%, new residences about 15%, and four other building types (old/new offices and old/new retail stores) together about 25%.

The results for the 11 MSAs are extrapolated to estimate the savings in the entire United States. This extrapolation is done first by scaling to the national population, and then by a method that accounts for the climatic variations of the savings. We find that the national savings are about four times the savings for the 11 MSAs: a decrease in annual direct electricity use by 9.3 to 11 TWh (about 3.0% of the national cooling electricity use in residential and commercial buildings), an increase in natural gas use by 25 to 28 GBtu (1.6%), decrease peak electrical demand by 6.2 to 7.2 GW (2.5%) (equivalent to 12 to 14 power plants each with a capacity of 0.5 GW), and a decrease in net energy bills for the rate-payers by $680M to $850M.

Table EX-1. Estimates of **metropolitan-scale** annual direct cooling electricity savings, annual natural gas penalty, net dollar savings, and peak electricity demand savings, resulting from application of light-colored roofing on residential and commercial buildings in 11 Metropolitan Statistical Areas. Net dollar savings are calculated using the local cost of electricity and gas. For example, in Phoenix, the average price of electricity and gas for commercial and residential consumers are: 1kWh costs $0.104; and 1MBtu $6.40.

Metropolitan Area	Residential Savings						Commercial Savings						Residential and Commercial Savings					
	elec		gas		**net**	peak	elec		gas		**net**	peak	elec		gas		**net**	peak
	(GWh)	(M$)	(GBtu)	(M$)	**(M$)**	(MW)	(GWh)	(M$)	(GBtu)	(M$)	**(M$)**	(MW)	(GWh)	(M$)	(GBtu)	(M$)	**(M$)**	(MW)
Atlanta	125	9.8	-349	-2.4	**7.4**	83	22	1.6	-55	-0.3	**1.3**	14	147	11.4	-404	-2.7	**8.7**	97
Chicago	100	11.2	-988	-5.4	**5.8**	89	84	7.0	-535	-2.7	**4.3**	56	183	18.2	-1523	-8.1	**10.1**	145
Los Angeles	210	20.6	-471	-2.9	**17.7**	218	209	18.6	-154	-0.9	**17.7**	102	419	39.2	-625	-3.8	**35.4**	320
Dallas / Ft Worth	241	18.6	-479	-2.8	**15.8**	175	71	4.5	-113	-0.5	**4.0**	36	312	23.1	-592	-3.3	**19.8**	211
Houston	243	22.6	-284	-1.7	**20.9**	127	79	6.0	-62	-0.3	**5.7**	30	322	28.6	-347	-2.0	**26.6**	156
Miami / Ft Lauderdale	221	17.9	-4	0.0	**17.9**	115	35	2.4	-3	0.0	**2.4**	11	256	20.3	-7	0.0	**20.3**	125
New Orleans	84	6.6	-107	-0.7	**5.9**	27	33	2.8	-28	-0.1	**2.7**	16	117	9.4	-135	-0.8	**8.6**	42
New York	35	5.6	-331	-2.7	**2.9**	56	131	16.5	-540	-3.3	**13.2**	95	166	22.1	-871	-6.0	**16.1**	151
Philadelphia	44	5.6	-954	-6.5	**-0.9**	108	47	5.5	-292	-1.8	**3.7**	49	91	11.1	-1246	-8.3	**2.8**	157
Phoenix	299	32.0	-74	-0.5	**31.5**	106	58	5.3	-31	-0.2	**5.1**	18	357	37.3	-105	-0.7	**36.6**	123
DC / Baltimore	182	13.1	-845	-7.0	**6.1**	183	45	3.2	-184	-1.1	**2.1**	31	227	16.3	-1029	-8.1	**8.2**	214
Total	1784	163.6	-4886	-32.6	**131.0**	1287	814	73.4	1997	11.2	**62.2**	458	2597	237.0	6884	43.8	**193.2**	1741

Table EX-2. Estimates of annual direct savings and penalties **per 1000 ft^2 of roof area of air-conditioned buildings** resulting from application of light-colored roofing on residential and commercial buildings in 11 Metropolitan Statistical Areas. Net dollar savings are calculated using the local cost of electricity and gas. For example, in Phoenix, the average price of electricity and gas for commercial and residential consumers are: 1kWh costs $0.104; and 1 therm = 0.1MBtu costs $0.64.

