

Appendixes

Retrofit Options for Thirteen Building Types in the St. Louis Climate Zone

This is the first of four appendixes (A through D) which present backup information on building retrofit. This appendix has individual retrofit lists for each of 13 distinctly different building types. The analysis of retrofit costs and savings has been done for the St. Louis climate. The list for each building shows the estimated costs of each retrofit option for that building type. Savings are presented in two forms:

1. *Million Btu per year regardless of energy source.*
In this estimate, Btu savings of electricity are counted equally with Btu savings of fuel.
2. *Million Btu per year, "fuel-adjusted."* In this estimate Btu savings of electricity are increased by multiplying by a factor of 2.46. The factor adjusts for the higher cost of electricity and is derived from the difference in cost per million Btus between fuel or \$1.00 per gallon (or \$7.14/MMBtu) and electricity at \$0.06/kWh (or \$17.58/MMBtu).

Finally the retrofit lists show the cost per million Btu saved of fuel-adjusted energy savings. The payback can be calculated from cost per million Btu by using

box B in chapter 3 as a guide. For fuel at \$1.00 per gallon, low capital cost retrofits which cost less than \$14.00 per annual million Btu saved, will payback in less than 2 years. Moderate capital cost retrofits will payback in 2 to 7 years and cost \$14 to \$49 per annual million Btu saved. In this appendix, as in chapter 3, low capital cost refers to low capital cost compared to savings. Some retrofits such as lighting retrofits can require substantial capital in an absolute sense even though they are low capital cost compared to savings.

High capital cost retrofits will payback in 7 to 15 years and will cost \$49 to \$105 per annual million Btu saved.

Users of this appendix should be aware that costs and savings presented here are estimates only. They are useful for order-of-magnitude comparisons among retrofit options but should not be relied on for subtle distinctions among retrofits. For any particular building estimated costs and savings could vary substantially from those presented here.

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btu [≡] (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
	<u>Low Capital Cost</u>				
E-1	Roof Insulation	565	32	39	14
E-2	Wall Insulation	646	83	107	6
E-5	Weatherstripping	110	7	8	14
H-8	Setback Thermostats	135	24	24	6
H-2C	Two Speed Fan	110	14	31	4
D-2	Flow Controls	19	14	14	1
D-3	Insulate Hot Water Storage	30	7	7	4
	<u>Moderate Capital Cost</u>				
E-3	Storm Windows	990	29	35	28
H-3	Vent Damper	225	9	9	25
H-18	Insulate Ducts	1230	23	29	42
D-4	Hot Water Vent Damper	150	6	6	25
	<u>High Capital Cost</u>				
E-6	Window Insulation	90	5	5	61

Table A2: Retrofit Options for a Small House
With Frame Walls, Central Water Heating
System and Window Air Conditioners

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
<u>Low Capital Cost</u>					
E-1	Roof Insulation	565	33	42	13
E-2	Wall Insulation	646	83	107	6
E-5	Weatherstripping	110	7	9	12
H-7	Modulating Aquastat	250	26	26	10
H-8	Setback Thermostats	135	24	24	6
D-2	Flow Controls	19	14	14	1
D-3	Insulate Hot Water Storage	30	7	7	4
<u>Moderate Capital Cost</u>					
E-3	Storm Windows	990	31	39	25
H-1	Replace Burner	880	19	19	46
H-3	Vent Damper	225	9	9	25
H-4	Stack Heat Reclaimer	875	24	24	36
H-1C	Replace Room Air Conditioners	890	22	54	16
D-4	Hot Water Vent Damper	150	6	6	25
<u>High Capital Cost</u>					
E-6	Window Insulation	90	5	5	61

Table A3: Retrofit Options for a Small House
Frame Walls Decentralized System

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
Low Capital Cost				
E-1	Roof Insulation	565	24	9
E-2	Wall Insulation	646	88	3
E-5	Weatherstripping	110	5	9
D-2	Flow Controls	19	14	0.5
D-3	Insulate Hot Water Storage	30	8	1.5
D-4	Hot Water Vent Damper	150	6	10
Moderate Capital Cost				
E-3	Storm Windows	99 ^o	22	18
E-6	Window Insulation	91 ^o	90	46
H-10	Replace Room Air Conditioners	89 ^o	22	16
D-5	Hot Water Heat Pump	98 ^o	19	21
High Capital Cost				
H-5	Install Heat Pumps	5520	39	58
			96	

