Chapter 7

Energy-Saving Potential of Trees in Chicago

Scattered trees throughout a neighborhood increase surface roughness, thereby reducing windspeeds by as much as 50 percent (Heisler 1990). Trees and shrubs located slightly upwind of buildings provide additional protection that reduces the amount of cold outside air that infiltrates. Lower windspeed results in reduced infiltration of outside air. Reduced infiltration is beneficial during both the heating and cooling seasons. However, lower windspeed is detrimental during the cooling

tions). Micropas multiplies the hourly shading coefficients by direct and diffuse radiation values to reduce solar-heat gains on opaque and glazing surfaces.

Energy savings are calculated as the difference between the unshaded base case and results from each of the shading, ET cooling, and windspeed-reduction scenarios. Standard-

Table 1.—Base case building characteristics and Micropas simulation assumptions

Building feature	1 Story	2 Story	3 Story	1 Story	2 Story

5. Two-story wood frame. One household, three occupants, 1,761 ft2 (164 m2) of floor area, constructed during 1990's

to the base load method is that the use of degree-days may not fully normalize energy use for different weather condi

Table 2.—Number of heating and cooling degree-days for Chicago

Period	Heating degree-days	Cooling degree-days
April 1991 - March 1992	5,928	1,154
April 1993 - March 1993	6,746	457

Table 3.—Tree dimensions for shading scenarios in feet

the role of any single tree. Yet, they are important because

1.0°C) decrease in temperature for every increase of 10-

the two- and three-story brick buildings contain two and six

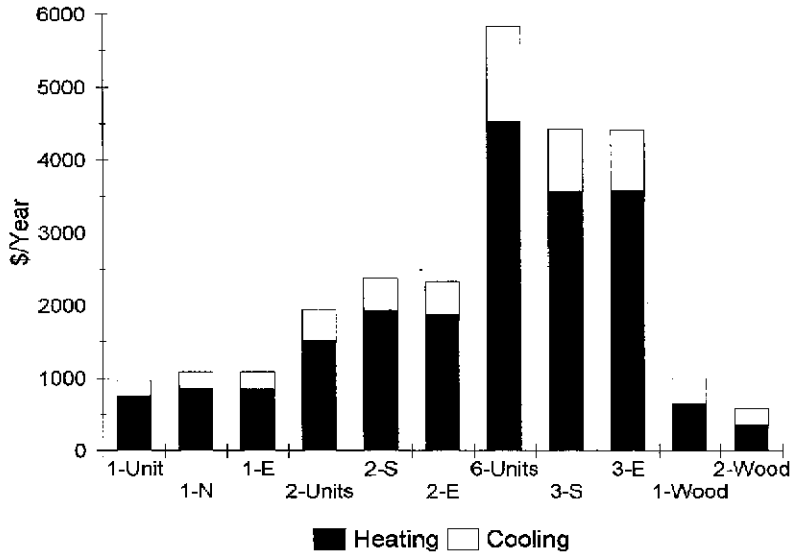
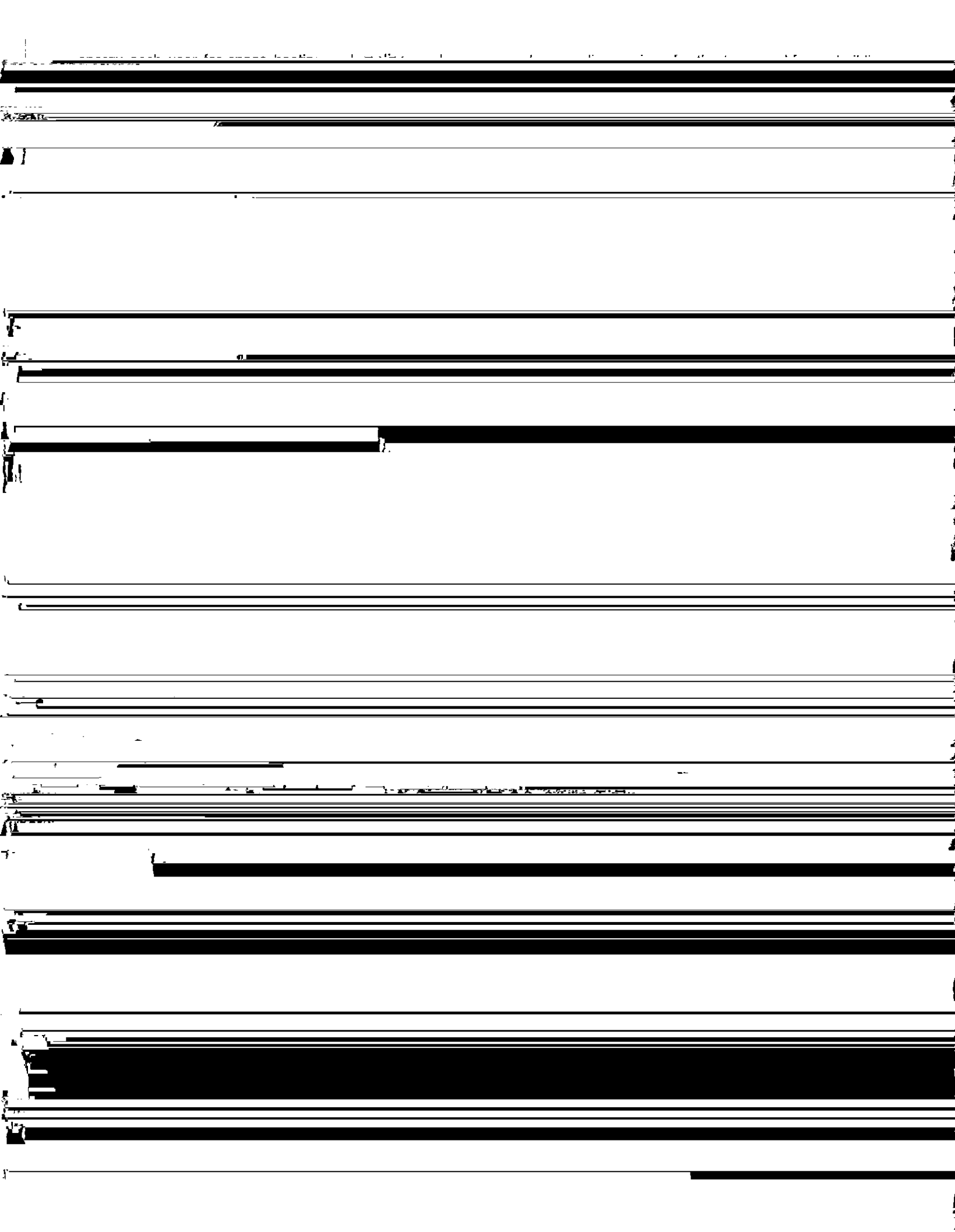


Figure 3.—Simulated annual heating and cooling costs are shown for each base case building, where the number corresponds to the number of stories and the letter corresponds to the brick building's front orientation (e.g., 1-N is one-story brick building facing north, 1-Wood is the one-story wood-frame base case). For comparison, average costs per Chinook household have been extrapolated for buildings with one, two

4a

located 22 feet from the building produces about one-third the savings as the 50-foot tree at the same location. Savings from the 24-foot tree (small) located 12 feet away from the west wall are about half the savings produced by the 36-foot tree at 22 feet. The 24-foot tree opposite the east wall produces no net savings because cooling savings are offset



7a

the brick buildings resulted from a large tree (50 feet and 36 feet wide) located 22 feet from the west wall, while a 25-foot tree located 12 feet from the west wall produced maximum savings for the wood-frame buildings.