Metropolitan Area	Residential Savings				Commercial Savings				Residential and Commercial Savings			
	elec (kWh)	gas (therms)	**net ($)**	peak (W)	elec (kWh)	gas (therms)	**net ($)**	peak (W)	elec (kWh)	gas (therms)	**net ($)**	peak (W)
Atlanta	153	-4	**10**	102	239	-6	**11**	152	162	-4	**10**	107
Chicago	131	-13	**8**	116	228	-15	**11**	152	162	-13	**9**	128
Los Angeles	182	-4	**16**	189	350	-3	**30**	171	239	-4	**20**	183
Dallas / Ft Worth	166	-3	**11**	121	224	-4	**13**	114	176	-3	**11**	119
Houston	198	-2	**17**	103	261	-2	**20**	99	211	-2	**18**	102
Miami / Ft Lauderdale	259	0	**21**	135	340	0	**19**	107	267	0	**21**	131
New Orleans	199	-3	**14**	64	287	-2	**26**	139	218	-3	**17**	78
New York	104	-10	**9**	166	211	-9	**21**	153	173	-9	**17**	158
Philadelphia	81	-18	**-2**	199	232	-14	**20**	241	122	-17	**4**	211
Phoenix	314	-1	**34**	111	409	-2	**35**	127	327	-1	**34**	113
DC / Baltimore	137	-6	**5**	138	221	-9	**10**	152	148	-7	**5**	140

Figure EX-1: Annual Net Cooling Energy Savings for 11 Metropolitan Areas

The contour map shows simulated annual cooling hours for a typical house (Source: Kelly & Parken 1978).