Table A4: Retrofit Options for a Small Masonry Rowhouse with Central Air Heating and Cooling

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
<u>Low Capital Cost</u>					
E-1	Roof Insulation	690	43	52	13
E-5	Weatherstripping	60	6	7	9
H-8	Setback Thermostats	135	15	15	5
H-20	2 Speed Fans	80	7	15	5
D-2	Flow Controls	19	14	14	1
D-3	Insulate Hot Water Storage	30	7	7	4
<u>Moderate Capital Cost</u>					
E-3	Storm Windows	450	17	21	21
H-3	Vent Damper	225	6	6	38
D-4	Hot Water Vent Damper	150	6	6	25
<u>High Capital Cost</u>					
E-2	Wall Insulation	4664	34	41	114
E-6	Window Insulation	420	8	8	53
H-18	Insulate Ducts	810	12	15	54

Table A5: Retrofit Options for a Small Masonry Rowhouse with Central Water Heating System and Window Air Conditioners

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
<u>Low Capital Cost</u>					
E-5	Weatherstripping	60	6	8	8
H-8	Setback Thermostats	135	15	15	9
D-2	Flow Controls	19	14	14	1
D-3	Insulate Hot Water Storage	30	7	7	4
<u>Moderate Capital Cost</u>					
E-1	Roof Insulation	690	37	47	15
E-3	Storm Windows	450	17	22	20
H-3	Vent Damper	225	6	6	38
H-7	Modulating Aquastat	250	13	13	19
H-10	Replace Room Air Conditioners	890	13	32	28
D-4	Hot Water Vent Damper	150	6	6	25
<u>High Capital Cost</u>					
E-2	Wall Insulation	4664	42	53	88
E-6	Window Insulation	420	8	8	53
H-4	Stack Heat Reclaimer	800	16	16	50

Table A6: Retrofit Options for a Small Masonry Rowhouse with a Decentralized Heating and Cooling System

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
E-1	Roof Insulation	690	24	59	12
E-5	Weatherstripping	60	4	10	6
H-8	Setback Thermostats	135	9	22	6
D-2	Flow Controls	19	14	34	0.5
D-3	Insulate Storage	30	8	20	1.5
D-4	Hot Water Vents Damper	150	6	15	10
<u>Moderate Capital Cost</u>					
E-3	Storm Windows	450	11	27	17
E-6	Window Insulation	420	4	10	42
H-10	Replace Window Air Conditioners	890	13	32	28
<u>High Capital Cost</u>					
E-2	Wall Insulation	4664	23	57	82
H-5	Heat Pumps	3680	19	47	78

Table A7: Retrofit Options for a Large Multi-Family
Buildings with Masonry Walls and Central
Air Heating and Cooling

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit Per Ft ²	Retrofit Cost in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
E-9	Roof Spray	\$3750	\$.03	408	1004
H-3	Vent Damper	1600	.02	369	369
H-8	Setback Thermostats	4320	.04	579	579
H-12	Vary chilled Water Temperature	3200	.03	180	443
H-20	2 Speed Motors	975	.01	322	725
D-2	Flow Controls	1550	.02	1244	1244
D-4	Hot Water Vent Damper	225	.01	340	340
L-2	Hybrid Lamps	9310	.09	718	2869
<u>Moderate Capital Cost</u>					
E-5	Weatherstripping	520	.05	93	112
E-6	Window Insulation	25,200	.25	631	631
H-18	Insulate Ducts	25,650	.25	484	613
<u>High Capital Cost</u>					
E-1	Roof Insulation	30,000	.30	476	576
E-2	Wall Insulation	216,240	2.16	689	2042
					52
					105

Table A8: Retrofit Options for a Large Multi-family Building with Masonry Walls, Central Water Heating System and Window Air Conditioners