Table 5.—Per-tree maximum annual savings in air-conditioning (AC) from tree shade[a]

	Base case AC			AC saved			Peak AC saved	
Base case buildings	kWh	$	Peak kW	kWh	%	$	kW	%
1-story brick north facing	1,795	215	4.2	187	10.4	22.85	0.3	6.2
1-story brick east facing	1,928	231	4.5	149	7.7	18.21	0.5	10.5
2-story brick south facing	3,682	442	10.6	399	10.8	48.76	1.3	12.3
2-story brick east facing	3,725	447	10.1	297	8.0	36.29	1.0	9.7
3-story brick south facing	7,199	864	16.7	345	4.8	42.16	1.0	5.8

The relative magnitudes of cooling savings from shade and ET cooling vary with building type and orientation. Annual savings from shade range from $4 (37 kWh, 2 percent) per tree for the one-story brick building facing north to $22 (186 kWh, 6.3 percent) per tree for the one-story wood-frame

high rates of air infiltration, and inefficient heating equipment

responsiveness to tree shade and dry-bulb temperature de-

years 1 to 20 (Appendix E). It is assumed that one typical tree is planted for energy savings near each typical building in

Robinette 1977; Sand 1991; Sand 1993a; Sand 1993b). In this section, general guidelines for energy-efficient residen-

Deciduous vines and shrubs can provide both summer shade and winter solar access.

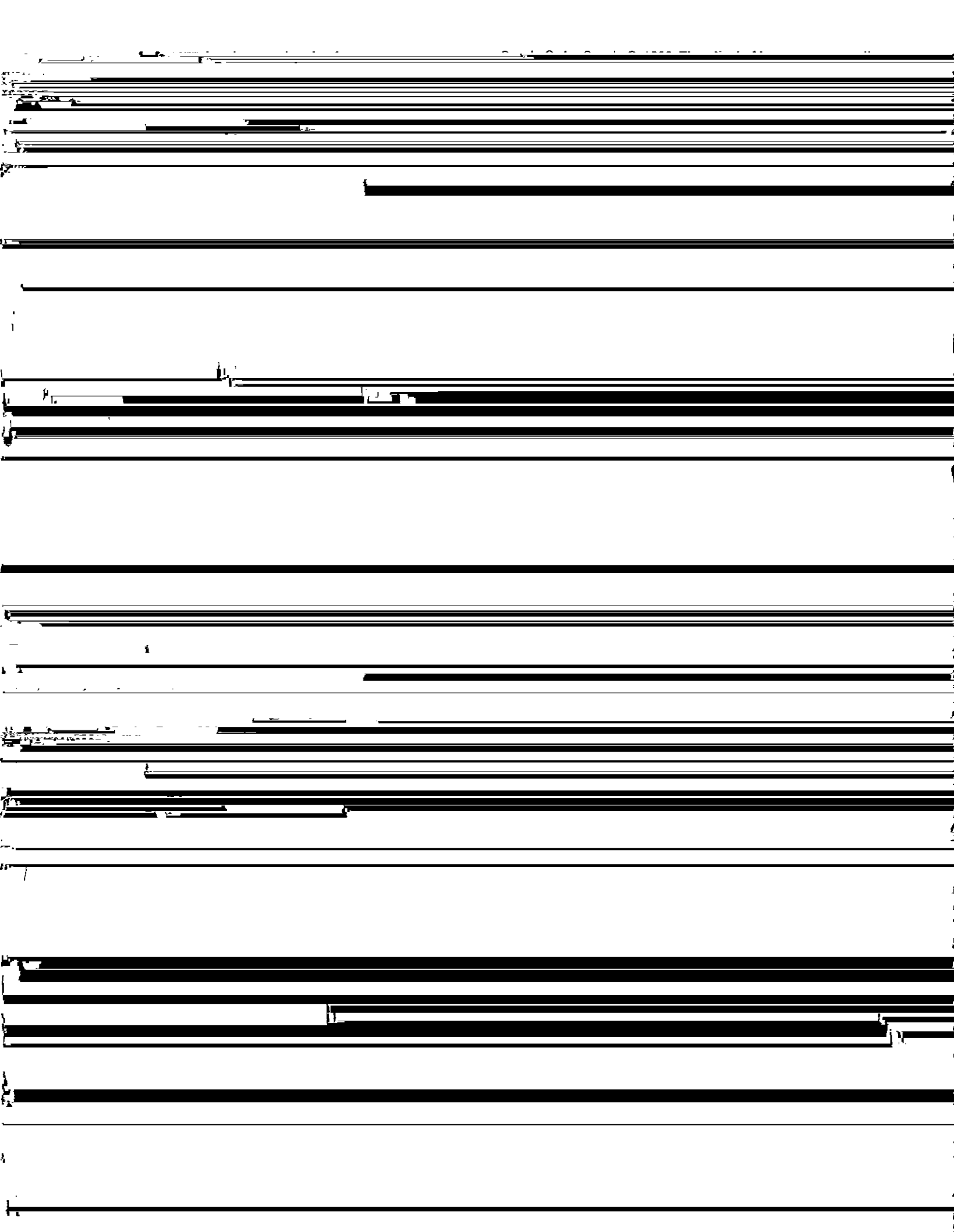
South shade can reduce summer peak cooling demand more

costs. Shade from large street trees to the south increase heating costs more than they decrease cooling costs for the buildings studied. Planting solar friendly trees to the south and east can minimize the energy penalty associated with

Acknowledgments

This study would not have been possible without information

Heisler, G. M. 1991. **Computer simulation for optimizing windbreak placement to save energy for heating and cooling**