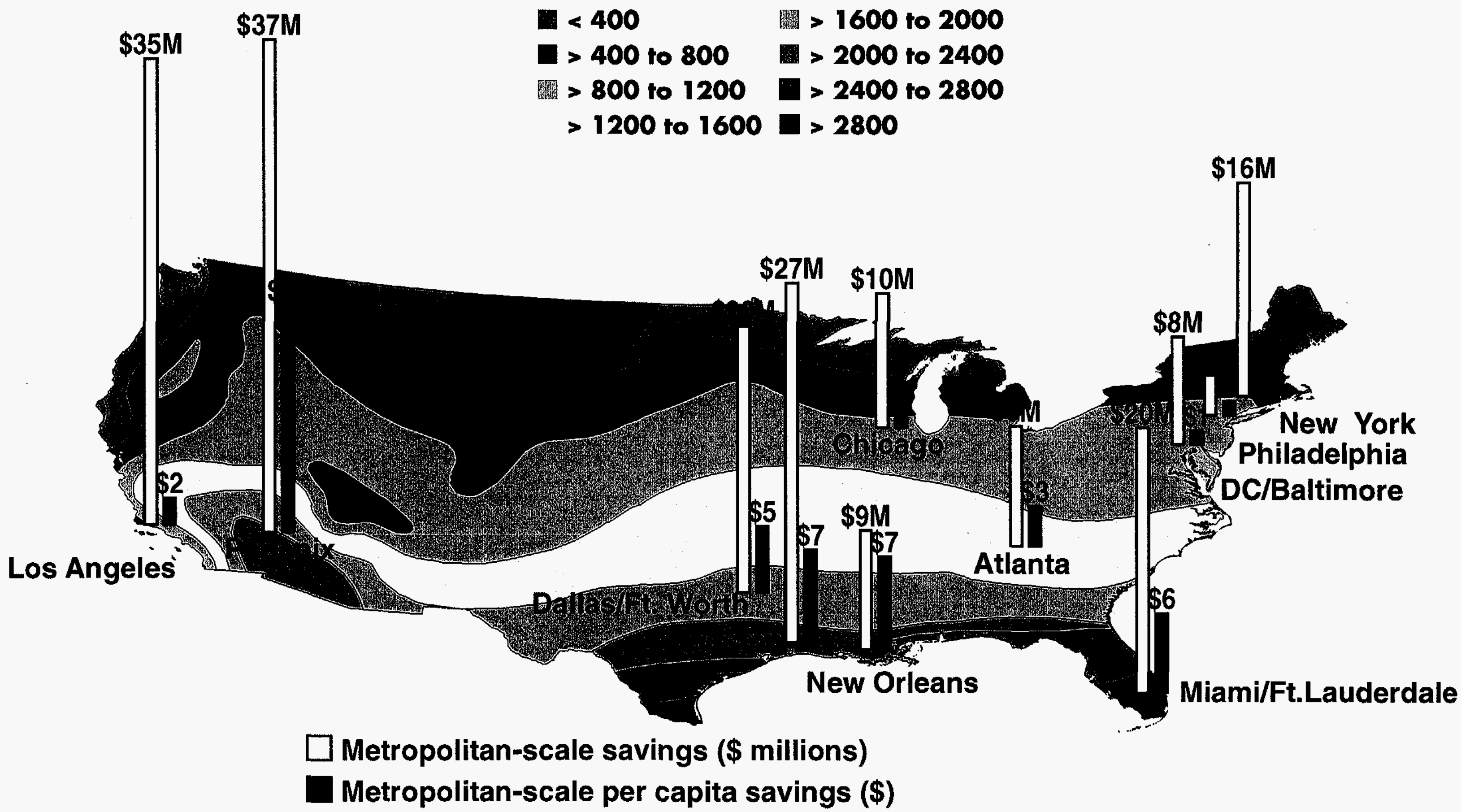

Figure EX-2: Annual Cooling-Electricity Savings for 11 Metropolitan Areas

The contour map shows simulated annual cooling hours for a typical house (Source: Kelly & Parken 1978).

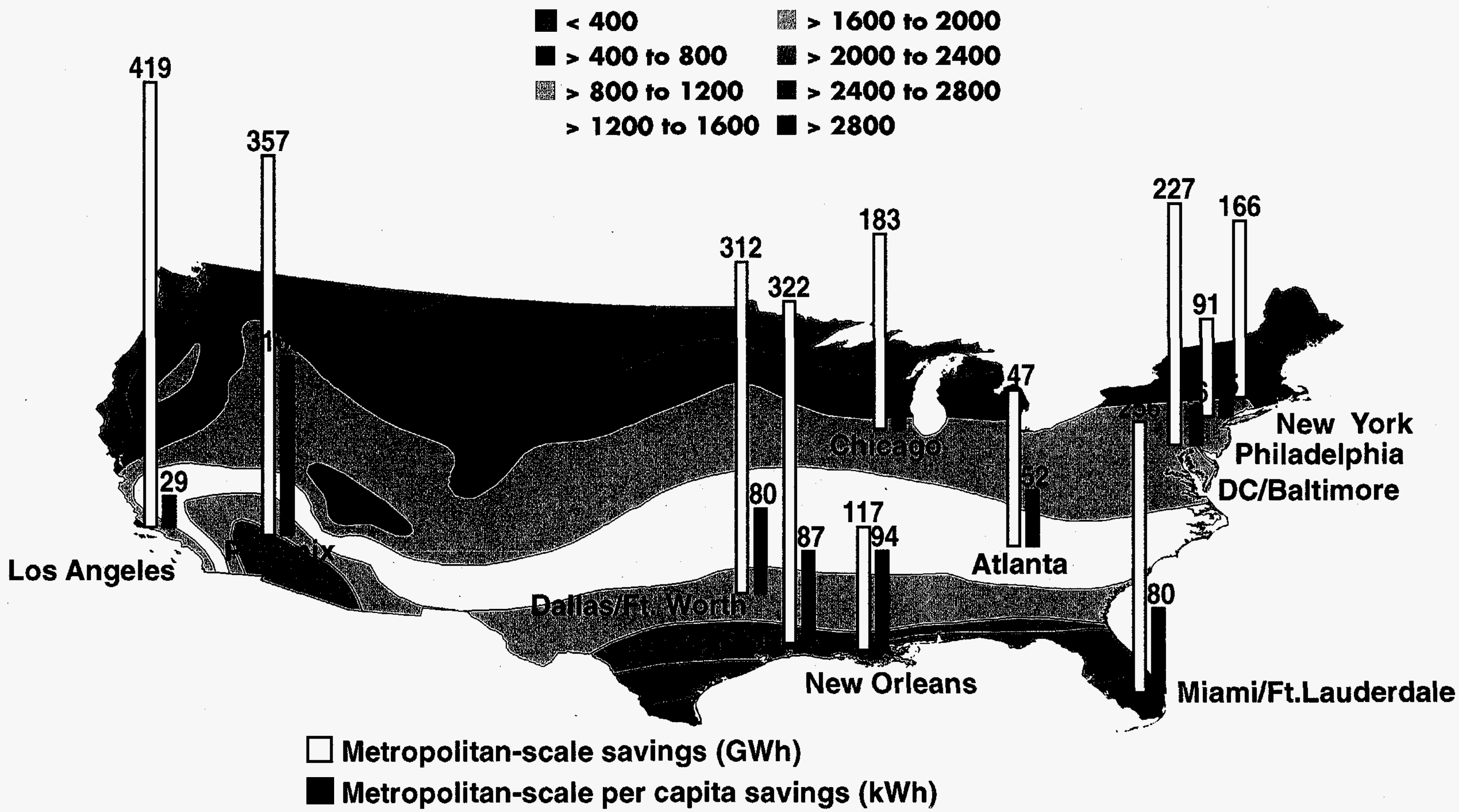

Figure EX-3: Annual Heating Energy Penalties for 11 Metropolitan Areas

The contour map shows simulated annual cooling hours for a typical house (Source: Kelly & Parken 1978).