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit	Retro·fit Cost Per Ft ²	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
<u>Low Capital Cost</u>						
E-9	Roof Spray	\$3750	\$.03	605	3	
H-1	Replace Burner	4300	.04	664	664	6
H-3	Vent Damper	1600	.02	369	369	4
H-4	Stack Heat Reclaim ^a	3200	.03	439	439	7
H-7	Modulating Aquastat ^a	535	.01	609	609	1
H-8	Setback Thermostat ^a	4320	.04	609	609	7
D-2	Flow Controls	1550	.02	1244	1244	1
D-4	Hot Water Ven ^a Damper	225	.01	340	340	0.5
L-2	Hybrid Lamps	9310	.09	190	1569	6
<u>Moderate Capital Cost</u>						
E-1	Roof Insulation	30,000	.30	503	637	47
E-5	Weatherstripping	5520	.05	97	123	45
E-6	Window Insulation	25,200	.25	631	631	40
H-6	Boiler Turbulators	6720	.07	155	155	43
H-10	Replace Room Air Conditioners	39,520	.40	619	1701	23
<u>High Capital Cost</u>						
E-2	Wall Insulation	216,240	2.16	787	2262	96

Table A9: Retrofit Options for a Large Multi-Family Building with
Masonry Walls and Decentralized Heating and Cooling System

Retrofit Number	Name of Retrofit	Total Cost of Retrofit	Retrofit Cost Per Ft ²	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
<u>Low Capital Cost</u>						
E-9	Roof Spray	\$3750	\$.03	605	1489	3
H-8	Setback Thermostats	4320	.04	302	743	6
D-2	Flow Controls	1550	.02	1244	3061	0.5
D-3	Insulate Hot Water Storage	3350	.03	1404	3455	1
A-4	Hot Water Vent Damper	225	.01	340	837	0.5
D-5	Hot Water Heat Pump	13,960	.14	1622	3992	3
L-2	Hybrid Lamps	9310	.09	594	1462	6
<u>Moderate Capital Cost</u>						
E-1	Roof Insulation	30,000	.30	296	728	41
E-5	Weatherstripping	5520	.05	57	140	39
E-6	Window Insulation	25,200	.25	329	810	31
H-5	Heat Pumps	08,000	1.08	878	2161	50
H-10	Replace Room Air Conditioners	39,520	.39	619	1523	26
<u>High Capital Costs</u>						
E-2	Wall Insulation	216,240	2.16	081	2660	81

Table A10: Retrofit Options for a Large Commercial Building with Clad Walls and Central Air Heating and Cooling

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit Per Ft ²	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
Low Capital Cost					
E-9	Roof Spray	\$3750	408	1003	4
H-8	Setback Thermostats	4320	535	535	8
H-9	Enthalpy Control	3000	3010	7408	0.5
H-12	Vary Chilled Water Temperature	3200	3010	7408	0.5
H-14	Reduce Ventilation	910	2752	3328	0.5
H-20	2 Speed Motors	1185	172	410	3
D-2	Flow Controls	32	46	46	1
D-3	Insulate Hot Water Storage	590	37	44	13
D-4	Hot Water Vent Damper	200	180	180	1
L-2	Hybrid Lamps	76,390	5155	20,500	4
L-4	Hi-Effic Fluorescent	12,750	417	1657	8
Moderate Capital Cost					
E-4	Double Glazing	64,80°	1300	1572	41
E-5	Weatherstripping	600°	131	158	38
E-6	Window Insulation	37,80°	847	847	45
E-8	Shading Devices	25,38°	1300	1810	24
H-3	Vent Damper	200°	135	135	15
H-4	Stack Heat Reclaimer	490°	331	331	15
H-16	Water Cooled Condenser	32,30°	461	1135	28
H-18	Insulate Ducts	44,60°	1368	2347	19
L-3	Task Lighting	68,00°	954	2616	26
High Capital Cost					
E-1	Roof Insulation	30,00°	432	522	57
E-2	Wall Insulation	133,56°	1095	1324	101

Table All: Retrofit Options for a Large Commercial Building with
Clad Walls, Central Water Heating System and Window
Air Conditioners