Chapter 8

Benefits and Costs of Tree Planting and Care in Chicago

E. Gregory McPherson, Research Forester, USDA Forest Service, Northeastern Forest Experiment Station, Davis, CA

damage property. Thorns and low-hanging branches can be

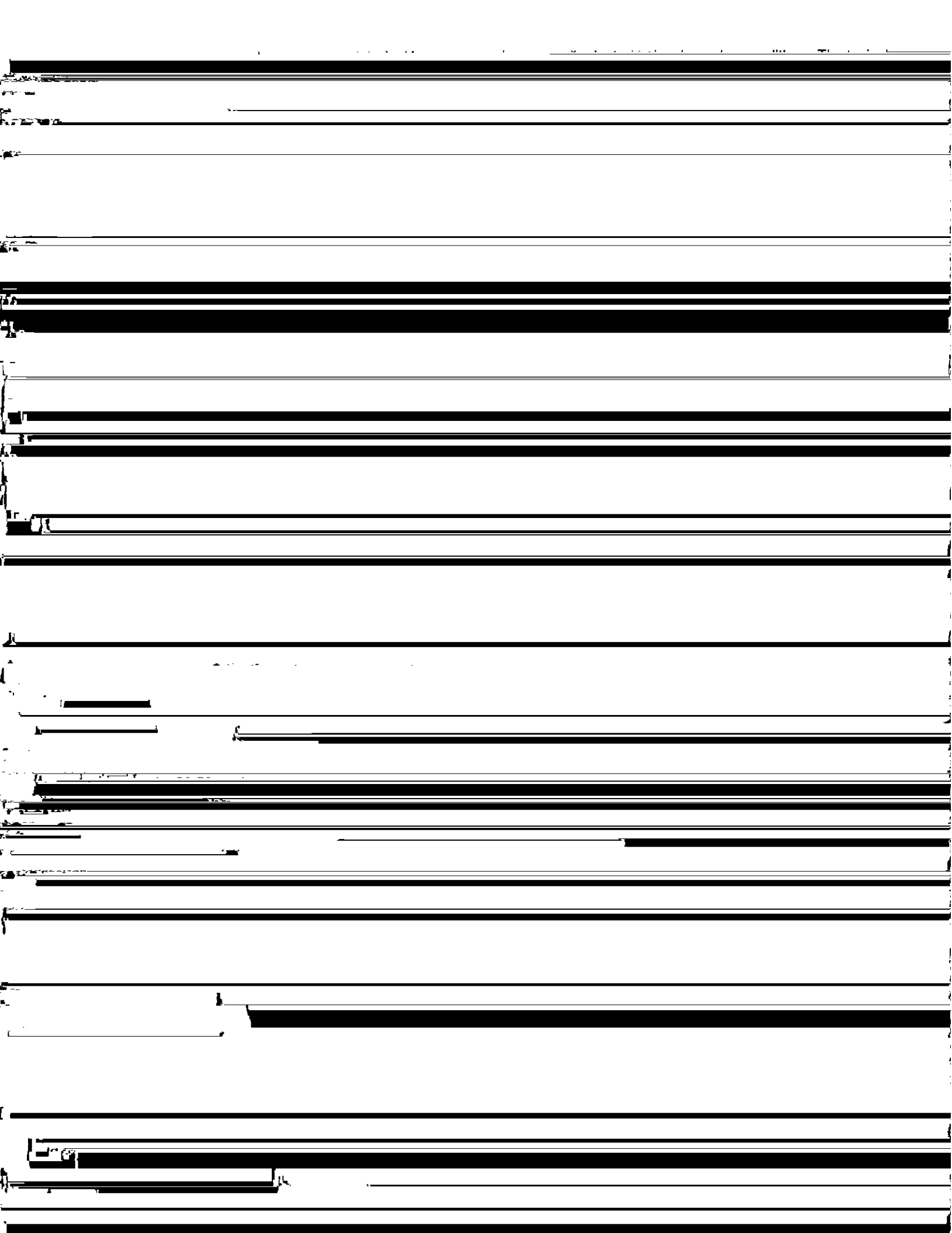
produce, and costs associated with infrastructure repair, [redacted] assigned to each cost (e.g., planting, pruning, removal, [redacted]

different functions (e.g., linear, sine, cosine). For parameters such as sidewalk repair, costs are small for young trees but increase relatively rapidly as tree roots grow large enough to

presented by McPherson (1994: Chapter 7, this report) are used in this study to directly estimate energy savings due to shading, temperature modification, and wind speed reduc-

Table 2.—Estimated tree planting and management costs

Cost category[a]	Tree location				
	Park	Yard	Street	Highway	Housing



windspeed. During winter, trees can conserve energy use for heating by lowering windspeeds and associated infiltration of cold outside air. However, even bare branches of deciduous

10 μm (PM10), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) are derived from the limited literature on this subject (Davidson and Wu 1989).

Table 4.—Assumptions for estimating implied value of air quality improvement

Item	PM10	O_3	NO_2	SO_2	CO
Deposition velocity (cm/sec)	0.60	0.45	0.40	0.66	0.0006
Control costs (dollars/ton)	1,307	490	4,412	1,634	920
Emission factors (lb/MWh)	0.14	0.03	2.10	6.81	0.63

[redacted]

Results and Discussion

Growth, Mortality, and Leaf Area

Growth curves for the typical trees are shown in Figure 2. The green ash in park, yard, and public housing sites display similar growth rates. Growth rates for trees along highways and residential streets are slower because less favorable growing conditions are assumed.

and 36 percent of new tree cover. Together, park and street-tree plantings contribute 56 percent of total future tree cover; trees planted along highways and on public housing sites account for the remaining 6 percent.

To place the magnitude of future tree cover in perspective it was compared to the amounts of current tree cover and total land area of Chicago. Based on our analysis of aerial photographs, trees and shrubs cover about 18,608 acres (7,530