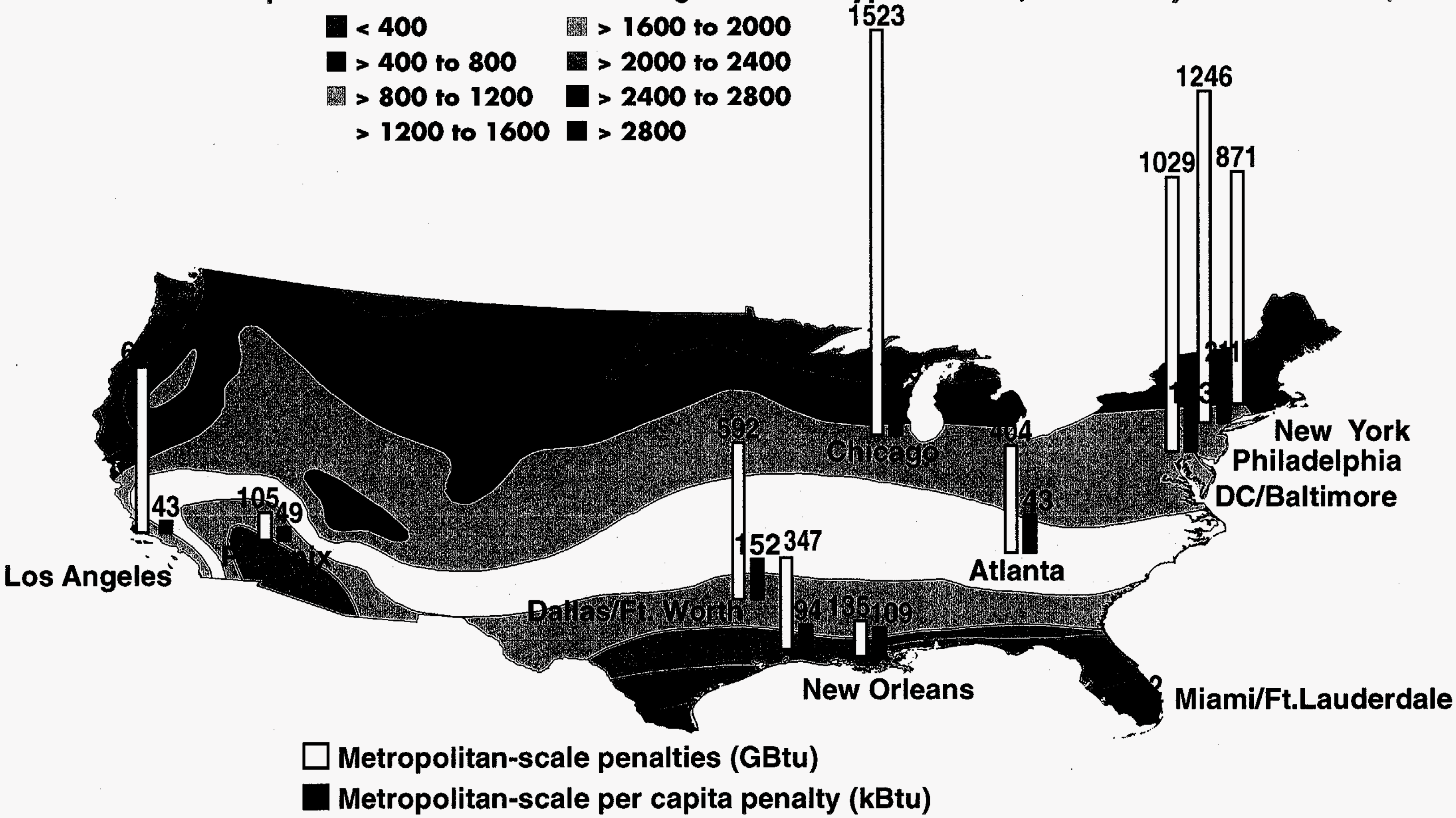

Figure EX-4: Peak-Cooling Electricity Demand Savings for 11 Metropolitan Areas

The contour map shows simulated annual cooling hours for a typical house (Source: Kelly & Parken 1978).