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit Per Ft ²	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
<u>Low Capital Cost</u>					
E-8	Shading Devices	25,380	1382	1924	13
E-9	Roof Spray	3750	605	1489	3
H-7	Modulating Aquastat	535	291	291	2
H-8	Setback thermostats	4320	535	535	8
D-2	Flow Controls	32	46	46	0.5
D-4	Hot Water Vent Damper	200	180	180	1
L-2	Hybrid Lamps	76,390	1977	12,678	6
L-4	Hi-Effic. Fluorescent	12,750	1025	12	
<u>Moderate Capital Cost</u>					
E-4	Double Glazing	64,000	1382	1749	37
E-5	Weatherstripping	6000	135	171	35
E-6	Window Insulation	37,000	847	847	45
x-1	Replace Burner	5300	285	285	18
x-4	Stack Heat Reclaimer	4000	331	331	15
x-10	Replace Room Air Conditioners	75,870	695	1710	44
<u>High Capital Cost</u>					
E-1	Roof Insulation	30,000	459	581	52
E-2	Wall Insulation	133,560	1161	1470	91
L-3	Task Lighting	68,000	366	1168	58

Table A12: Retrofit Options for a large Commercial Building with Clad Walls and Decentralized Heating and Cooling

Retrofit Number	Name of Retrofit	Total Retrofit		Annual		Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
		Cost Of Retrofit Per Ft ²	Savings in Million Btus (not fuel-adjusted)	Savings in Million Btus (fuel-adjusted)	Savings in Million Btus (fuel-adjusted)	
<u>Low Capital Cost</u>						
E-8	Shading Devices	25,380	.25	811	1996	13
E-9	Roof Spray	3750	.04	605	1489	3
H-8	Setback Thermostats	4320	.04	312	768	6
D-2	Flow Controls	32	.01	46	113	0.5
D-3	Insulate Hot Water Storage	590	.01	22	54	11
L-2	Hybrid Lamps	76,390	.6	4209	10,358	7
<u>Moderate Capital Cost</u>						
E-1	Roof Insulation	30,000	.30	296	728	41
E-4	Double Glazing	64,800	.65	911	2242	29
E-5	Weatherstripping	6000	.06	84	207	29
E-6	Window Insulation	37,800	.38	494	1216	31
H-10	Replace Room Air Conditioners	75,870	.76	695	1710	44
L-3	Task Lighting	68,000	.68	779	1917	35
L-4	Hi-Effic. Fluorescent	12,750	.13	341	839	15
<u>High Capital Cost</u>						
E-2	Wall Insulation	133,560	1.34	763	1878	71

Table A13: Retrofit Options for a Large Commercial Building with Clad Walls and Complex Reheat Heating and Cooling System

Retrofit Number	Name of Retrofit	Total Cost Of Retrofit Per Ft ²	Annual Savings in Million Btus (not fuel-adjusted)	Annual Savings in Million Btus (fuel-adjusted)	Total Retrofit Cost Per Annual Million Btu Saved (fuel adjusted)
<u>Low Capital Cost</u>					
E-9	Roof Spray	3750	412	1014	4
H-1	Replace Burner	5000	2117	2117	2
H-3	Vent Damper	2000	774	774	3
H-4	Stack Heat Reclaimer	4900	2835	2835	2
H-6	Boiler Turbulators	8850	856	856	10
H-8	Setback Thermostats	4320	433	433	10
H-13	Convert Reheat to Variable Air Volume	13,760	3674	4496	3
D-2	Flow Controls	32	46	46	0.5
D-4	Hot Water Vent Damper	200	180	180	1
L-2	Hybrid Lamps	76,390	2413	12,259	6
L-3	Hi-Effic. Fluorescent	12,750	195	991	13
<u>Moderate Capital Cost</u>					
E-4	Double Glazing	64,800	327	409	73
E-5	Weatherstripping	6000	108	135	44
E-6	Window Insulation	37,800	847	1059	36
E-8	Shading Devices	25,380	1082	1506	17
H-18	Insulate Ducts	44,600	1151	1974	17
D-3	Insulate Hot Water Storage	590	30	35	17
<u>High Capital Cost</u>					
E-1	Roof Insulation	30,000	327	409	73
H-16	Water Cooled Condenser	32,300	153	376	86
L-3	Task Lighting	68,000	447	1315	52