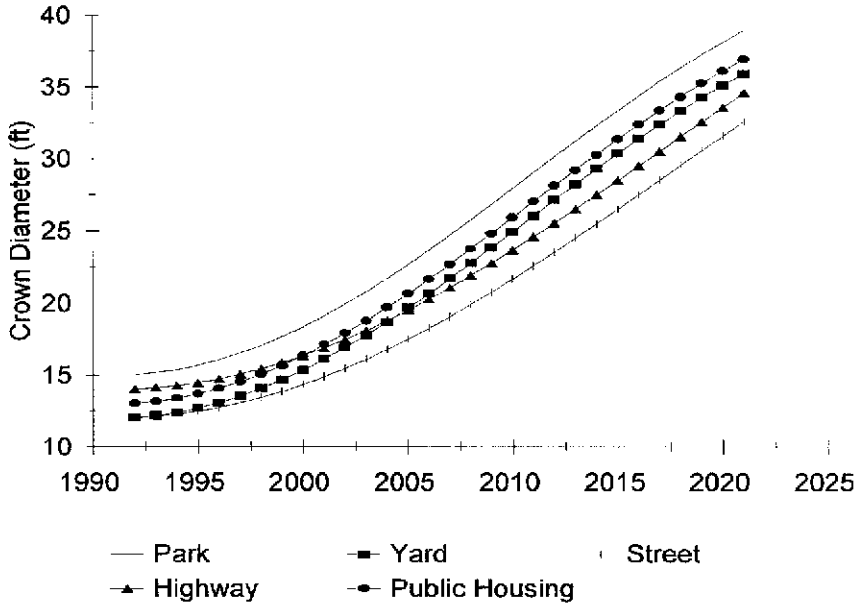


Figure 2. Growth curves modeled for the typical crown ash tree at each

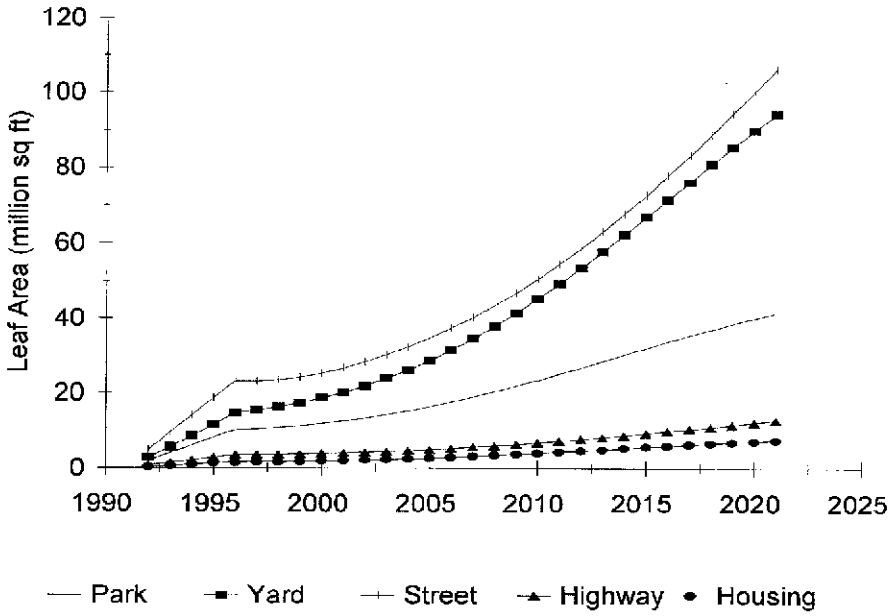


Figure 4. —Projected leaf-surface area for trees at each planting location.

discount rates, ranging from $638,153 at public housing sites with a 10 percent discount rate to $30.6 million for street trees with a 4 percent discount rate. At a 7 percent discount rate, the NPV of the entire planting (95,000 trees) is projected to be $38 million or about $402 per planted tree (Table 5). This means that on average the present value of the yield on

this 30 year analysis. Given this result, a 7 percent discount rate is assumed for findings that follow.

The estimated present value of total benefits and costs is $59 and $21 million, respectively (Tables 6 -7). Expenditures

Table 6 Projected present value of benefits for tree plantings in Chicago (30 year analysis, 7-percent discount rate, In

Table 7.—Projected present value of costs for tree plantings in Chicago (30 year analysis, 7-percent discount rate, in thousands of dollars)

Cost category	Tree location					
	Park	Yard	Street	Highway	House	Total

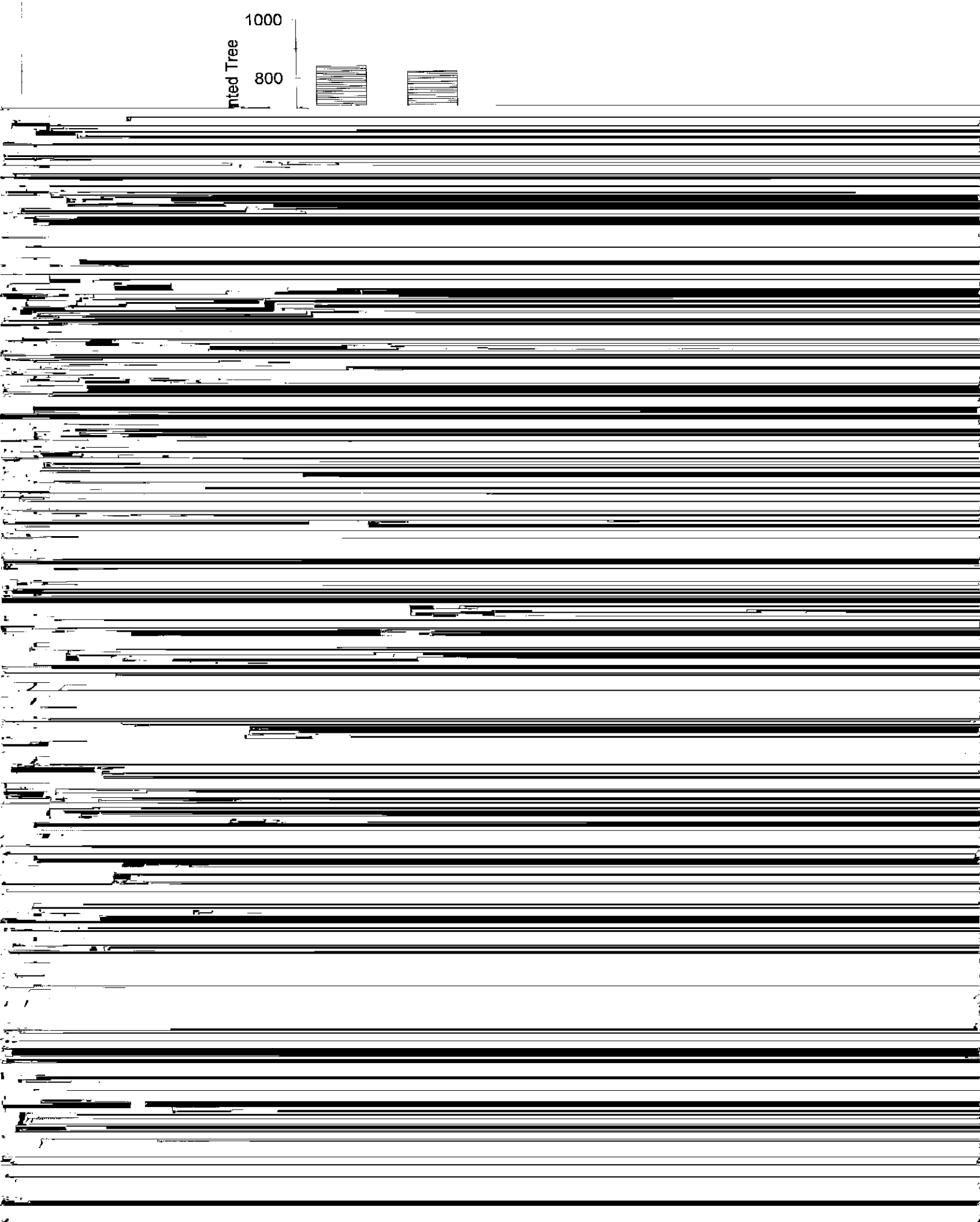

1000
800
nted Tree

Table 8.—Projected annual benefits produced 30 years after planting by the typical green ash tree at typical locations

Tree location

slightly longer at the 10 percent discount rate (11 to 18 years), and shorter at most locations with a 4-percent discount rate (9 to 13 years).

Early payback at public housing sites can be attributed to several factors. Trees are projected to add leaf area at a relatively rapid rate due to low initial mortality and fast growth compared to trees at other locations. These trees are rela-

maximize net benefits from investment in Chicago's urban forest. These concepts are not new and many currently are being applied in Chicago. Most of the following recommendations also have application in communities outside Chicago as well.

1. Select the right tree for each location. Given that planting and establishment costs represent a large fraction of total

initial estimates of the value of some of these benefits, as

Forestry and Range Experiment Station; California Division of

of the Chicago Urban Forest Climate Project. Gen. Tech. Rep. Richards, N. A. 1983. Reasonable guidelines for street tree di-

Chapter 9

the greatest need for increased tree cover. Finally, business opportunities for local entrepreneurs might be increased in a more serene and attractive retail environment associated with a healthy urban forest.

produced by yard trees in Chicago can be 3 1/2 times their cost. Trees provide benefits other than energy savings that should interest utilities, such as removal of air pollutants and atmospheric carbon dioxide. (Chapters 5 and 12, this

[redacted]

Appendix A

Supplemental Tables for Chapter 2

Table 2. —Scientific names of tree species or genera

Common name	Scientific name	Common name	Scientific name

Table 3. —Tree composition in Chicano based on number and percentage of trees, and species dominance based on percentage

Table 3.—continued

Table 4. —Tree composition in suburban Cook County based on number and percentage of trees, and species dominance based on percentage of total leaf-surface area

Species	Tree population				Species dominance	
	Number	SE	Percent	Rank	Percent	Rank
Buckthorn	4,601,600	1,430,800	14.5	1	2.9	12
Green/white ash	3,181,900	745,300	10.0	2	9.6	3
Prunus spp.	2,619,300	660,100	8.2	3	4.0	9
American elm	2,126,400	741,700	6.7	4	9.8	2
Boxelder	1,757,800	447,200	5.5	5	4.6	6
Hawthorn	1,715,600	440,100	5.4	6	3.6	10
Alder	1,337,200	1,130,400	4.2	7	0.5	33
Silver maple	1,220,200	287,900	3.8	8	10.9	1
Red/black oak	1,044,100	328,200	3.3	9	5.2	4
Poplar (other)	841,400	527,800	2.6	10	1.3	21
Black locust	831,000	618,200	2.6	11	0.4	38
Slippery elm	732,900	582,800	2.3	12	1.2	23
Cottonwood	715,700	352,600	2.3	13	3.0	11

Table 4. —continued

Table 5. —continued

	Tree population								Species dominance			

Table 6. —Tree composition in study area based on number and percentage of trees, and species dominance based on percentage of total leaf-surface area

Table 6. —continued

Species	Tree population				Species dominance	
	Number	SE	Percent	Rank	Percent	Rank

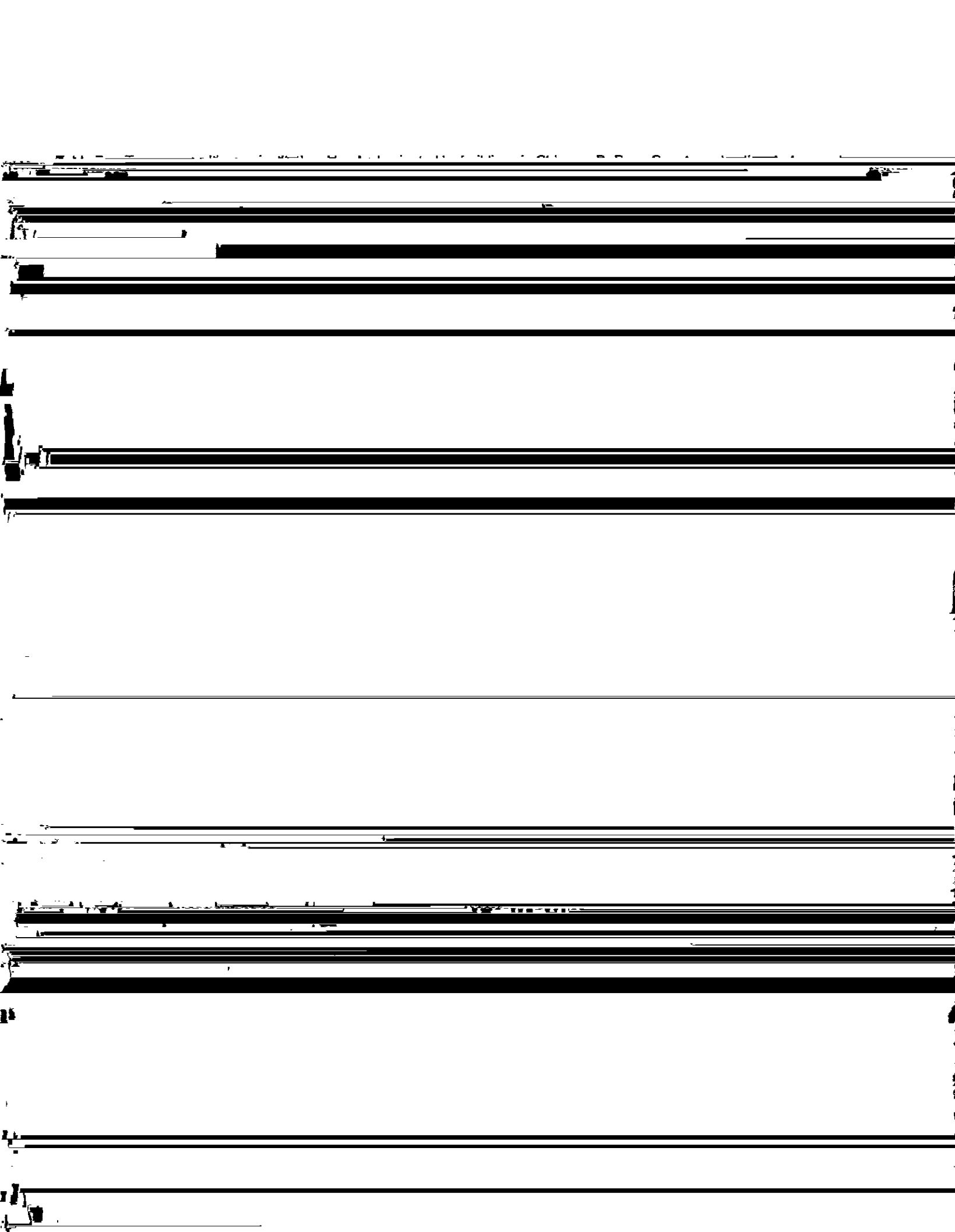


Table 8. —Tree composition on transportational lands in Chicago, DuPage County and entire study area (no trees were sampled on transportational lands in suburban Cook County) based on number and percentage of trees, and species dominance based

Table 10. —*Tree composition on multifamily residential lands in Chicago, suburban Cook County, DuPage County, and entire study area based on number and percentage of trees, and species dominance based on percent of total leaf-surface area in each sector*

Species	Tree population				Species dominance	
	Number	SE	Percent	Rank	Percent	Rank
CHICAGO						
Boxelder	68,700	68,700	34.5	1	23.3	3
Cottonwood	34,400	34,400	17.2	2	34.9	1
Green/white ash	34,400	34,400	17.2	2	7.7	5
Honeylocust	20,600	20,600	10.3	4	8.5	4
Crabapple	20,600	20,600	10.3	4	25.0	2
Norway maple	20,600	20,600	10.3	4	0.7	6
SUBURBAN COOK COUNTY						
Honeylocust	64,500	33,400	27.8	1	20.5	2
Boxelder	51,600	51,600	22.2	2	10.4	5

Table 11. —Tree composition on commercial/industrial lands in Chicago, suburban Cook County, DuPage County, and entire study area based on number and percentage of trees, and species dominance based on percent of total leaf-surface area in each sector

Species	Tree population				Species dominance	
	Number	SE	Percent	Rank	Percent	Rank
CHICAGO						
Cottonwood	16,700	16,700	50.0	1	84.1	1

Table 12. —Tree composition on vacant lands in Chicago, suburban Cook County, DuPage County, and entire study area

Table 12. —continued

Species	Tree population				Species dominance	
	Number	SE	Percent	Rank	Percent	Rank

Table 13. —Tree composition on residential lands in Chicago, suburban Cook County, DuPage County, and entire study area based on top 20 species in number and percentage of trees, and species dominance based on percent of total leaf-surface area in each sector

Species	Tree population				Species dominance	
	Number	SE	Percent	Rank	Percent	Rank
CHICAGO						
Green/white ash	116,100	43,600	9.2	1	11.8	2
Mulberry	112,000	34,400	8.9	2	2.8	12
Honeylocust	108,400	29,800	8.6	3	4.6	7
Norway maple	96,800	22,800	7.7	4	12.7	1
Silver maple	78,000	18,400	6.2	5	8.0	5
Prunus spp.	76,700	25,700	6.1	6	1.6	15
Blue spruce	58,900	25,200	4.7	7	3.2	10
Ailanthus	55,200	20,900	4.4	8	8.4	4
American elm	45,200	23,900	3.6	9	1.5	17
Swamp white oak	42,300	33,900	3.4	10	3.6	9
Honeysuckle	38,700	25,300	3.1	11	1.0	22
Ash (other)	34,800	21,300	2.8	12	2.7	13
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 13. —continued

	Tree population	Species dominance

Table 14. —Tree composition on institutional lands dominated by vegetation in Chicago, suburban Cook County, DuPage County, and entire study area based on top 20 species in number and percentage of trees, and species dominance based on percent of total leaf-surface area in each sector

Species	Tree population				Species dominance	
	Number	SE	Percent	Rank	Percent	Rank
CHICAGO						
Cottonwood	292,300	284,500	15.8	1	9.2	5
American elm	230,300	164,000	12.5	2	11.9	1
Hawthorn	230,300	104,100	12.5	2	4.8	9
Buckthorn	214,700	100,200	11.6	4	2.8	11
Green/white ash	195,400	67,700	10.6	5	9.6	4
Prunus spp.	191,400	99,900	10.4	6	5.5	8
Boxelder	82,800	50,800	4.5	7	2.5	12
Hackberry	62,100	33,200	3.4	8	8.0	7
White oak	38,800	28,700	2.1	9	11.6	2
Silver maple	33,600	16,900	1.8	10	10.0	3
Red/black oak	28,500	26,000	1.5	11	8.6	6
Siberian elm	25,900	25,900	1.4	12	1.1	16
Crabapple	23,300	12,700	1.3	13	0.9	18
Shagbark hickory	20,700	14,500	1.1	14	0.5	24
Ash (other)	20,700	15,000	1.1	14	0.2	26
Hickory	20,700	8,600	1.1	14	0.7	21
Honeylocust	19,400	10,500	1.1	17	0.8	19
Basswood	18,100	10,500	1.0	18	1.5	15
Mulberry	15,500	9,500	0.8	19	2.8	10
Other	12,900	7,600	0.7	20	0.1	31
Linden	7,800	4,400	0.4	22	1.0	17
Norway maple	5,200	3,600	0.3	24	1.6	14
Sugar maple	5,200	3,600	0.3	24	0.7	20
Swamp white oak	5,200	3,600	0.3	24	1.8	13
SUBURBAN COOK COUNTY						
Buckthorn	3,999,200	1,423,000	20.0	1	5.3	7
Prunus spp.	1,836,800	571,400	9.2	2	4.9	8
Green/white ash	1,737,200	443,300	8.7	3	9.6	3
Hawthorn	1,655,700	439,400	8.3	4	7.2	4

Table 14. —continued

Species	Tree population				Species dominance	
	Number	SE	Percent	Rank	Percent	Rank
DUPAGE COUNTY						
Prunus spp.	566,900	233,500	17.9	1	8.1	4
Boxelder	532,900	265,600	16.8	2	9.8	2
Hawthorn	430,900	159,400	13.6	3	2.9	11
Buckthorn	349,600	162,500	11.1	4	3.1	10
Jack pine	226,800	169,700	7.2	5	0.8	15
American elm	219,200	115,600	6.9	6	5.7	6
Cottonwood	207,900	204,100	6.6	7	4.1	8
Sumac	83,200	75,900	2.6	8	0.1	23
Green/white ash	79,400	36,900	2.5	9	3.3	9
White oak	68,000	28,700	2.2	10	34.1	1

Table 15. —Distribution of tree diameters in Chicago, suburban Cook County, DuPage County, and entire study area, by land use

Table 17. Distribution of ground surface materials in Chicago, suburban Cook County, DuPage County, and entire study area

Table 17. —continued

Table 17. —continued

[redacted]

Appendix B

Trees for Energy-Efficient Landscapes in Chicago

Trees for energy-efficient landscapes in the Chicago area .

Tree species		Solar friendly	Form	Growth rate	Longevity
Small (< 20 feet)					
Dogwood, Corneliancherry	*Cornus mas*	NA	R	S	I
Filbert, European	*Corylus avellana*	NA	S	M	I
Hawthorn	*Crataegus spp.*				
[illegible]	[illegible]	Y	[illegible]	M	I

Trees for energy-efficient landscapes in the Chicago area (continued).

Tree species		Solar friendly	Form	Growth rate	Longevity
Large (>40 feet)					
Maple	*Acer spp.*				
Balck	*A. nigrum*	Y	O	M	L
Norway	*A. platanoides*	Y	R	M	L
Oak	*Quercus spp.*				
Bur	*Q. macrocarpa*	N	B	M	L
English	*Q. robur*	N	R	M	L
Pin or Swamp	*Q. palustris*	N	P	R	L
Red	*Q. rubra*	N	R	M	L
Sawtooth	*Q. acutissima*	NA	P	M	L

Appendix C

Standard Reports for Brick Base Case Buildings

Chicago, Illinois Tree Shade Only

Nat. Gas ($/therm): 0.5

Annual Heating and Cooling Savings From Base Case

Due to Shade from A Large Deciduous Tree - 22 ft Away

Chicago, Illinois Energy Analysis

Nat. Gas ($/therm): 0.5

1 [redacted]

Chicago, Illinois **Tree Shade Only**

1 Story, Brick Construction - 2,125 sq ft Residence (Front Facing North)

Nat. Gas ($/therm): 0.5
Electricity ($/kWh): 0.12

Source Energy Use (kBtu/ sq ft) Tree Height and Distance from Building

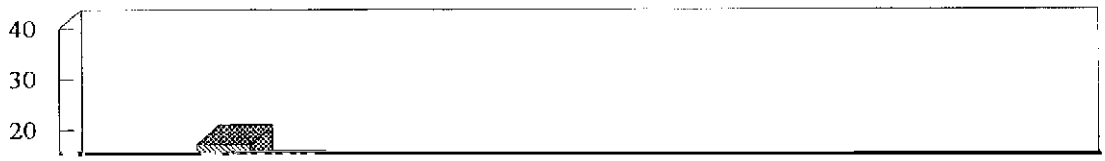
	Small (24 ft)	Med. (36 ft)	Large (50 ft)	Large (50 ft)
East Tree				

% Saved from Base Case

	Small (24 ft)	Med. (36 ft)	Large (50 ft)	Large (50 ft)
East Tree				

Annual Heating and Cooling Savings From Base Case

Due to Shade from A Large Deciduous Tree - 22 ft Away



Annual Heating and Cooling Savings From Base Case

Due to Shade from A Large Deciduous Tree - 22 ft Away

Chicago, Illinois

Energy Analysis

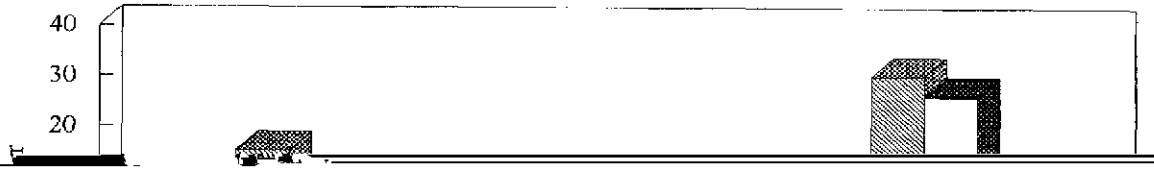
Nat. Gas ($/therm): 0.5

Chicago, Illinois Tree Shade Only

Nat. Gas ($/therm): 0.5

Annual Heating and Cooling Savings From Base Case

Due to Shade from A Large Deciduous Tree - 22 ft Away



Chicago, Illinois **Energy Analysis**

2 Story, Brick Construction - 3,562 sq ft Residence (Front Facing South)

Nat. Gas	($/therm):	0.5
Electricity	($/kWh):	0.12

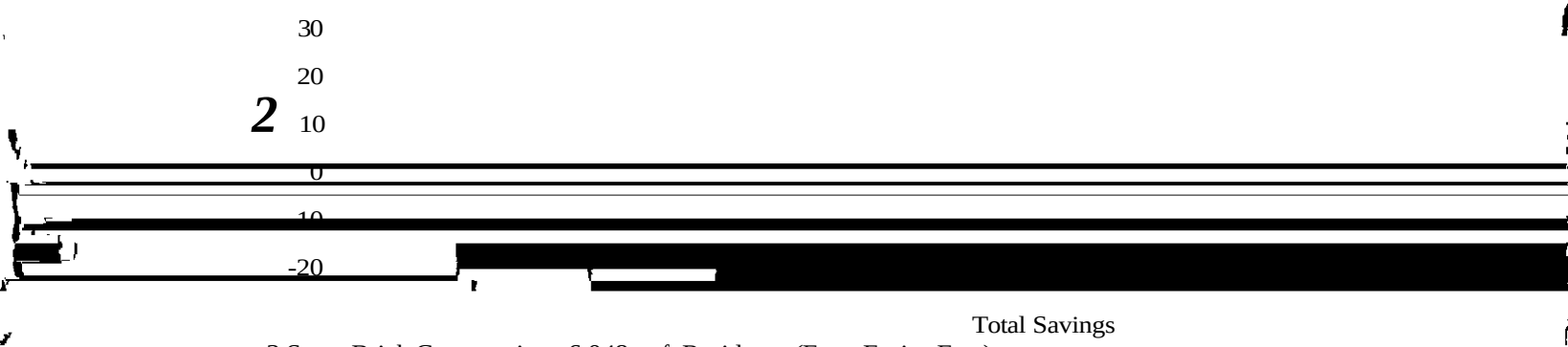
Chicago, Illinois **Tree Shade Only**

3 Story, Brick Construction - 6,048 sq ft Residence (Front Facing East)

Nat. Gas ($/therm): 0.5
Electricity ($/kWh): 0.12

Annual Heating and Cooling Savings From Base Case

&om A Large Deciduous Tree - 22 ft Away



Total Savings

3 Story, Brick Construction - 6,048 sq ft Residence (Front Facing East)

Annual Percentage Cooling Savings From Base Case

Due to Shade from One Deciduous Tree

East South West

Chicago, Illinois Energy Analysis

	Nat. Gas	($/therm):	0.5
3 Story, Brick Construction - 6,048 sq ft Residence (Front Facing East)	Electricity	($/kWh):	0.12
Deciduous tree, 36-ft tall and 24-ft crown spread, 22 ft away from building.	Avoided Peak Electricity	($/Avoid kW):	65

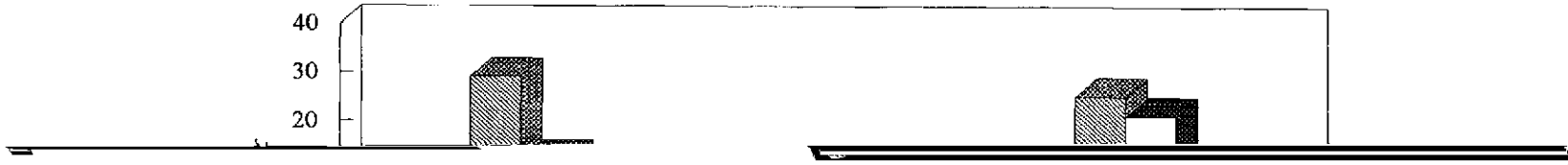
Chicago, Illinois Tree Shade Only

2 Story Brick Construction - 6,048 sq ft Residence (Front Facing South)

Nat. Gas ($/therm): 0.5

Annual Heating and Cooling Savings From Base Case

Due to Shade from A Large Deciduous Tree - 22 ft Away



Chicago, Illinois **Energy Analysis**

3 Story, Brick Construction - 6,048 sq ft Residence (Front Facing South)
Deciduous tree, 36-ft tall and 24-ft crown spread, 22-ft away from building

Nat. Gas	($/therm):	0.5
Electricity	($/kWh):	0.12
Avoided Peak Electricity	($/Avoid kW):	65

Annual Energy Use	Unshaded Base Case	Shade East	Shade South	Shade West	ET Cooling	Reduced Wind	East Shade + ET + Wind	South Shade + ET + Wind	West Shade + ET + Win

Appendix D

Chicago, Illinois Tree Shade Only

1 Story - Wood Frame Residence (1,500 sq ft)

Space Conditioning Source Energy Use (kBtu/ sq ft)

Nat. Gas	($/therm):	0.5					
Electricity	($/kWh):	0.12					
			% Saved from Base Case				
Year 5	Base Case	1 Tree	2 Tree	3 Tree	**Year 5**	1 Tree	2 Tree	3 Tree

[redacted]

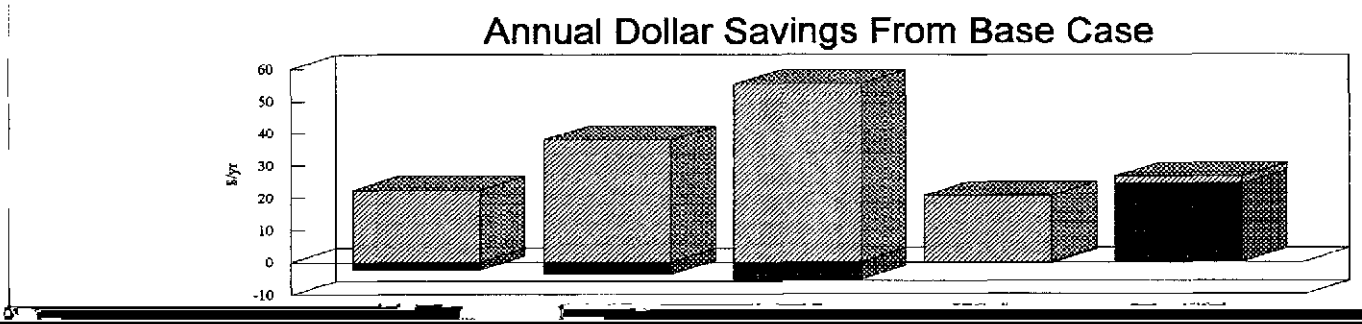
Annual Dollar Savings From Base Case

Chicago, Illinois
1 Story - Wood Frame
Year 20 - 25 ft trees

Energy Analysis
1500 sq ft

Nat. Gas	($/therm):	0.5
Electricity	($/kWh):	0.12
Avoided Peak Electricity	($/Avoid kW):	65

Annual	Unshaded	Shade	ET	Reduced	3 Tree+ET	Avg. Savings


Annual Dollar Savings From Base Case
60
50
40
30
20
10
0
-10
$/yr

Chicago, Illinois **Tree Shade Only**

2 Story - Wood Frame Residence (1,761 sq ft)

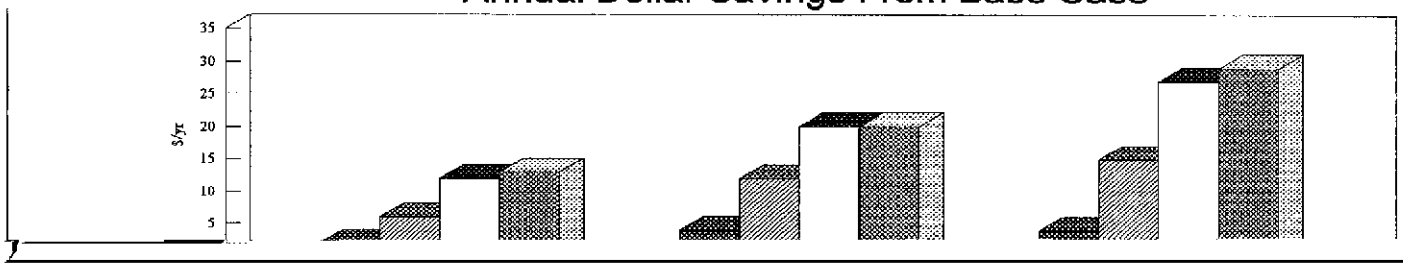
Nat. Gas	($/therm):	0.5
Electricity	($/kWh):	0.12

Space Conditioning Source Energy Use (kBtu/ sq ft)

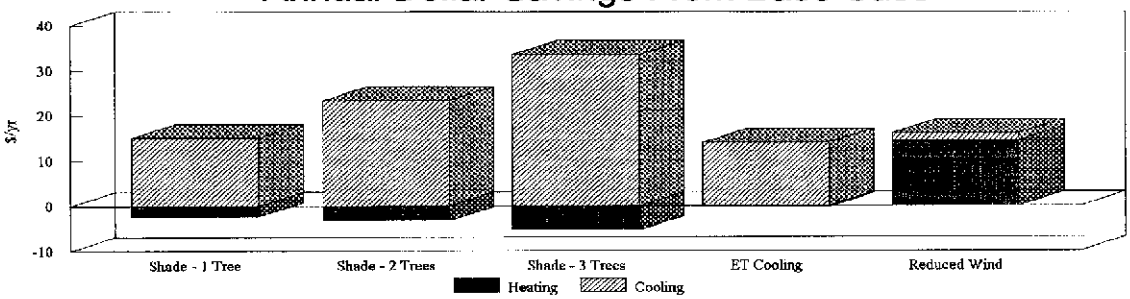
Year 5	Base Case	1 Tree	2 Tree	3 Tree
Total Heating Use	42.24	42.37	42.39	42.44

Year 5	% Saved from Base Case 1 Tree	2 Tree	3 Tree
	-0.29	-0.36	-0.46

Annual Dollar Savings From Base Case



Annual Dollar Savings From Base Case



1,761 sf, 2 story wood frame home in Chicago

Annual Dollar Savings From Base Case

Chicago, Illinois Energy Analysis Nat. Gas ($/therm): 0.6

Appendix E

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ECONOMIC ANALYSIS OF SHADE TREE PROGRAM IN CHICAGO, ILLINOIS

ECONOMIC ANALYSIS OF SHADE TREE PROGRAM IN CHICAGO, ILLINOIS

Headquarters of the Northeastern Forest Experiment Station is in Radnor, Pennsylvania.
Field laboratories are maintained at: