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P93. RATIO OF INCOME IN 1999 TO POVERTY LEVEL BY HOUSEHOLD TYPE [19] - Universe: Households
Data Set: Census 2000 Summary File 3 (SF 3) - Sample Data

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	Missouri	Adair County, Missouri	Andrew County, Missouri	Atchison County, Missouri	Audrain County, Missouri	Barry County, Missouri	Barton County, Missouri	Bates County, Missouri	Benton County, Missouri	Bollinger County, Missouri
Total:	2,197,214	9,645	6,249	2,736	9,872	13,371	4,908	6,521	7,444	4,589
Under 1.50: 20.86%	458,416	3,451	1,123	658	2,262	3,911	1,454	1,769	2,157	1,407
Family households:	234,777	1,119	585	340	1,280	2,348	832	987	1,132	846
Married-couple family	112,063	659	349	229	741	1,537	573	628	740	585
Other family:	122,714	460	236	111	539	811	259	359	392	261
Male householder, no wife present	21,346	103	43	22	94	259	47	86	101	39
Female householder, no husband present	101,368	357	193	89	445	552	212	273	291	222
Nonfamily households:	223,639	2,332	538	318	982	1,563	622	782	1,025	561
Male householder	84,859	1,089	187	94	273	647	205	253	407	175
Female householder	138,780	1,243	351	224	709	916	417	529	618	386
1.50 and over:	1,738,798	6,194	5,126	2,078	7,610	9,460	3,454	4,752	5,287	3,182
Family households:	1,251,769	4,284	4,042	1,450	5,561	7,353	2,634	3,617	4,077	2,645
Married-couple family	1,045,487	3,818	3,562	1,278	4,804	6,503	2,278	3,282	3,740	2,406
Other family:	206,282	466	480	172	757	850	356	335	337	239
Male householder, no wife present	59,767	119	172	92	305	309	123	134	104	74
Female householder, no husband present	146,515	347	308	80	452	541	233	201	233	165
Nonfamily households:	487,029	1,910	1,084	628	2,049	2,107	820	1,135	1,210	537
Male householder	233,213	826	589	298	881	1,089	397	597	662	290
Female householder	253,816	1,084	495	330	1,168	1,018	423	538	548	247

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	Boone County, Missouri	Buchanan County, Missouri	Butler County, Missouri	Caldwell County, Missouri	Callaway County, Missouri	Camden County, Missouri	Cape Girardeau County, Missouri	Carroll County, Missouri	Carter County, Missouri	Cass County, Missouri
Total:	53,106	33,592	16,737	3,522	14,449	15,740	27,031	4,169	2,377	30,236
Under 1.50:	12,693	7,920	5,548	883	2,556	3,081	5,947	1,067	952	3,560
Family households:	4,429	3,793	2,922	479	1,393	1,770	2,500	521	565	1,981
Married-couple family	1,821	1,719	1,607	291	627	1,118	1,282	399	382	1,053
Other family:	2,608	2,074	1,315	188	766	652	1,218	122	183	928
Male householder, no wife present	471	300	271	33	162	184	192	20	57	149
Female householder, no husband present	2,137	1,774	1,044	155	604	468	1,026	102	126	779
Nonfamily households:	8,264	4,127	2,626	404	1,163	1,311	3,447	546	387	1,579
Male householder	4,040	1,525	965	148	456	580	1,193	165	155	525
Female householder	4,224	2,602	1,661	256	707	731	2,254	381	232	1,054
1.50 and over:	40,413	25,672	11,189	2,639	11,893	12,659	21,084	3,102	1,425	26,676
Family households:	27,236	18,299	8,473	2,026	9,023	9,533	15,569	2,358	1,101	21,115
Married-couple family	22,841	15,212	7,340	1,793	7,777	8,662	13,498	2,113	966	18,422
Other family:	4,395	3,087	1,133	233	1,246	871	2,071	245	135	2,693
Male householder, no wife present	1,207	916	268	96	417	321	558	73	50	903
Female householder, no husband present	3,188	2,171	865	137	829	550	1,513	172	85	1,790
Nonfamily households:	13,177	7,373	2,716	613	2,870	3,126	5,515	744	324	5,561
Male householder	6,396	3,468	1,209	342	1,440	1,643	2,554	324	166	2,749
Female householder	6,781	3,905	1,507	271	1,430	1,483	2,961	420	158	2,812

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	Cedar County, Missouri	Chariton County, Missouri	Christian County, Missouri	Clark County, Missouri	Clay County, Missouri	Clinton County, Missouri	Cole County, Missouri	Cooper County, Missouri	Crawford County, Missouri	Dade County, Missouri
Total:	5,664	3,462	20,473	2,967	72,613	7,170	27,064	5,943	8,870	3,222
Under 1.50:	1,793	886	3,821	742	7,832	1,206	4,243	1,230	2,521	851
Family households:	851	437	2,352	391	3,836	667	1,980	631	1,424	457
Married-couple family	614	309	1,368	286	1,715	389	793	373	881	266
Other family:	237	128	984	105	2,121	278	1,187	258	543	191
Male householder, no wife present	64	22	126	28	436	66	183	79	100	71
Female householder, no husband present	173	106	858	77	1,685	212	1,004	179	443	120
Nonfamily households:	942	449	1,469	351	3,996	539	2,263	599	1,097	394
Male householder	385	164	461	140	1,324	180	939	167	415	141
Female householder	557	285	1,008	211	2,672	359	1,324	432	682	253
1.50 and over:	3,871	2,576	16,652	2,225	64,781	5,964	22,821	4,713	6,349	2,371
Family households:	3,050	1,921	13,541	1,705	46,623	4,674	16,010	3,529	4,978	1,832
Married-couple family	2,778	1,736	12,104	1,520	39,040	4,131	13,734	3,085	4,541	1,648
Other family:	272	185	1,437	185	7,583	543	2,276	444	437	184
Male householder, no wife present	70	63	502	79	2,203	187	712	154	165	62
Female householder, no husband present	202	122	935	106	5,380	356	1,564	290	272	122
Nonfamily households:	821	655	3,111	520	18,158	1,290	6,811	1,184	1,371	539
Male householder	355	281	1,417	234	8,951	616	2,980	581	712	278
Female householder	466	374	1,694	286	9,207	674	3,831	603	659	261

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	Dallas County, Missouri	Daviess County, Missouri	DeKalb County, Missouri	Dent County, Missouri	Douglas County, Missouri	Dunklin County, Missouri	Franklin County, Missouri	Gasconade County, Missouri	Gentry County, Missouri	Greene County, Missouri
Total:	6,063	3,184	3,553	6,017	5,214	13,414	35,081	6,188	2,745	98,003
Under 1.50:	1,933	824	887	1,877	1,785	5,253	5,268	1,303	721	22,460
Family households:	1,149	476	412	1,043	982	2,960	2,633	631	391	9,610
Married-couple family	743	343	291	706	692	1,613	1,328	376	276	4,464
Other family:	406	133	121	337	290	1,347	1,305	255	115	5,146
Male householder, no wife present	60	17	16	81	67	227	323	52	30	1,034
Female householder, no husband present	346	116	105	256	223	1,120	982	203	85	4,112
Nonfamily households:	784	348	475	834	803	2,293	2,635	672	330	12,850
Male householder	291	75	165	283	307	686	844	211	114	5,217
Female householder	493	273	310	551	496	1,607	1,791	461	216	7,633
1.50 and over:	4,130	2,360	2,666	4,140	3,429	8,161	29,813	4,885	2,024	75,543
Family households:	3,301	1,797	2,074	3,271	2,723	6,274	23,294	3,695	1,515	52,537
Married-couple family	3,026	1,629	1,856	2,895	2,490	5,442	20,153	3,296	1,378	44,650
Other family:	275	168	218	376	233	832	3,141	399	137	7,887
Male householder, no wife present	145	73	79	118	91	229	1,149	145	42	2,348
Female householder, no husband present	130	95	139	258	142	603	1,992	254	95	5,539
Nonfamily households:	829	563	592	869	706	1,887	6,519	1,190	509	23,006
Male householder	437	296	276	382	377	854	3,610	613	194	10,642
Female householder	392	267	316	487	329	1,033	2,909	577	315	12,364

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	Grundy County, Missouri	Harrison County, Missouri	Henry County, Missouri	Hickory County, Missouri	Holt County, Missouri	Howard County, Missouri	Howell County, Missouri	Iron County, Missouri	Jackson County, Missouri	Jasper County, Missouri
Total:	4,395	3,683	9,192	3,947	2,236	3,838	14,805	4,209	266,501	41,471
Under 1.50:	1,337	1,128	2,444	1,209	612	937	5,254	1,389	51,955	10,988
Family households:	689	576	1,345	659	333	486	3,055	804	25,673	5,695
Married-couple family	405	401	759	513	225	276	2,051	487	8,360	2,817
Other family:	284	175	586	146	108	210	1,004	317	17,313	2,878
Male householder, no wife present	61	42	130	19	32	47	237	69	2,757	467
Female householder, no husband present	223	133	456	127	76	163	767	248	14,556	2,411
Nonfamily households:	648	552	1,099	550	279	451	2,199	585	26,282	5,293
Male householder	196	212	405	232	104	158	726	220	10,919	1,879
Female householder	452	340	694	318	175	293	1,473	365	15,363	3,414
1.50 and over:	3,058	2,555	6,748	2,738	1,624	2,901	9,551	2,820	214,546	30,483
Family households:	2,221	1,982	5,000	2,101	1,185	2,171	7,658	2,174	141,676	22,402
Married-couple family	2,016	1,754	4,374	1,939	1,041	1,876	6,859	1,964	108,967	19,168
Other family:	205	228	626	162	144	295	799	210	32,709	3,234
Male householder, no wife present	80	94	252	66	52	98	242	84	8,832	950
Female householder, no husband present	125	134	374	96	92	197	557	126	23,877	2,284
Nonfamily households:	837	573	1,748	637	439	730	1,893	646	72,870	8,081
Male householder	414	238	918	308	230	372	950	320	34,752	3,901
Female householder	423	335	830	329	209	358	943	326	38,118	4,180

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	Jefferson County, Missouri	Johnson County, Missouri	Knox County, Missouri	Laclede County, Missouri	Lafayette County, Missouri	Lawrence County, Missouri	Lewis County, Missouri	Lincoln County, Missouri	Linn County, Missouri	Livingston County, Missouri
Total:	71,567	17,390	1,794	12,809	12,584	13,612	3,965	13,882	5,741	5,796
Under 1.50:	9,653	4,523	576	3,763	2,377	3,712	1,055	2,364	1,633	1,484
Family households:	5,444	2,149	304	2,205	1,257	2,138	584	1,393	865	662
Married-couple family	2,630	1,270	228	1,451	610	1,281	362	771	529	351
Other family:	2,814	879	76	754	647	857	222	622	336	311
Male householder, no wife present	605	209	21	160	109	152	52	98	74	49
Female householder, no husband present	2,209	670	55	594	538	705	170	524	262	262
Nonfamily households:	4,209	2,374	272	1,558	1,120	1,574	471	971	768	822
Male householder	1,447	1,095	88	522	359	615	166	380	240	210
Female householder	2,762	1,279	184	1,036	761	959	305	591	528	612
1.50 and over:	61,914	12,867	1,218	9,046	10,207	9,900	2,910	11,518	4,108	4,312
Family households:	49,445	9,698	917	7,077	7,856	7,776	2,139	9,203	2,962	3,205
Married-couple family	41,492	8,603	818	6,303	6,886	6,907	1,885	7,890	2,564	2,858
Other family:	7,953	1,095	99	774	970	869	254	1,313	398	347
Male householder, no wife present	2,835	455	41	273	311	263	116	479	147	113
Female householder, no husband present	5,118	640	58	501	659	606	138	834	251	234
Nonfamily households:	12,469	3,169	301	1,969	2,351	2,124	771	2,315	1,146	1,107
Male householder	7,349	1,674	134	1,028	1,220	1,069	370	1,359	502	512
Female householder	5,120	1,495	167	941	1,131	1,055	401	956	644	595

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	McDonald County, Missouri	Macon County, Missouri	Madison County, Missouri	Maries County, Missouri	Marion County, Missouri	Mercer County, Missouri	Miller County, Missouri	Mississippi County, Missouri	Moniteau County, Missouri	Monroe County, Missouri
Total:	8,133	6,494	4,711	3,536	11,064	1,601	9,288	5,379	5,264	3,640
Under 1.50:	2,802	1,692	1,631	883	2,733	431	2,476	2,227	1,034	918
Family households:	1,705	762	902	487	1,445	238	1,337	1,228	547	431
Married-couple family	976	457	567	327	759	158	744	461	310	297
Other family:	729	305	335	160	686	80	593	767	237	134
Male householder, no wife present	209	73	59	36	124	23	74	82	71	20
Female householder, no husband present	520	232	276	124	562	57	519	685	166	114
Nonfamily households:	1,097	930	729	396	1,288	193	1,139	999	487	487
Male householder	518	343	208	146	366	70	410	341	186	190
Female householder	579	587	521	250	922	123	729	658	301	297
1.50 and over:	5,331	4,802	3,080	2,653	8,331	1,170	6,812	3,152	4,230	2,722
Family households:	4,189	3,594	2,398	2,056	6,131	857	5,113	2,488	3,185	2,123
Married-couple family	3,645	3,095	2,155	1,834	5,412	783	4,430	2,114	2,809	1,846
Other family:	544	499	243	222	719	74	683	374	376	277
Male householder, no wife present	239	196	85	81	200	26	238	136	139	92
Female householder, no husband present	305	303	158	141	519	48	445	238	237	185
Nonfamily households:	1,142	1,208	682	597	2,200	313	1,699	664	1,045	599
Male householder	658	576	373	351	994	138	912	311	461	314
Female householder	484	632	309	246	1,206	175	787	353	584	285

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	Montgomery County, Missouri	Morgan County, Missouri	New Madrid County, Missouri	Newton County, Missouri	Nodaway County, Missouri	Oregon County, Missouri	Osage County, Missouri	Ozark County, Missouri	Pemiscot County, Missouri	Perry County, Missouri
Total:	4,782	7,847	7,831	20,163	8,164	4,269	4,956	3,987	7,906	6,929
Under 1.50:	1,159	2,113	2,701	4,578	2,319	1,756	913	1,391	3,514	1,434
Family households:	623	1,165	1,588	2,534	737	1,007	410	840	2,061	661
Married-couple family	348	804	759	1,640	426	677	243	633	814	419
Other family:	275	361	829	894	311	330	167	207	1,247	242
Male householder, no wife present	62	73	87	222	69	77	30	76	187	55
Female householder, no husband present	213	288	742	672	242	253	137	131	1,060	187
Nonfamily households:	536	948	1,113	2,044	1,582	749	503	551	1,453	773
Male householder	170	400	449	736	655	301	221	238	575	297
Female householder	366	548	664	1,308	927	448	282	313	878	476
1.50 and over:	3,623	5,734	5,130	15,585	5,845	2,513	4,043	2,596	4,392	5,495
Family households:	2,736	4,407	3,937	12,245	4,164	2,016	3,202	2,080	3,304	4,292
Married-couple family	2,355	4,023	3,354	10,855	3,713	1,826	2,866	1,869	2,735	3,780
Other family:	381	384	583	1,390	451	190	336	211	569	512
Male householder, no wife present	139	155	166	473	190	68	143	70	177	183
Female householder, no husband present	242	229	417	917	261	122	193	141	392	329
Nonfamily households:	887	1,327	1,193	3,340	1,681	497	841	516	1,088	1,203
Male householder	496	691	548	1,706	857	252	480	290	514	672
Female householder	391	636	645	1,634	824	245	361	226	574	531

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	Pettis County, Missouri	Phelps County, Missouri	Pike County, Missouri	Platte County, Missouri	Polk County, Missouri	Pulaski County, Missouri	Putnam County, Missouri	Ralls County, Missouri	Randolph County, Missouri	Ray County, Missouri
Total:	15,616	15,677	6,417	29,317	9,899	13,456	2,240	3,725	9,217	8,725
Under 1.50:	3,591	4,631	1,746	2,788	2,877	2,943	690	759	2,371	1,394
Family households:	2,016	2,136	943	1,283	1,546	1,795	375	418	1,209	791
Married-couple family	1,069	1,148	578	541	1,048	1,034	258	309	635	432
Other family:	947	988	365	742	498	761	117	109	574	359
Male householder, no wife present	144	221	99	180	107	131	30	15	131	73
Female householder, no husband present	803	767	266	562	391	630	87	94	443	286
Nonfamily households:	1,575	2,495	803	1,505	1,331	1,148	315	341	1,162	603
Male householder	570	1,245	346	533	441	409	90	95	397	166
Female householder	1,005	1,250	457	972	890	739	225	246	765	437
1.50 and over:	12,025	11,046	4,671	26,529	7,022	10,513	1,550	2,966	6,846	7,331
Family households:	8,697	8,158	3,498	19,142	5,644	8,242	1,151	2,367	5,074	5,737
Married-couple family	7,369	7,280	3,002	16,248	5,069	7,342	1,067	2,172	4,335	5,145
Other family:	1,328	878	496	2,894	575	900	84	195	739	592
Male householder, no wife present	424	259	184	916	226	316	36	96	247	223
Female householder, no husband present	904	619	312	1,978	349	584	48	99	492	369
Nonfamily households:	3,328	2,888	1,173	7,387	1,378	2,271	399	599	1,772	1,594
Male householder	1,597	1,453	640	3,805	607	1,288	221	353	914	866
Female householder	1,731	1,435	533	3,582	771	983	178	246	858	728

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Standard Error/Variance documentation for this dataset:
Accuracy of the Data: Census 2000 Summary File 3 (SF 3) - Sample Data (PDF 141.5KB)

P93. RATIO OF INCOME IN 1999 TO POVERTY LEVEL BY HOUSEHOLD TYPE [19] - Universe: Households
Data Set: Census 2000 Summary File 3 (SF 3) - Sample Data

NOTE: Data based on a sample except in P3, P4, H3, and H4. For information on confidentiality protection, sampling error, nonsampling error, and definitions see http://factfinder.census.gov/home/en/datanotes/expsf3.htm.

	Reynolds County, Missouri	Ripley County, Missouri	St. Charles County, Missouri	St. Clair County, Missouri	Ste. Genevieve County, Missouri	St. Francois County, Missouri	St. Louis County, Missouri	Saline County, Missouri	Schuyler County, Missouri	Scotland County, Missouri
Total:	2,735	5,438	101,826	4,031	6,602	20,788	404,607	8,984	1,725	1,895
Under 1.50:	978	2,300	7,936	1,386	1,075	5,745	48,779	2,143	499	605
Family households:	537	1,352	4,297	785	597	3,000	24,268	1,163	251	344
Married-couple family	378	933	1,678	503	350	1,552	8,273	572	199	240
Other family:	159	419	2,619	282	247	1,448	15,995	591	52	104
Male householder, no wife present	33	77	386	57	19	346	2,216	164	8	21
Female householder, no husband present	126	342	2,233	225	228	1,102	13,779	427	44	83
Nonfamily households:	441	948	3,639	601	478	2,745	24,511	980	248	261
Male householder	209	406	1,116	214	129	934	8,061	372	91	92
Female householder	232	542	2,523	387	349	1,811	16,450	608	157	169
1.50 and over:	1,757	3,138	93,890	2,645	5,527	15,043	355,828	6,841	1,226	1,290
Family households:	1,407	2,534	73,156	2,004	4,352	11,822	248,251	4,822	943	974
Married-couple family	1,272	2,282	63,686	1,816	3,842	10,083	200,714	4,112	831	899
Other family:	135	252	9,470	188	510	1,739	47,537	710	112	75
Male householder, no wife present	57	91	3,011	88	172	628	10,864	226	35	35
Female householder, no husband present	78	161	6,459	100	338	1,111	36,673	484	77	40
Nonfamily households:	350	604	20,734	641	1,175	3,221	107,577	2,019	283	316
Male householder	196	321	10,532	326	687	1,576	46,030	966	136	114
Female householder	154	283	10,202	315	488	1,645	61,547	1,053	147	202

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	Scott County, Missouri	Shannon County, Missouri	Shelby County, Missouri	Stoddard County, Missouri	Stone County, Missouri	Sullivan County, Missouri	Taney County, Missouri	Texas County, Missouri	Vernon County, Missouri	Warren County, Missouri
Total:	15,689	3,329	2,754	12,047	11,824	2,921	16,175	9,379	8,018	9,210
Under 1.50:	4,549	1,446	773	3,907	2,787	951	4,006	3,338	2,283	1,639
Family households:	2,548	907	436	2,132	1,592	462	2,179	2,006	1,188	845
Married-couple family	1,135	654	318	1,316	1,027	294	1,326	1,296	654	420
Other family:	1,413	253	118	816	565	168	853	710	534	425
Male householder, no wife present	208	54	32	176	126	33	220	185	85	73
Female householder, no husband present	1,205	199	86	640	439	135	633	525	449	352
Nonfamily households:	2,001	539	337	1,775	1,195	489	1,827	1,332	1,095	794
Male householder	644	193	127	627	468	186	732	472	467	233
Female householder	1,357	346	210	1,148	727	303	1,095	860	628	561
1.50 and over:	11,140	1,883	1,981	8,140	9,037	1,970	12,169	6,041	5,735	7,571
Family households:	8,814	1,481	1,431	6,353	7,266	1,508	8,917	4,694	4,303	6,053
Married-couple family	7,561	1,314	1,298	5,683	6,636	1,272	7,942	4,209	3,798	5,368
Other family:	1,253	167	133	670	630	236	975	485	505	685
Male householder, no wife present	368	73	37	232	226	104	323	192	172	275
Female householder, no husband present	885	94	96	438	404	132	652	293	333	410
Nonfamily households:	2,326	402	550	1,787	1,771	462	3,252	1,347	1,432	1,518
Male householder	940	192	229	875	901	249	1,447	637	672	897
Female householder	1,386	210	321	912	870	213	1,805	710	760	621

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P93. RATIO OF INCOME IN 1999 TO POVERTY LEVEL BY HOUSEHOLD TYPE [19] - Universe: Households
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	Washington County, Missouri	Wayne County, Missouri	Webster County, Missouri	Worth County, Missouri	Wright County, Missouri	St. Louis city, Missouri
Total:	8,376	5,540	11,080	1,007	7,094	147,286
Under 1.50:	2,935	2,022	2,802	318	2,735	49,756
Family households:	1,824	1,157	1,723	158	1,620	24,735
Married-couple family	1,125	690	1,275	113	1,080	5,848
Other family:	699	467	448	45	540	18,887
Male householder, no wife present	145	134	126	10	135	2,332
Female householder, no husband present	554	333	322	35	405	16,555
Nonfamily households:	1,111	865	1,079	160	1,115	25,021
Male householder	499	313	433	58	330	10,577
Female householder	612	552	646	102	785	14,444
1.50 and over:	5,441	3,518	8,278	689	4,359	97,530
Family households:	4,422	2,688	6,742	520	3,448	53,049
Married-couple family	3,851	2,437	5,973	466	3,081	32,942
Other family:	571	251	769	54	367	20,107
Male householder, no wife present	237	94	278	16	129	5,041
Female householder, no husband present	334	157	491	38	238	15,066
Nonfamily households:	1,019	830	1,536	169	911	44,481
Male householder	528	439	791	88	484	21,996
Female householder	491	391	745	81	427	22,485

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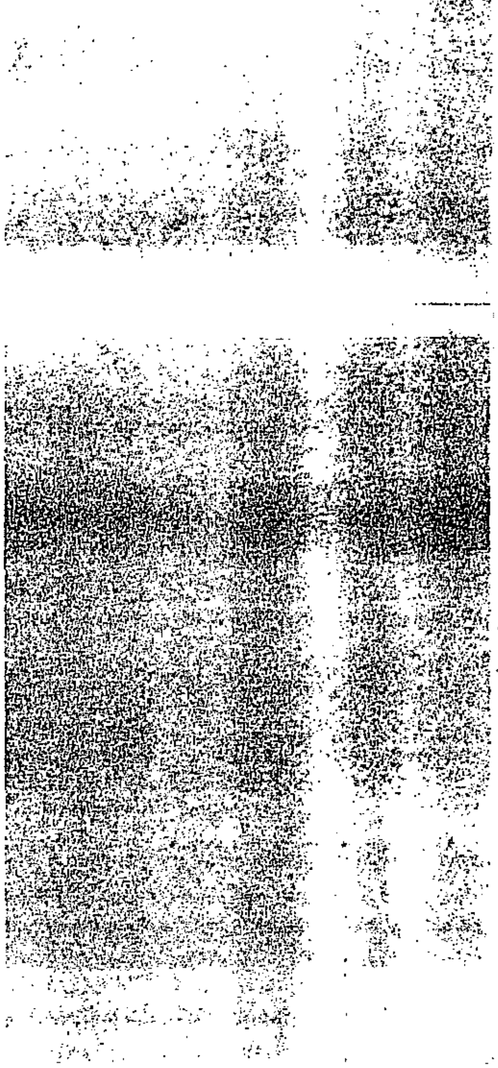

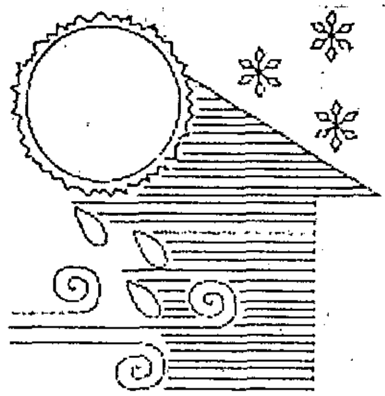

Progress Report of the National Weatherization Assistance Program

Linda G. Berry
Marilyn A. Brown
Laurence F. Kinney

Exhibit (Schedule) 4

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LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

WEATHERIZATION ASSISTANCE PROGRAM

ORNL-27 (3-96)

ORNL/CON-450

Progress Report of the National Weatherization Assistance Program

Linda G. Berry
Marilyn A. Brown
Laurence F. Kinney*

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Jeanne Van Vlandren
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INCREASES IN PROGRAM ENERGY SAVINGS AND COST EFFECTIVENESS (1989-1996) AT A GLANCE

ENERGY SAVINGS IN GAS-HEATED HOMES

First-year savings	Savings per dwelling	Percent of total gas consumption	Percent of gas space heat consumption
1989 (PRISM analysis of billing data for homes in the representative national sample that heat with gas)	17.3 Mbtu	13.0%	18.3%
1996 (national estimate derived from Metaevaluation of 17 state-level evaluations of savings in gas-heated homes)	31.2 Mbtu	23.4%	33.5%

VALUE OF GAS ENERGY SAVINGS (in 1996 dollars)	First year	20 years
1989	$107/dwelling	$1,707/dwelling
1996	$193/dwelling	$3,047/dwelling

COST EFFECTIVENESS	1989	1996
Program Benefit/Cost Ratio [a]	1.06	1.79
Installation Benefit/Cost Ratio [b]	1.58	2.39
Societal Benefit/Cost Ratio [c]	1.61	2.40

[a] The program benefit/cost ratio compares the discounted value of the energy savings to total program costs with an assumed lifetime of 20 years and a discount rate of 4.7%.

[b] The installation benefit/cost ratio compares the discounted value of energy savings to installation (labor and materials) costs with an assumed lifetime of 20 years and a discount rate of 4.7%.

[c] The societal benefit/cost ratio compares the discounted value of both energy and nonenergy benefits (such as employment and environmental impacts) to total program costs with an assumed lifetime of 20 years and a discount rate of 4.7%.

CONTENTS

The National Weatherization Evaluation of the 1989 Program Year and the Metaevaluation of 1996 are described in two ways in this summary document. The text on the right-hand (odd) pages summarizes the results of the two evaluations conducted by the Oak Ridge National Laboratory. The photographs and explanations on the left-hand (even) pages illustrate weatherization operations and tactics.

"I have seen first hand how many jobs weatherization programs create and also how much good they can do . . . A lot of this weatherization work for poor people, especially for a lot of elderly people who are stuck in these old houses that have holes in the walls . . . or in the floor, not only makes them warmer in the winter and cooler in the summer, they also save money on their utility bills. [Weatherization] conserves energy and puts more money in the pockets of people who have just barely enough to get by. So I strongly support [weatherization programs] . . . It's a kind of hard sell in the Congress now because the price of oil is so low and energy is so cheap--it's much cheaper in America than it is in any other major country. But if you just have enough to get by on, [if] you're living on a Social Security check or you're living on a minimum wage, [utility bills] are still very, very expensive and a big part of your budget."

President Clinton's remarks concerning the Department of Energy's Weatherization Assistance Program at the Summer of Service Forum held at the University of Maryland, August 31, 1993.

"By implementing energy-saving measures in low-income homes, the Weatherization Program works to correct the disproportionate energy burden faced by low-income Americans who often face the difficult choice between buying food or fuel. Consequently, weatherization helps low-income residents gain financial independence, thus offering a hand-up not a hand-out."

Excerpt from Secretary Peña's testimony before the Senate Committee on Energy and Natural Resources, May 13, 1997.

Progress Report of the National Weatherization Assistance Program

I. OVERVIEW

The U.S. Department of Energy's (DOE) Weatherization Assistance Program (the Program) has long served as the nation's core program for delivering energy conservation services to low-income Americans. The Program reduces the heating and cooling costs for low-income families -- particularly the elderly, persons with disabilities, and children -- by improving the energy efficiency of their homes and ensuring their health and safety. In combination with closely related programs sponsored by the Department of Health and Human Services (HHS) and supplemental funding from other sources, the DOE Weatherization network is operated by state entities in all 50 states and is managed by the DOE Office of State and Community Programs (OSCP). This network has weatherized more than *four and one-half million* households since its inception in 1976.

In 1990, DOE sponsored a comprehensive evaluation and assessment (the National Evaluation) of the Weatherization Program under the supervision of Oak Ridge National Laboratory (ORNL). The National Evaluation concluded that the Program meets the objectives of its enabling legislation and fulfills its mission statement. Specifically, it

- saves energy,
- lowers fuel bills, and
- improves the health and safety of dwellings occupied by low-income people.

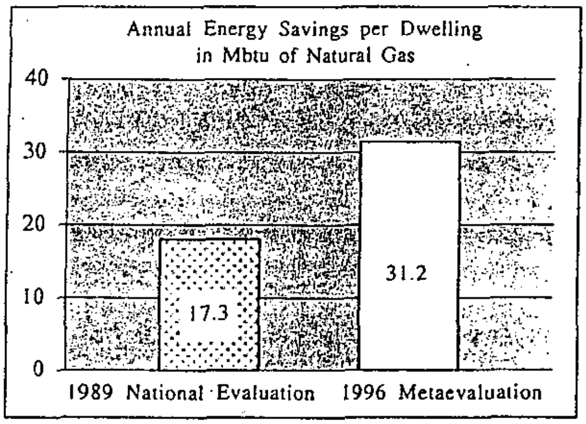
In addition the National Evaluation concluded that, based on 1989 data, the Program has been achieving its mission in a cost-effective manner, with benefits exceeding costs according to all three standards employed by the evaluators. Annual savings for households heated with natural gas, the predominant home heating fuel, were estimated to average 17.3 Mbtu per weatherized dwelling. This constituted a reduction of 18.3 percent in natural gas consumption for space heating, or a 13.0 percent reduction in natural gas consumption for all end uses. The National Evaluation also pointed to several promising approaches and practices that could further improve the overall performance of the Program in future years.

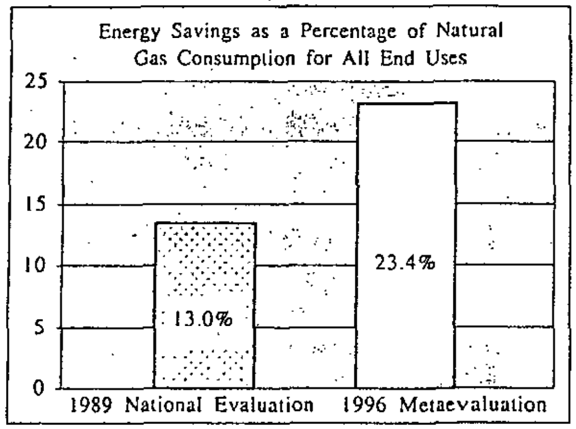
A 1996 Metaevaluation of 17 state-level evaluations (the Metaevaluation) suggested that improved practices have indeed produced 80 percent higher average energy savings per dwelling today as compared to the measured savings in 1989. The Metaevaluation, which developed a regression-based national estimate of savings, indicated that average savings in homes using natural gas as the primary heating fuel were 31.2 Mbtu, which was 33.5 percent of natural gas space heating consumption. The savings constituted a reduction of 23.4 percent in consumption of natural gas for all end uses.

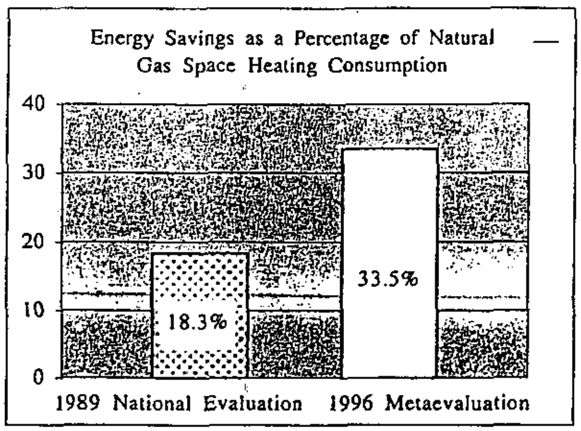
References are at the end of the text on pages 74-75

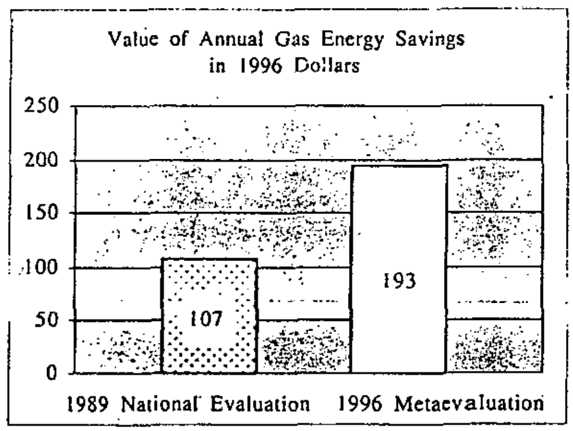
1996 INCREASES IN PROGRAM PERFORMANCE

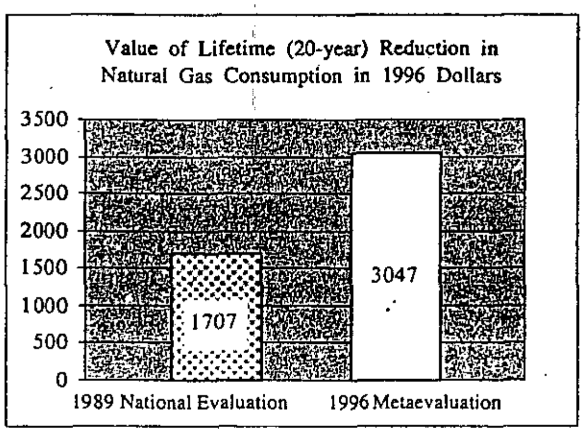
The Metaevaluation in 1996 showed an 80% increase in energy savings, greater reductions in CO_2 emissions, and increased cost effectiveness since 1989

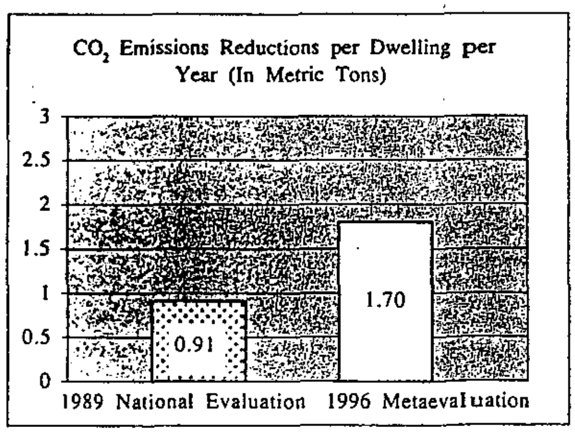










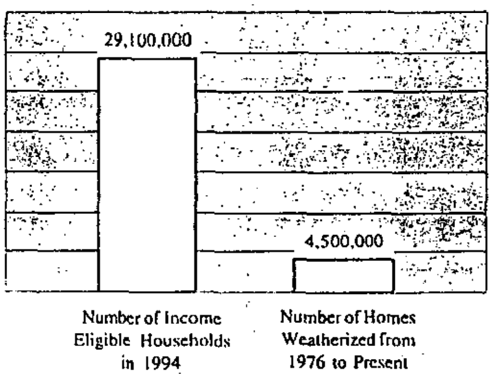


Cost-Effectiveness Results for Gas-Heated Homes: Benefit/Cost Ratios* from Three Perspectives in 1989 and 1996

	Program	Installation	Societal
National Evaluation 1989	1.06	1.58	1.61
Metaevaluation Results 1996	1.79	2.39	2.40

*See page 29 for an explanation of the calculation procedures and a definition of the three perspectives.

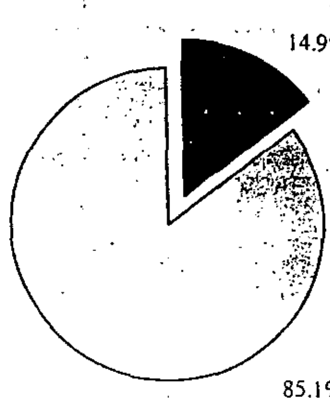
With the increased energy savings, the value of annual avoided energy costs per gas-heated household also increased from an average of $107 to $193, and the benefit/cost ratio for the Program rose from 1.61 to 2.40.



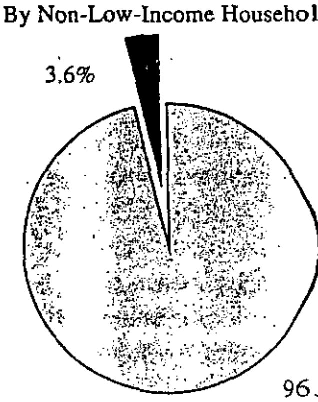
Although the Weatherization Program has successfully accomplished a significant portion of its mission, additional activities need to be undertaken to meet the ongoing need for low-income weatherization. The Department of Health and Human Services has reported that, based on Energy Information Administration data, there were 29.1 million households with incomes near or below the federal poverty guidelines for Weatherization eligibility in 1994. These households were spending an average of 14.9 percent of income for residential energy. This compares to an average expenditure of 3.6 percent of income for residential energy by non-low-income households. The most recent Residential Energy Consumption Survey indicates that 1.5 million households experienced heating interruptions because of their financial situations during one year.

From Program Year (PY) 1985 through PY 1995, the Program's network of 1,100 local agencies weatherized an average of 200,000 dwellings per year. Substantial budget reductions for Weatherization Assistance in PY 1996 and PY 1997 have forced a reduction in the number of agencies performing weatherization and have cut the number of dwellings weatherized to approximately 70,000 annually. This downsizing is the most recent challenge to carrying out the Program's mission in an efficient and effective manner.

Percent of Income Spent on Residential Energy By Low-Income Households

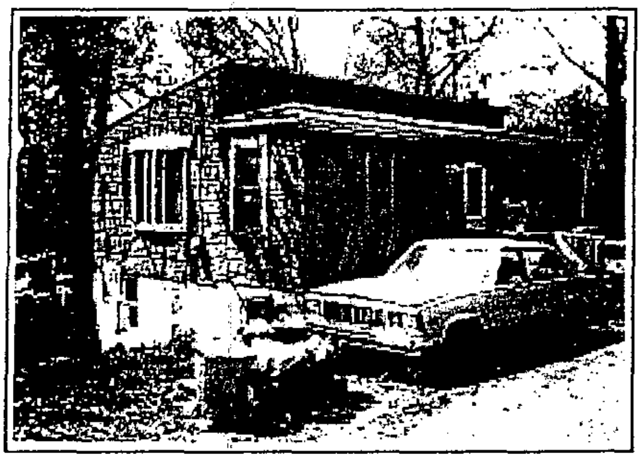


Percent of Income Spent on Residential Energy By Non-Low-Income Households

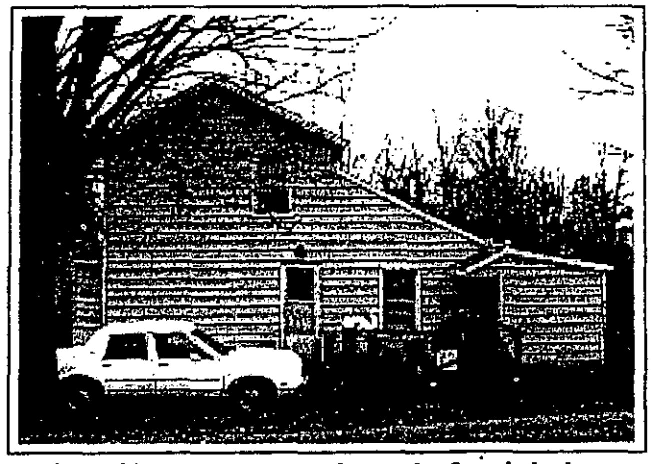


SINGLE-FAMILY DETACHED HOMES

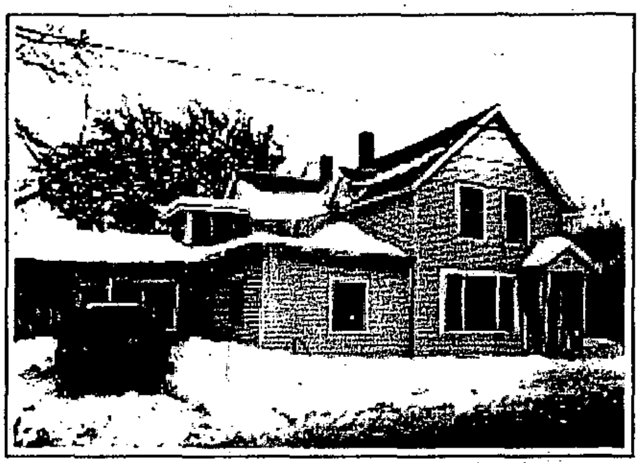
This series of photographs illustrates the age and diversity of single-family homes weatherized by the Program.



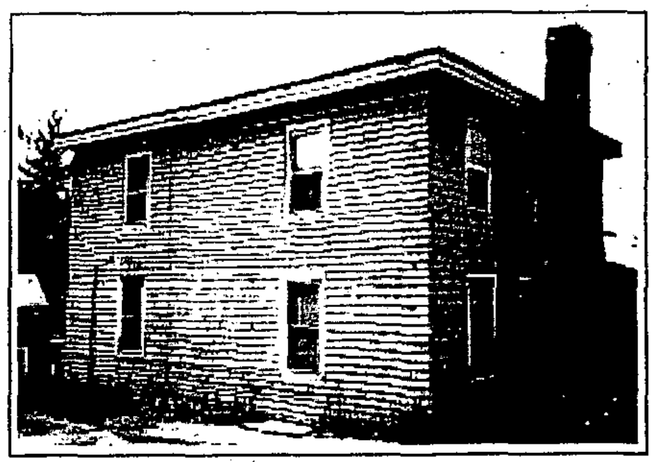
The weatherization job on this house will include foundation wall repair.



This roofline suggests complex paths for air leakage.



Patterns of snow and ice indicate a leaky, poorly *insulated attic.*

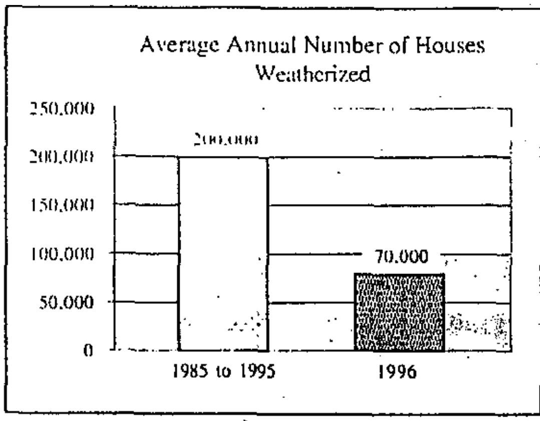


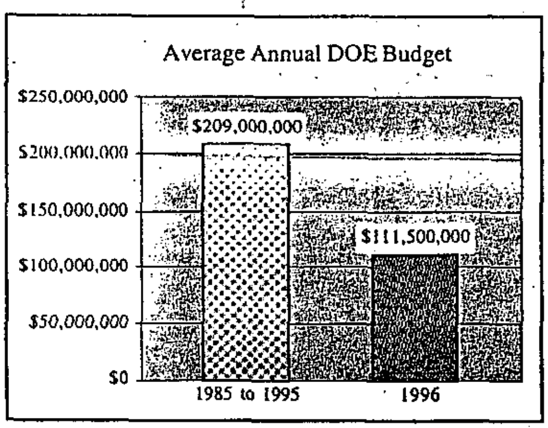
A good candidate for wall insulation.

This concrete block house is typical of homes that are weatherized in rural Georgia.

II. PROGRAM HISTORY

Most Americans were dramatically affected by the 1973 oil crisis. Huge home heating bills were a heavy burden on some household budgets, sinking many families into debt. Low-income families in cold climate states, who received high heating bills, suffered the most severe consequences. In Maine, where nine out of ten homes are heated with oil, state officials and community action agencies worked with homeowners and renters to seal house leaks (where costly heated air poured out and cold air entered). Retrofitting cut bills and saved oil. Out of this effort, the Nation's first weatherization program was born. Congress created the DOE's Weatherization Assistance Program in 1976 under Title IV of the Energy Conservation and Production Act.





The Program initially emphasized emergency and temporary measures, including caulking and weatherstripping of windows and doors, and low-cost measures such as covering windows with plastic sheets. By the early 1980's, the emphasis had turned to more permanent and more cost-effective measures, such as installing storm windows and doors and insulating attics. In 1984, regulations were passed to allow Weatherization Assistance funds to be spent on space and water heating system efficiency changes. In 1985, spending for the replacement of defective furnaces and boilers was approved.

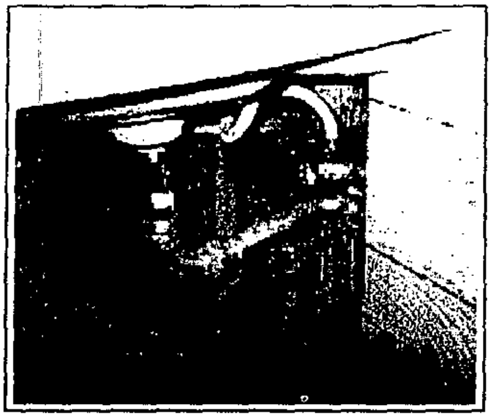
In the 1990's, the trend toward emphasizing more cost-effective measures continued with the development and widespread adoption of advanced audits. Advanced audits are now used in 37 states. By 1996, the Program's performance had improved significantly because of the implementation of many of the recommendations of the National Evaluation and of other DOE-sponsored research. In spite of funding reductions, technical advances produced 80 percent higher energy savings per dwelling. Increases in energy savings were achieved through better training, audit tools, and management practices with little increase in cost.

Among the new DOE regulations implemented in 1994 were changes that promote the use of advanced audits, and that permit the use of cooling efficiency measures such as air conditioner replacements, ventilation equipment, and screening and shading devices. In warm climates, where cooling costs may be higher than heating costs, cooling measures can now be installed when appropriate. Barriers to performing work on heating systems and mechanical equipment have also been removed. The requirement that 40 percent of Program funds be spent on materials is waived in states that adopt approved advanced audits, thus ensuring audit-driven cost-effectiveness tests of investments. With increased flexibility, better measure selection procedures, and more advanced diagnostics (such as blower-door directed air sealing), the Program now installs more cost-effective combinations of measures tailored to the needs of particular dwellings and climates.

ADVANCED AIR SEALING

In the last several years, it has been shown that some previously ignored areas of dwellings can be potent sources of convective losses. If such losses are found and treated, they offer high potential for savings. As illustrated in the figures, these include interstices between floors, spaces between the conditioned envelope and such buffer zones as porches and garages, and areas between old and new portions of dwellings. The blower door, in conjunction with a gauge that measures differences in pressure, is a valuable tool in identifying leakage to or from these areas, helping both in identifying the magnitude of the leakage and in verifying when such measures as the blowing of high-density cellulose or other air-sealing measures will solve the problem. Weatherization agencies that integrate these tests and tactics into routine operations achieve excellent savings.

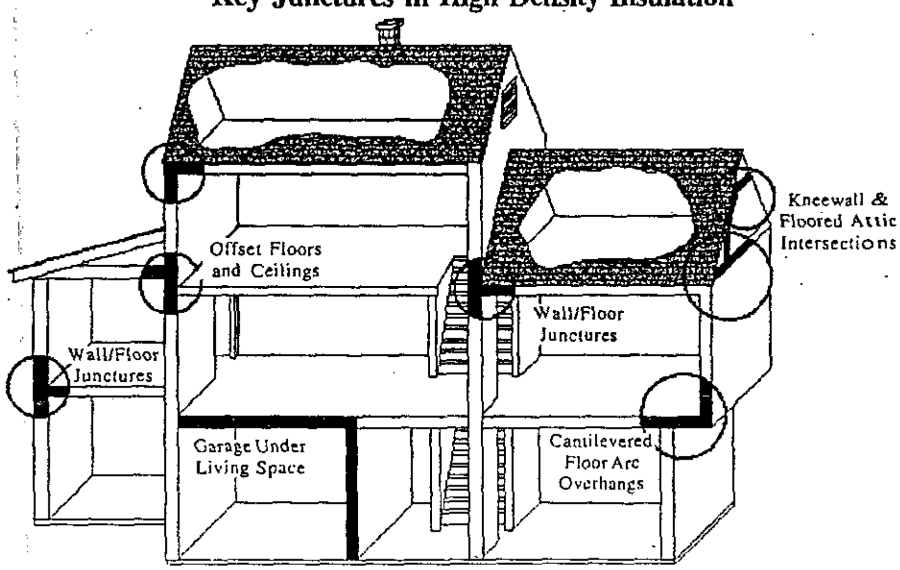
As revealed by a blower door and a pressure gauge in a test that takes only several minutes, the area under this porch is directly connected to the envelope through floor joists between the first and second floor. High-density insulation is being used to air seal this largest hole in the dwelling.



Note the infiltration area under the bathroom sink, which connects to the attic via a stud cavity in an interior wall.

Air sealing a plumbing chase on the first floor that corresponds with both attic and basement. Sealing holes in inconspicious and hard-to-get-to places are frequently those which result in good, cost-effective weatherization jobs.

Key Junctures in High Density Insulation



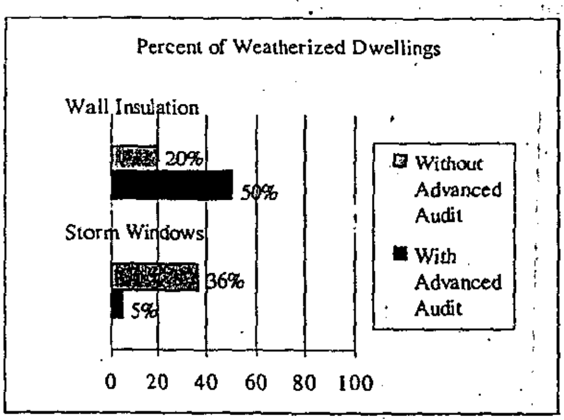
III. THE SCOPE OF WEATHERIZATION

A. Types of Measures Used

A variety of weatherization measures are used by DOE's Weatherization Program to improve the energy efficiency of dwellings occupied by low-income people. Although audit methods to optimize the type and amount of weatherization measures have improved, the set of measures that is typically considered has remained relatively constant between 1989 and 1996. Detailed results from the National Evaluation indicated that the following measures were those most commonly used in 1989:

Air leakage control was the most common type of weatherization measure installed in single-family and small multifamily dwellings. General caulking and weatherstripping around windows and doors were by far the most common of these measures at the time of the National Evaluation. Today, blower-door directed air sealing and air leakage control measures for distribution systems are used frequently. These techniques reduce air leakage much more effectively.

Advanced Audits Select More Insulations, Fewer Storm Windows



Insulation was the next most common type of energy conservation measure installed. Attic insulation was either used for the first time or added to existing insulation in the majority of homes receiving insulation. Wall insulation was installed in less than 20 percent of homes. Today, with the use of advanced audits, attic and, especially, wall insulation are installed much more frequently.

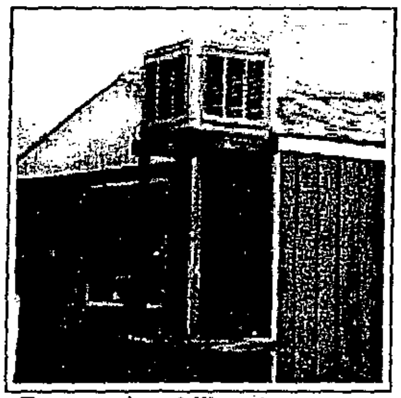
Energy-efficiency improvements to **water heater systems** were made in 56 percent of the weatherized homes in 1989. Most of these retrofits involved tank or pipe insulation. Today an even larger majority of homes receive water heater measures. In addition, water temperatures are reduced and low-flow showerheads are added in a higher percentage of homes.

Energy-efficiency improvements to **windows and doors** occurred in 42 percent of homes weatherized at the time of the National Evaluation. Additional window and door work was conducted primarily for repair purposes. By far, the majority of these improvements involved the addition of storm windows (36 percent) or the replacement of entire windows (37 percent). Advanced audits are unlikely to recommend storm windows or window or door replacements in most homes. Therefore, these measures are installed less frequently today.

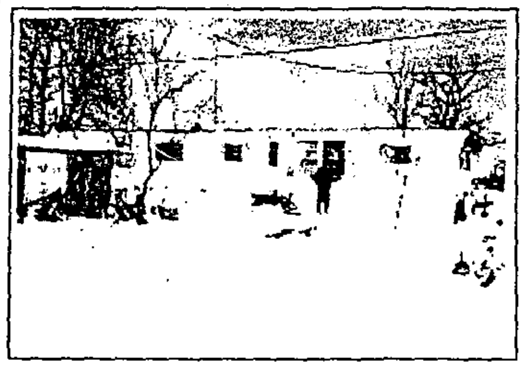
Nearly one-third (30 percent) of the homes weatherized had energy-efficiency improvements made to their **space heating systems**. Most of these improvements involved tune-ups, during which heating systems were cleaned, controls adjusted, and filters replaced. Increased attention to space heating measures probably characterizes the Program

MOBILE HOMES

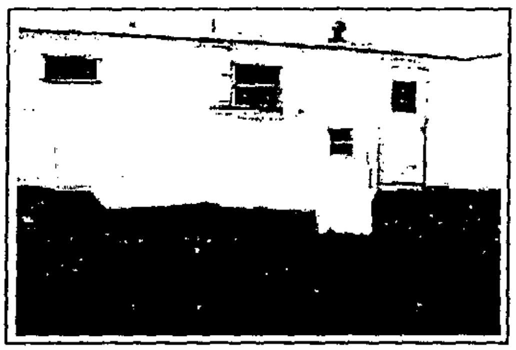
Due to the economic realities of affordable housing, many low-income families live in mobile homes.



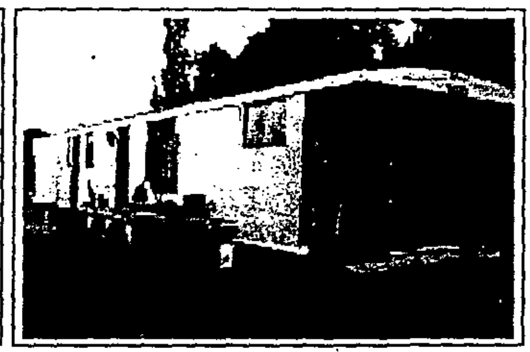
Evaporative chillers (swamp coolers) often mean large leaks.



This home used over $1,000 of fuel oil per heating season before weatherization tightened it up and installed a more efficient oil burner.



New doors and windows sometimes save energy, but air sealing ducts in mobile homes are usually a more cost-effective retrofit.



Mobile homes with poor foundations often develop major structural problems.

Very poor insulation causes major problems with mobile homes built before HUD's energy standards were adopted in 1976.

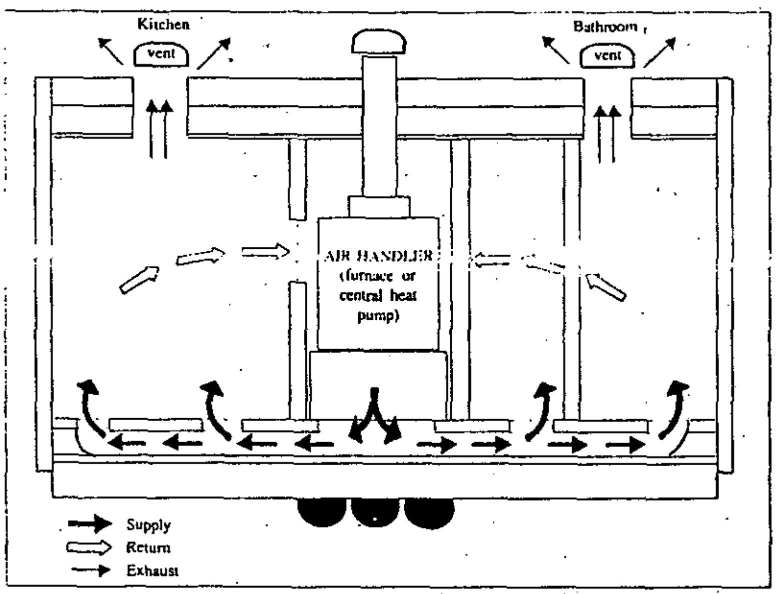
Skirting under a mobile home is not as important for the heating bill as belly board insulation, which can be blown in by weatherization crews.

today because barriers to performing work on heating systems and mechanical equipment have been removed. Distribution systems also now receive increased attention for both heating and cooling applications. In addition, new regulations implemented in 1994 allow for the use of **cooling efficiency measures** including air conditioner replacement, ventilation equipment, and screening and shading devices. These measures enable the Program to more effectively address the energy efficiency needs of homes in warm climates.

The requirement that 40 percent of Program funds be spent on materials is waived in the 37 states that have adopted approved audits, thus ensuring that the most cost-effective package of investments will be selected. These and other Program updates allow increased flexibility to select the most appropriate measures for specific dwellings in particular regions.

Measures for Mobile Homes

There are seven million "manufactured homes" in the United States and the number is growing. Well over half were constructed before 1976, when HUD initiated its mandatory national standards on manufactured home construction. These older units, which tend to be occupied by lower-income people, suffer from a variety of ills. Energy problems stem from shoddy construction, improper site set ups, and poor maintenance. As a result, many are leaky, uncomfortable, and have high energy bills.



Mobile Home Heating System Distribution System

The profile of weatherization measures installed in mobile homes differed from that of other housing types. In 1989, mobile homes were much less likely to receive any type of insulation than the average home (20% vs. 62%), and nearly all mobile home insulation consisted of floor insulation. Blowing the space between the belly board and the floor of older mobile homes with insulation, in combination with attention to air sealing and duct leakage, solves many conductive and convective problems so that less heat is wasted.

Blower-door-assisted air sealing is becoming a more prominent part of mobile home weatherization. Quite frequently, major leaks are found in unobvious places, such as main electrical boxes, plumbing chases, and ducts. The combination of leaks in mobile home ducts and belly boards results not only in low heating and cooling efficiency, but also in uncontrolled air leakage. This wastes energy and can affect indoor air quality, raise moisture levels, and cause structural deterioration.

In 1989, water heating measures were installed less frequently (48% vs. 56%) in mobile homes than in other types of structures, while window and door measures (50% vs. 42%) were installed more frequently. Installation of inside storm windows covering leaky jalousie-type win-

Although most dwellings weatherized are single-family detached structures, other dwelling types are also common.

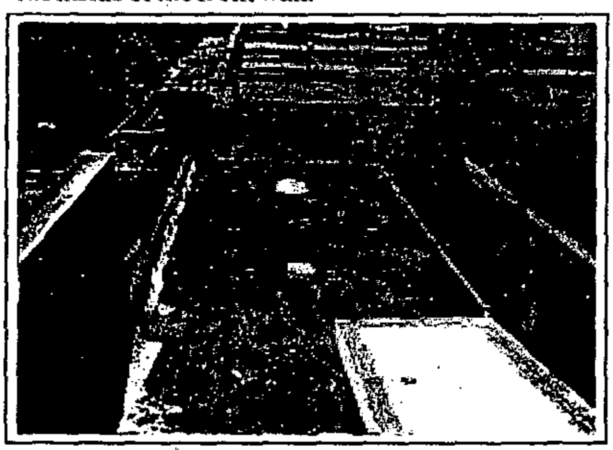
ROW HOUSES (SINGLE-FAMILY ATTACHED DWELLINGS)

Row houses, which predominate in many older American cities in the Northeast, can be extremely wasteful of energy. Leaky flat roofs cause falling ceilings and massive air leakage.

The space under these bay windows may cause more energy waste than the windows themselves.

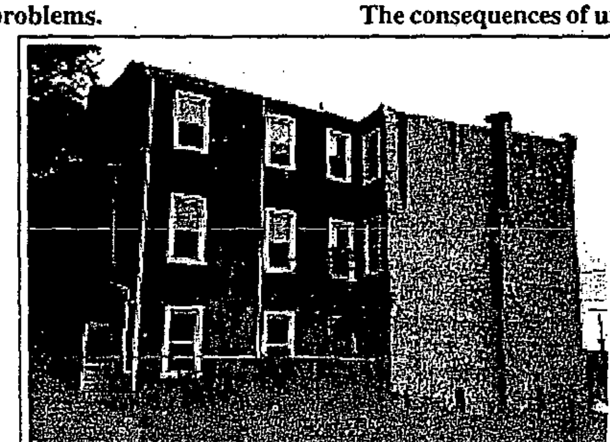
The space above porch ceilings is often connected to the inside of the front wall.

A solid exterior may conceal inner decay.



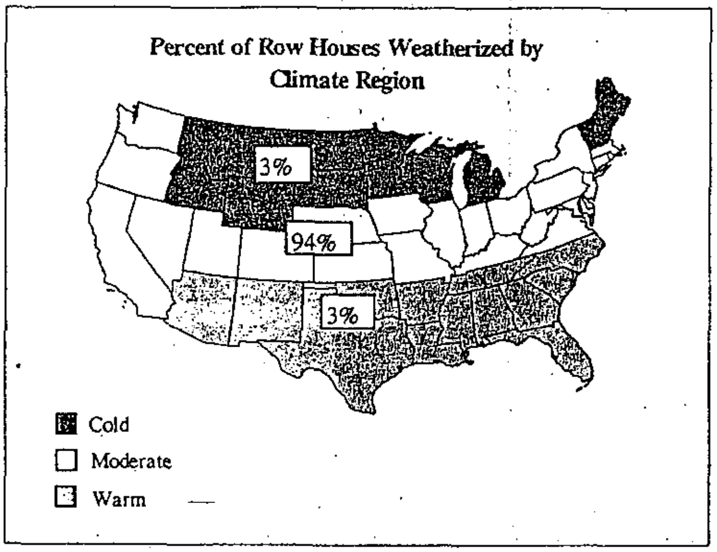
Leaky roofs pose big problems.

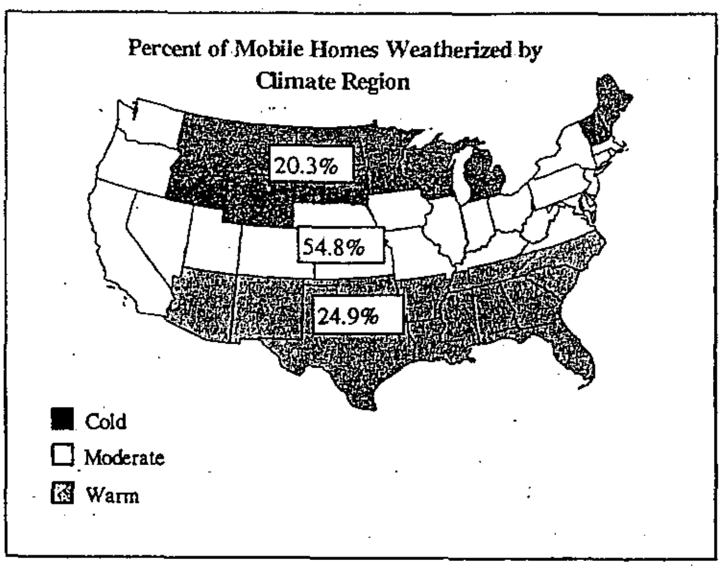
The consequences of unrepaired roof leaks.



Newly missing next-door neighbor causes major air infiltration.

Weatherized Row Houses and Mobile Homes Are Concentrated in the Moderate Climate Region





dows was especially common in mobile homes. Most mobile homes received one or more measures that were especially suitable for this type of dwelling, including underpinning, skirting, cool seals on the roof, and belly board insulation.

An audit designed specifically for mobile homes is being developed for the Program's use. This advanced audit will improve the auditor's ability to select the most cost-effective packages of measures for mobile homes.

Measures for Row Houses

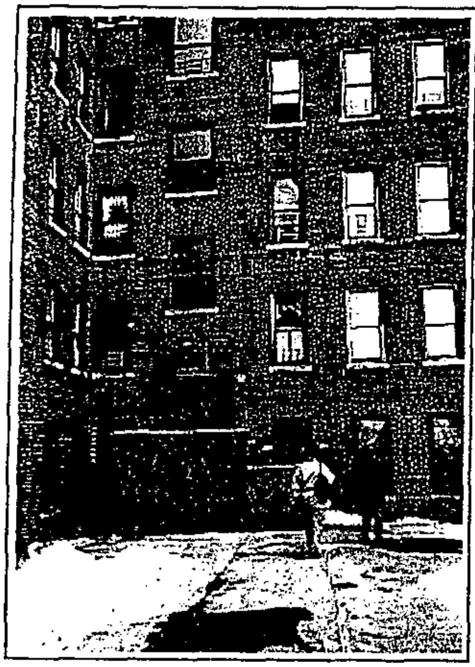
Row houses tend to be among the most wasteful and leaky housing stock in the country. Accordingly, extensive air sealing measures were undertaken on virtually all weatherization jobs performed in 1989. The work is complicated in that some air leakage may be conditioned air from an adjoining house, a fact that affects both energy use and indoor air quality. In addition, part of the inherent architectural charm of row houses, including such details as porches and bay windows, can mask subtle convective and conductive problems. Thus, air sealing these homes requires special care and sealing techniques.

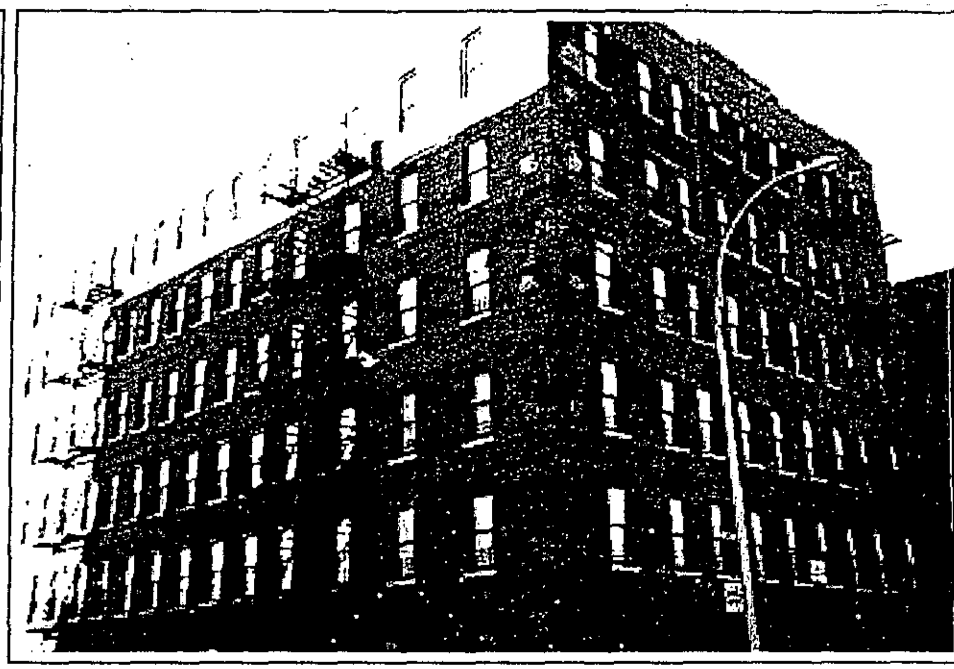
In 1989, "first time" attic insulation was installed at higher rates in row houses than in any other type of housing, pointing out their poor thermal condition. In addition, roof repairs were used more frequently for row houses than for other housing types. A major source of energy waste in older row houses occurs when their flat roofs leak water, ultimately causing ceilings to fall. This allows stack-effect infiltration to have devastating effects on the fuel bill. As explained on page 30, stack-effect infiltration results from the rising of warm air in the interior, pulling in air at the bottom of the conditioned envelope and exhausting warm air at the top. Pressure differences at the top and bottom are at their maximum, which makes holes in these areas critical to repair.

Measures for Large Buildings

The weatherization of large multifamily buildings, those with five or more units, presents local agencies with challenges different from those presented by smaller dwellings. Most of the work is accomplished in distressed urban areas where both buildings and much of the surrounding communities suffer from maintenance problems and even abandonment. Consequently, facade facelifts in the form of window repair and replace-

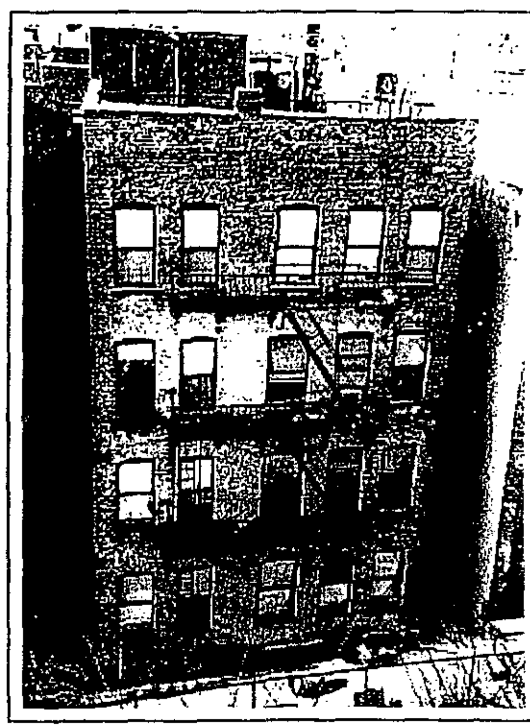
LARGE MULTIFAMILY BUILDINGS





This large building in the Bronx was almost ready for abandonment when weatherization played a key role in its restoration.

This is a large multifamily dwelling in Holyoke, Massachusetts, which was weatherized by HAP Inc., from Springfield, Massachusetts.

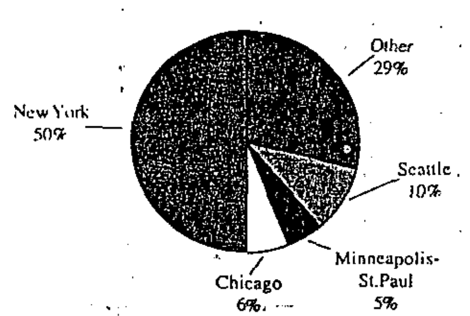


This is the back of a four-story building in Brooklyn. After air sealing, boiler, and window replacements, the energy expenditures for this building are approximately 40 percent less than the previous year's fuel expenditures.

ment has been the focal point of most large multifamily operations, accounting for 80 percent of material expenditures in Program Year 1989 in which 20,000 units in multifamily buildings were weatherized (MacDonald, 1993). In rental units, which dominate in multifamily buildings, local agencies have special safeguards in place to ensure that energy saving benefits are passed along to the tenant. In addition, a significant landlord financial contribution to the project is often required.

The diversity of housing stock and approaches to weatherization found in single-family housing also holds true in the multifamily sector, where the unique features of the urban environment require especially creative responses. This diversity is illustrated by findings from three case studies summarized below (Kinney et al., 1994).

50 Percent of Multifamily Weatherizations Take Place in New York and the Rest in Other Large Cities



Multifamily Weatherization Takes Place in Large Cities

The New York City weatherization operation, with its 22 local agencies, accomplishes over half of the multifamily weatherization work done nationally by the Weatherization Program. The need for such services is apparent. New York City has 126,000 multifamily buildings with more than 1.9 million apartments. An average apartment uses over 865 gallons of fuel oil (or its equivalent) annually for heat and domestic warm water, a startlingly large number for the climate and average apartment size. This inefficiency makes multifamily buildings very good targets for cost-effective conservation retrofits.

The trend in current multifamily weatherization operations in New York City is to concentrate on the heart of the building, the boiler room, and on its arteries, the distribution system. Poorly designed, controlled, and maintained heating systems are a major culprit in causing some buildings to consume five to six times as much energy as their neighbors. In response, professional energy auditors using state-of-the-art testing equipment and EA-QUIP analytical software undertake building audits that result in detailed work orders. These include computations of costs and benefits of all retrofit measures anticipated and specifications of each element of the proposed work. These work orders, most of which are accomplished by the staff of the New York City Weatherization Coalition, are instrumental both in ensuring that resulting weatherization work meets rigorous standards and in leveraging funding from building owners.

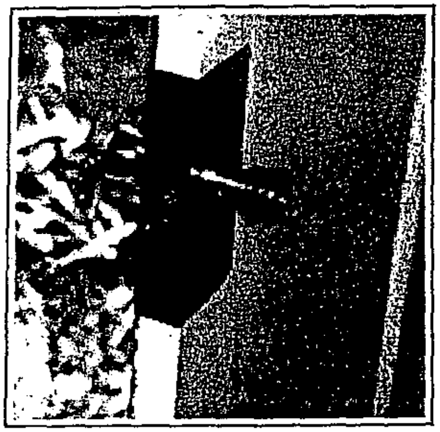
In Chicago, the City government administers the Weatherization Program, serving single-family, smaller, privately owned multifamily buildings (typically three and four story walk-ups), and larger public housing projects managed by the Chicago Housing Authority. Because of the Program's excellent reputation for quality performance, a waiting list of over one year for weatherization services has resulted. Buildings on the waiting list are served on a first-come, first-served basis.

Past weatherization measures were concentrated at the apartment level with strong emphasis on storm and replacement windows.

DOORS AND WINDOWS

Although most dwellings require air sealing, insulation, furnace retrofits, and at least minor repair work, exactly which tactics to employ is a decision that depends on the circumstances of the dwelling, the funding of the agency, and the **know-how of the auditor and crews**. The National Evaluation, plus testimony from experienced practitioners in the field, has shown that cookbook procedures employed in the early days of the Program—weatherstripping, caulking, and storm windows—were only marginally effective. Audits using advanced diagnostics direct crews to the real problems in a dwelling and usually result in more cost-effective work.

Window and door repair is a necessary part of most weatherization operations, but many agencies have abandoned the practice of routinely installing storm windows and exterior doors because they have found these measures do not save as much as many other less costly conservation measures.

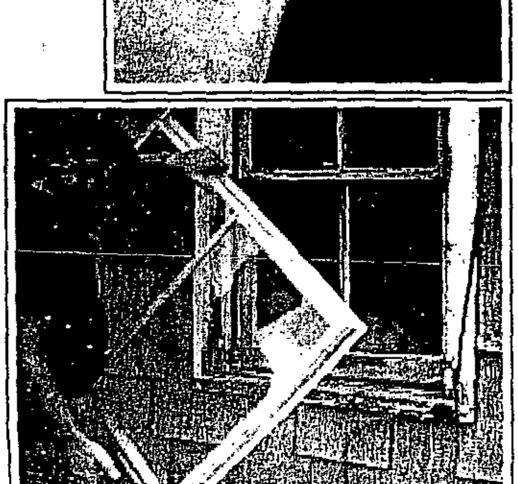


A new lock set is only marginally cost effective as a weatherization measure (it can aid in air sealing), but since it supplies a measure of security, this repair can be the most important one for client. Sometimes a new door performs a similar security function.

When doors and frames are in this condition, weatherizatio jobs include replacement of both.

Although this storm window is still functional, missing window trim and a rotten sill plate have done substantial damage. The sash weight is visible from the outside of this dwelling.

Glass replacement is inevitably time consuming but necessary. Most agencies rebuild the sash to ensure good air sealing.



When window frames are out of square in an older home—usually due to foundation problems—some agencies try to repair the primary window and install new storm windows.

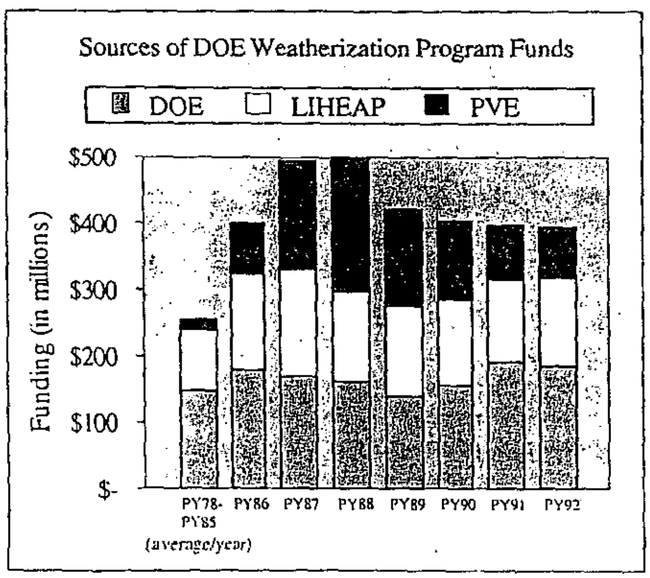
This basen window wi be replace by fixed-board insulation sealed in place by foam.

The new policy in Chicago is to weatherize whole buildings, which allows for working on heating systems before treating thermal losses in apartments. Frequently, the new policy results in the replacement of large, inefficient boilers and the integration of modern electronic controls. In all cases, whenever major measures such as boiler replacements or large-scale window replacements are undertaken, building owners are required to bear 50 percent of the costs. In smaller buildings where tenants can control their own heat, digital thermostats are frequently installed.

Weatherization agencies in Minnesota weatherize about 1,000 large multifamily units each year, most of which are in the Minneapolis-St. Paul area. These units range from row houses to 20-story high-rise buildings, but the most common are two- and three-story frame walk-ups with brick facades. Larger building work concentrates on boiler repair, controls, and distribution systems, with little emphasis on window repair work or even air sealing. Smaller buildings are air sealed (with emphasis on attic bypasses) and insulated like single-family dwellings. Multifamily work is guided by information from fuel bills and instrumented audits.

Weatherization of large buildings in our nation's largest cities is a complex process. There is a growing cadre of technically competent engineers and contractors that is involved in the Weatherization Program's large multifamily retrofits. These individuals practice such important crafts as making single-pipe steam systems work efficiently. When their practical wisdom is communicated clearly to building supervisors, systems tend to be maintained much better, with the consequence that savings endure. These long-term energy savings can play a key role in the revitalization of distressed neighborhoods in our nation's larger cities.

B. Sources of Funds

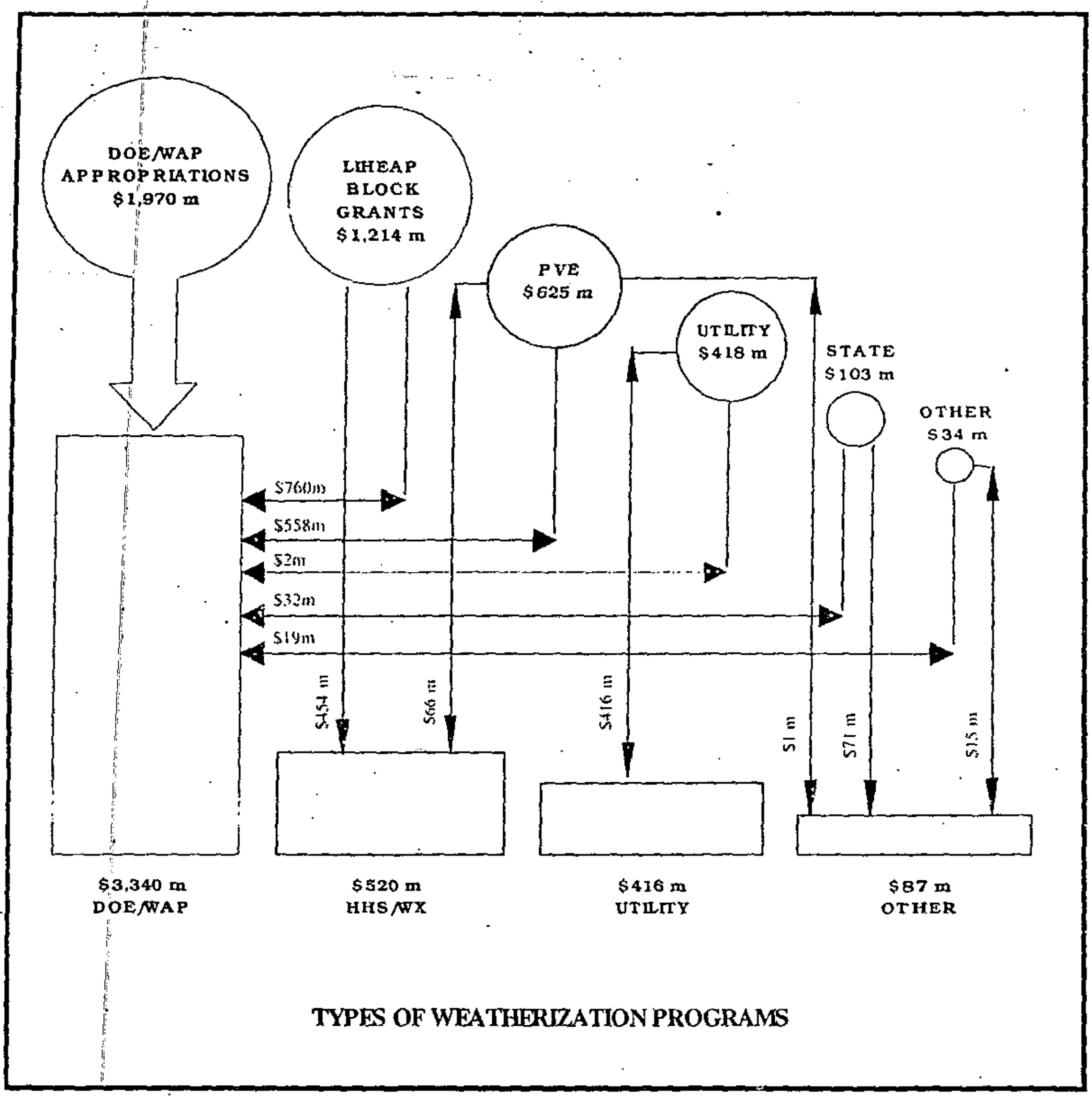


Three Major Sources of DOE Weatherization Program Funds, 1978 to 1992

To implement the Weatherization Program, DOE provides money to State Weatherization Agencies, more than 80 percent of which are located within executive departments responsible for human services, community development, or economic development. In turn, these agencies allocate funds to local agencies, of which 81 percent are private, nonprofit Community Action Agencies. Most of the remaining entities are local or county governmental agencies and Native American tribes. The weatherization work is done by employees of these local agencies or by contractors.

Although other organizations fund and implement low-income weatherization programs, DOE has been the dominant source of funding for low-income weatherization. Between 1978 and 1996, DOE provided 45 percent of total funding. More investment was made in low-income weatherization in the late 1980's than in earlier years, and considerably less in the 1990's than in the 1980's. More homes have been weatherized in cold states than in warm states, which partly reflects the formula used to allocate DOE's funds in the 1980's. That formula

SOURCES OF WEATHERIZATION PROGRAM FUNDS PY 1978-1989



Definitions of Program Types:

DOE/WAP = funds spent under DOE Weatherization Program rules and regulations.

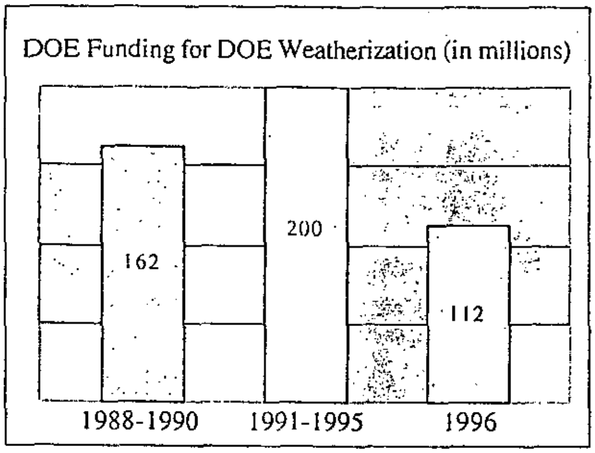
HHS/WX = funds spent under HHS LIHEAP guidelines and not DOE's rules and regulations.

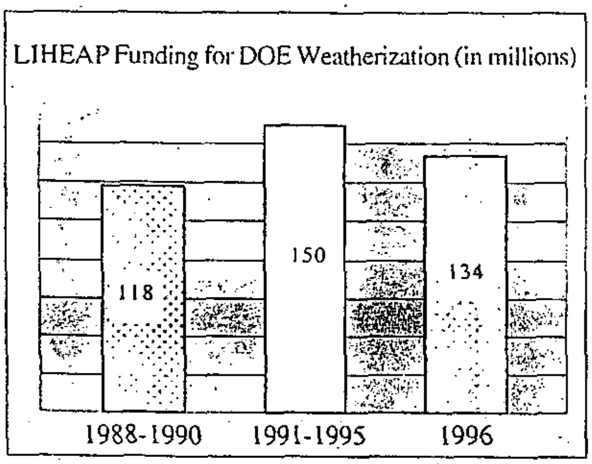
Utility = funds spent in utility programs independent of DOE's rules and regulations.

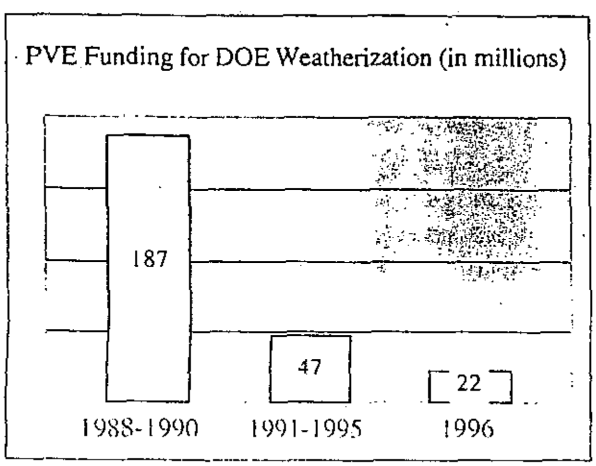
Other = funds spent in state weatherization programs or other independent programs.

weighted heating degree days much more heavily than cooling degree days. In 1995, the funding formula was changed to increase the proportion of funding going to warm climate states. The intent of the changes was to provide warm climate states with a greater share of the funding while protecting the Program capacity of the states with cooler climates. The revised formula emphasizes all residential energy expenditures (including heating and cooling costs). It provides states with a fixed base amount derived from the FY 1993 allocation. Funds in excess of those needed to meet the base amounts are allocated according to the revised formula. On a national level, DOE funding for its 1996 program totaled $111.5 million, which compares to DOE funds of $214.8 million in 1995. This nearly 50% reduction in funding in one year's time was the result of budget cuts passed by the 104th Congress.

Major Funding Sources for the DOE Weatherization Program Decreased Sharply in 1996



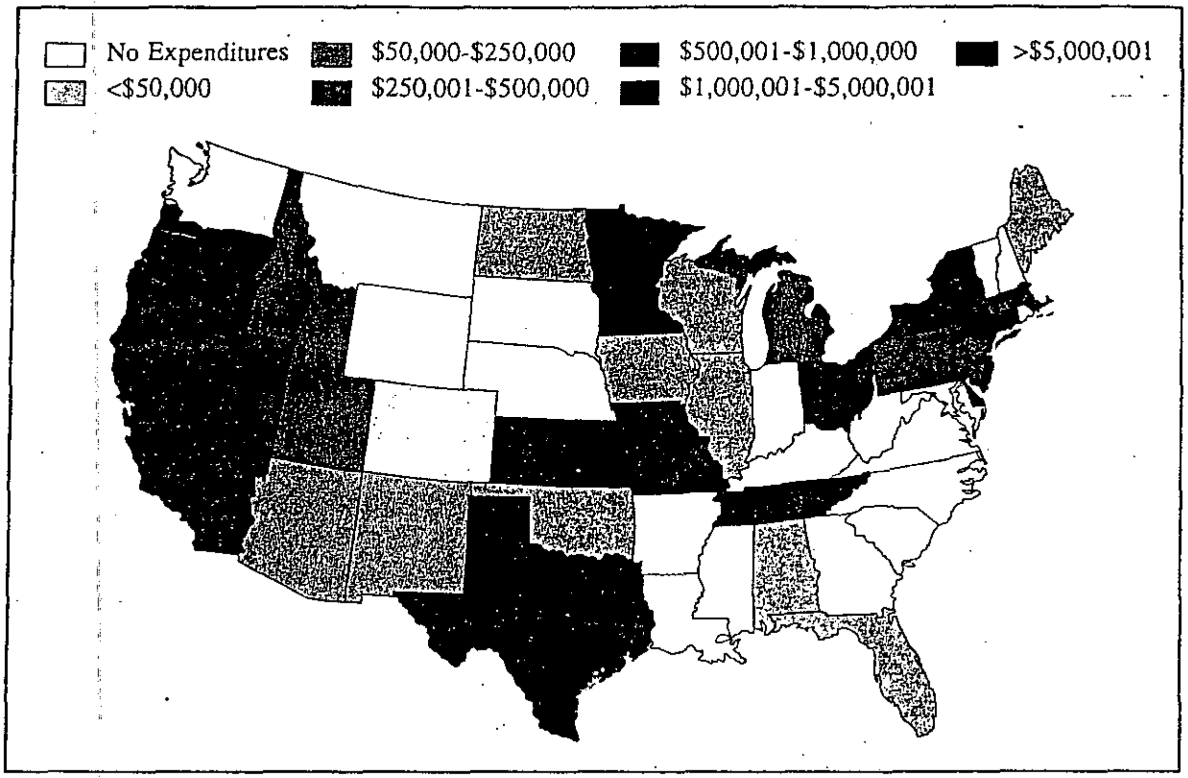




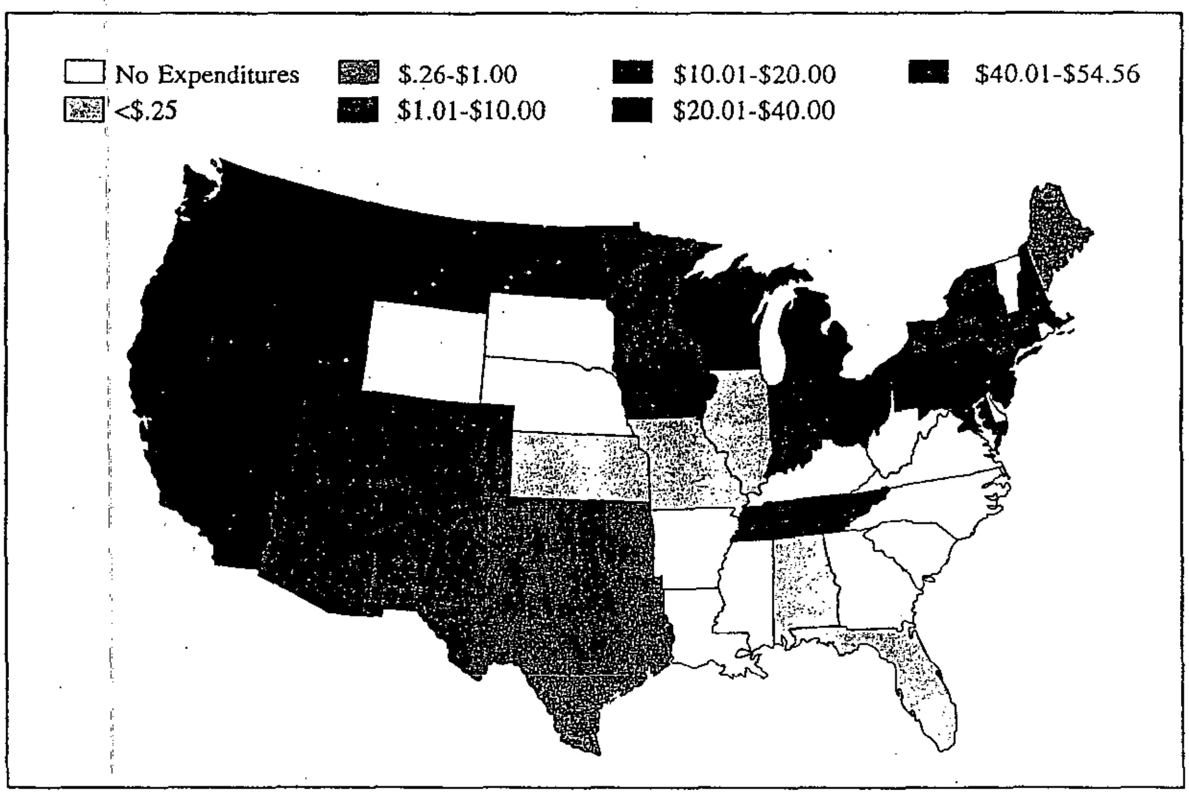
In the 1980s a major source of weatherization resources was the **Low-Income Home Energy Assistance Program (LIHEAP)**, administered by HHS. Since 1982, states have had the flexibility to allocate up to 15 percent of LIHEAP funds (now 25 percent after receiving a waiver) to energy conservation measures. Total LIHEAP funding peaked in 1987 and has since declined. In 1996, LIHEAP funds were about 72% of what they were in 1989. In spite of the reduction in total LIHEAP funding, however, the amount of LIHEAP funding spent on weatherization has actually increased. In 1989, $106.1 million in LIHEAP funds were spent on weatherization. In 1996, $134.0 million in LIHEAP funds were used for weatherization. This increase in LIHEAP contributions to weatherization, during a time when its overall budget declined, suggests that weatherization is seen as an especially effective way of producing a long-term reduction in the energy burdens of low-income households.

A third major source of weatherization money in the 1980s was the **Petroleum Violation Escrow (PVE) Fund.** These funds came from legal penalties assessed against oil companies convicted of violating price controls. The exhaustion of PVE funds devoted to low-income weatherization on a one-time basis was the most dramatic cause of the decline in total weatherization funding from 1987 to 1992. State program managers indicated that total funding for low-income weatherization dipped 30 to 40 percent between 1990 and 1994, primarily because of the exhaustion of PVE funds.

Utilities provided 9.6 percent of funding available for low-income weatherization between 1978 and 1989. Utility programs and funding were responsible for 22 percent of all units weatherized during that 12-year period. Among the 49 utilities that spent $418 million on energy measures between 1978 and 1989 the average investment per unit was only about one-third as much as in the DOE Weatherization Program. A small amount of funding for low-income weatherization came



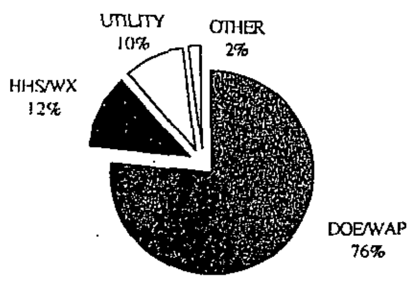
Geographic Distribution of Utility Expenditures on Low-Income DSM Programs in 1992



Geographic Distribution of Utility Expenditures per Low-Income Household in 1992 from miscellaneous other sources, including owners of rental housing weatherized under the Program and state weatherization programs, which in some cases emphasized comprehensive home repair or heating system retrofits.

The impending restructuring of the electric utility industry poses uncertain prospects for continued utility funding of low-income programs. Past programs to assist low-income households with energy efficiency have been funded through regulated utility rates, but obtaining low-income funding may become more difficult in a more competitive and less regulated industry structure. The Weatherization network has been actively presenting low-income interests and concerns to policymakers in state regulatory commissions and legislatures. As a result of these efforts, restructuring programs in states such as California and Massachusetts, which have been the first to initiate restructuring, have continued funding for low-income energy efficiency. The Weatherization network also continues to be successful in securing funding from utilities in other states where the pace of change is slower and traditional regulation remains firmly in place.

FULL SCALE WEATHERIZATION
BY PROGRAM PY1978-PY1989



$4.364 Billion

C. Uses of Funds: DOE Sets the Pace

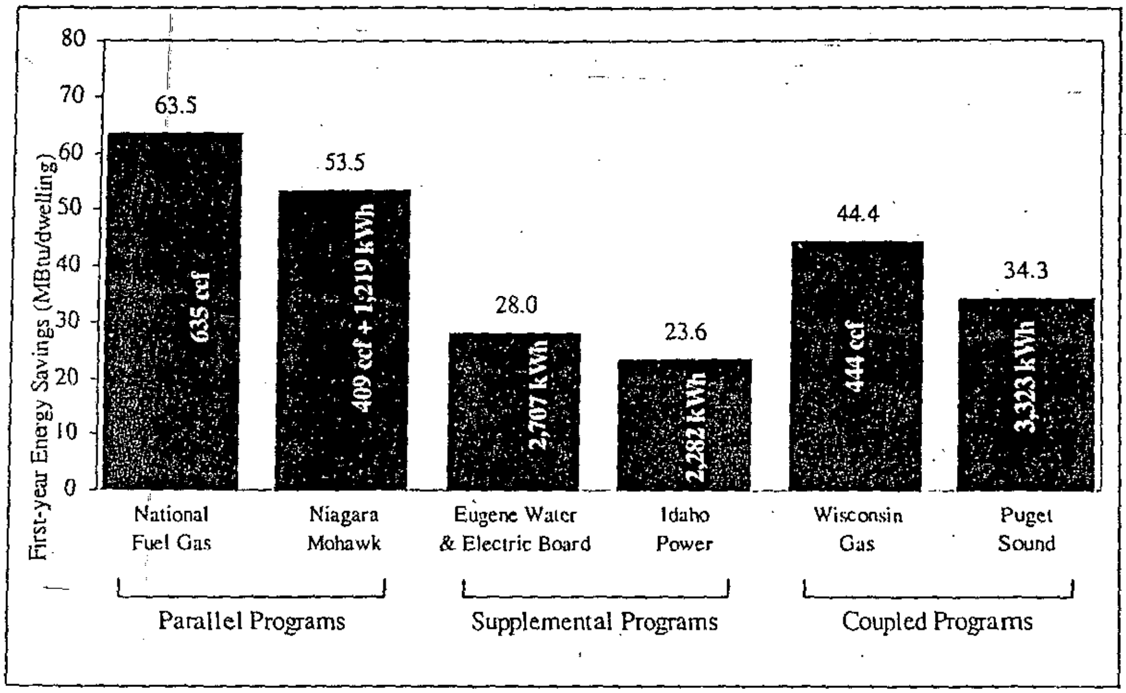
Regardless of its source, most funding for low-income weatherization has been spent according to DOE's Weatherization Assistance Program rules. By law, all funds appropriated to the Program by DOE are governed by DOE rules and regulations. In contrast, funds appropriated by LIHEAP can be spent by that program's much broader guidelines, which have allowed, for example, greater expenditures on furnace and boiler retrofits and replacements. Similarly, utility low-income DSM programs and state funding for weatherization can be spent as the funding agency deems appropriate.

In practice, 76 percent of all low-income weatherization money spent in the 12-year period between 1978 and 1989 was guided by DOE rules and procedures. Before 1989, about 12 percent was spent in programs under LIHEAP regulations. Today the percentage of funds spent under LIHEAP regulations has risen to 35 percent. DOE's central role in directing weatherization activities nationwide is underscored by the fact that the vast majority of non-DOE funds have been channeled through the Program. This distribution process also indicates the importance of the new Program rules in guiding future weatherization activities.

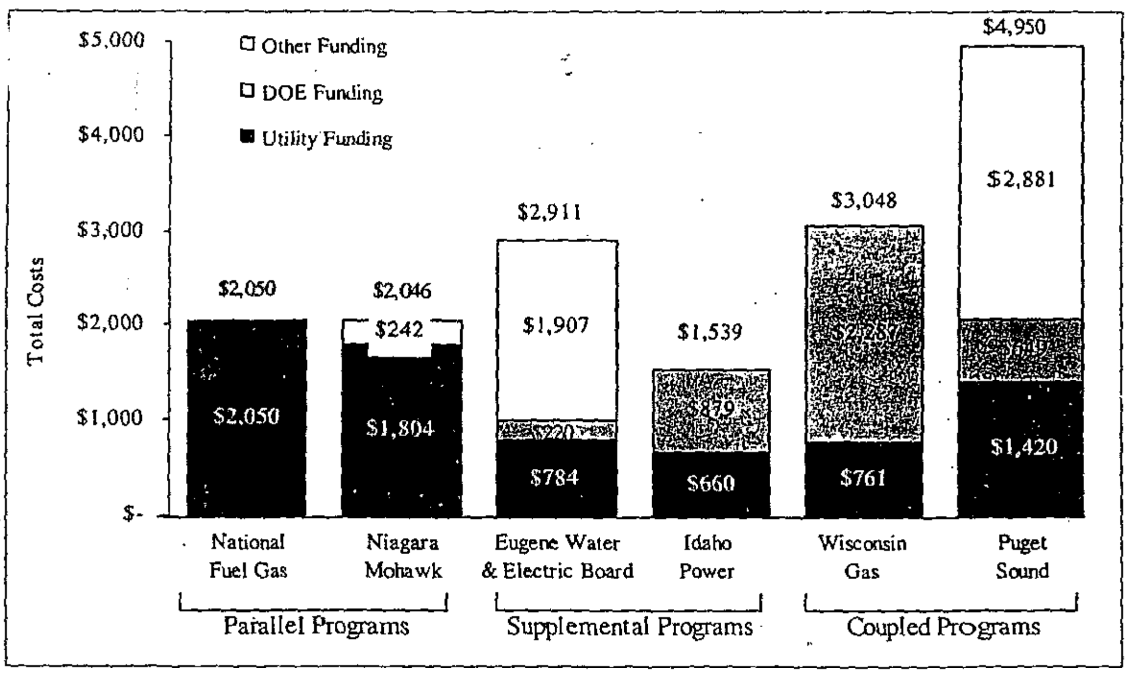
D. Utility Partnerships

Utility programs made significant contributions to the effort to weatherize low-income dwellings. According to Power et al. (1992), 102 utility low-income energy-efficiency programs operated in 1989, with investments totaling $97 million (or $109 million, expressed in 1992 dollars). By 1992, these numbers had increased to 132 programs with an annual expenditure of $141 million (Brown et al., 1994).

PROFILES OF SIX COORDINATED PROGRAMS



First-Year Energy Savings of Six Coordinated Programs



Costs of Six Coordinated Programs by Source of Funding

Utility programs tend to be concentrated in a few states where weatherization services for low-income customers have been mandated by regulatory bodies. On average, utility-sponsored low-income programs invest about one-third as much per dwelling as the DOE Program. Unlike the DOE Weatherization Program, many of the electric utility programs for low-income customers focus primarily on lighting and appliance measures. Water-heating measures (particularly low-flow showerheads) are common to both gas and electric utility low-income programs. "Major" measures such as attic, wall, and floor insulation and storm windows are less common in these utility programs than in DOE's Weatherization Program.

By pooling utility and government resources in "coordinated" programs, utilities are able to offer more comprehensive weatherization to their low-income customers. Three types of utility low-income partnerships exist, which involve varying degrees of coordination between government and utility cosponsors (Brown and Hill, 1994).

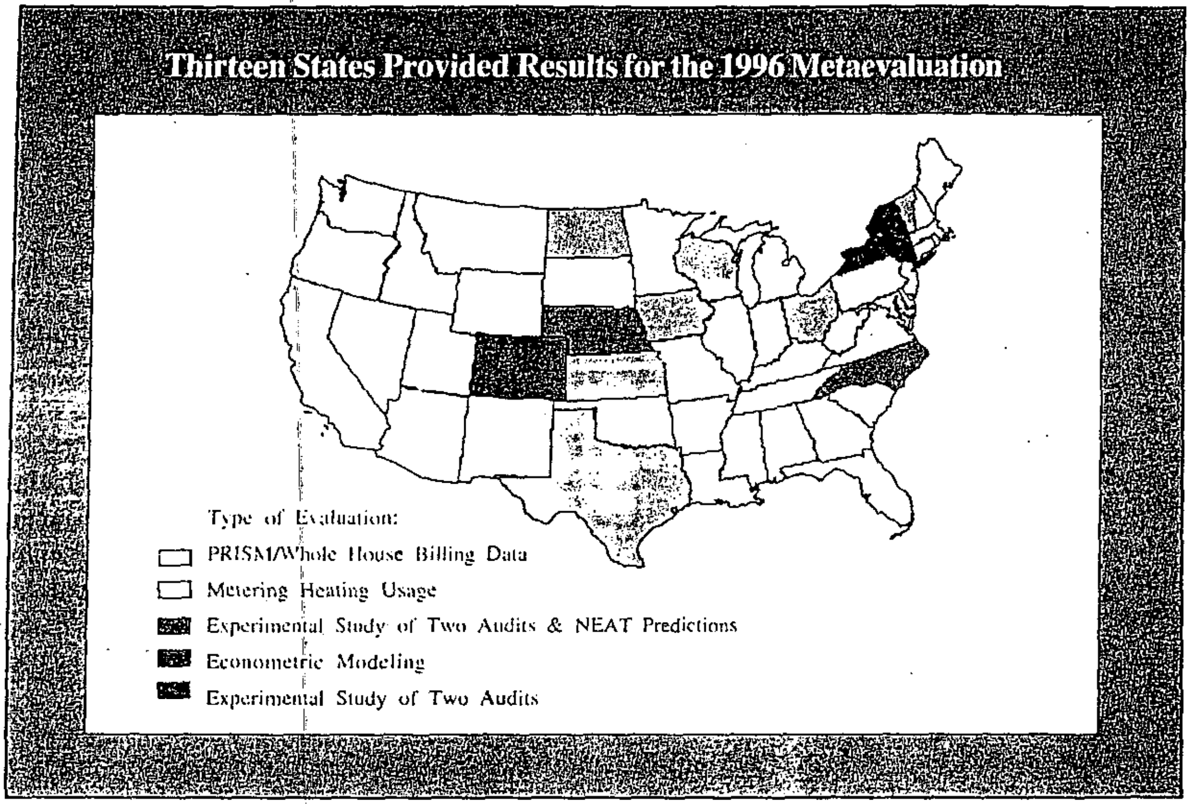
•**Parallel Programs.** In these cases, the local weatherization agency operates two parallel programs--one funded by government grants and the other funded by utility contracts. The utility simply employs the agency as a subcontractor to deliver energy-efficiency services to low-income households. The utility-funded program is coordinated in the sense that some of the same staff and equipment are used by both programs.

•**Supplemental Programs.** These programs use utility funds to supplement the agency's government-funded weatherization program, with no changes to the operation of that program. The result is more weatherized homes, more comprehensive weatherization, or both.

•**Coupled Programs.** These programs employ a combination of utility and government funds to deliver weatherization services as part of an integrated program that is distinct from the agency's preexisting government-funded program. This type of program has the potential to outperform parallel and supplemental programs by taking advantage of the unique capabilities of each cosponsor.

Each of these types of coordinated programs provides utilities with access to trained weatherization professionals and associated equipment, which is often quite sophisticated and conducive to high-quality weatherization. In many regions of the country, there is a scarcity of such capability. In addition, community action agencies are often uniquely qualified to tackle the problems associated with substandard shelter.

Brown and Hill (1994) conducted case studies of six coordinated low-income weatherization programs. All six programs achieved impressive levels of energy savings. For the three coordinated gas programs, annual savings ranged from 409 to 635 ccf (hundred cubic feet) per dwelling, and for the three electric utility programs, annual savings ranged from 2,282 to 3,323 kWh (kilowatt-hours) per dwelling. Costs for the six coordinated programs ranged widely from $1,539 to $4,950 per dwelling. This range of costs is high relative to the amount typically spent in the DOE Weatherization Program, which averaged $1,550 per dwelling in 1989. In



Estimated National Program Energy Savings in 1989 and 1996 in Homes that Heat Primarily with Natural Gas

	Mbtu of Natural Gas Saved per Dwelling	Percentage Reduction in Natural Gas Consumption for Space Heating	Percentage Reduction in Natural Gas Consumption for All End Uses
National Evaluation Results for 1989	17.3	18.3%	13.0%
Metaevaluation Results for 1996 Based on Regression Model	31.2	33.5%	23.4%

addition, it is much higher than the typical investment levels of stand-alone utility-operated low-income weatherization programs.

The utilities and community action agencies managing each of the six coordinated programs indicated that the benefits of coordination far outweighed the costs.

Need to Update National Estimate of Savings

- National Evaluation estimated savings for homes weatherized in 1989.
- Program performance has improved during the last seven years.

Objectives of Metaevaluation

- Locate state-level evaluations
- Review evaluations
- Organize findings
- Develop method of applying state-level findings to nation
- Estimate regression models
- Apply model results to national inputs to develop national estimate

Ten States With One Evaluation

- Colorado (1993-1995)
- Indiana (1991-1992)
- Kansas (1992)
- Nebraska (1994)
- New York (1990)
- North Carolina (1990)
- North Dakota (1990-1992)
- Texas (1991-1992)
- Wisconsin (1992)
- Wyoming (1996)

Three States With More Than One Evaluation

- Iowa (1992-93) and (1995)
- Ohio (1990-91), (1993-94), and (1994-95)
- Vermont (1992-93) and (1993-94)

IV. METAEVALUATION METHODS AND RESULTS FOR 1996

A number of state Program offices conduct periodic evaluations of the energy savings produced by their efforts. With the help of these offices, a metaevaluation of 17 state-level evaluations conducted since 1990 was recently completed for DOE by Oak Ridge National Laboratory.

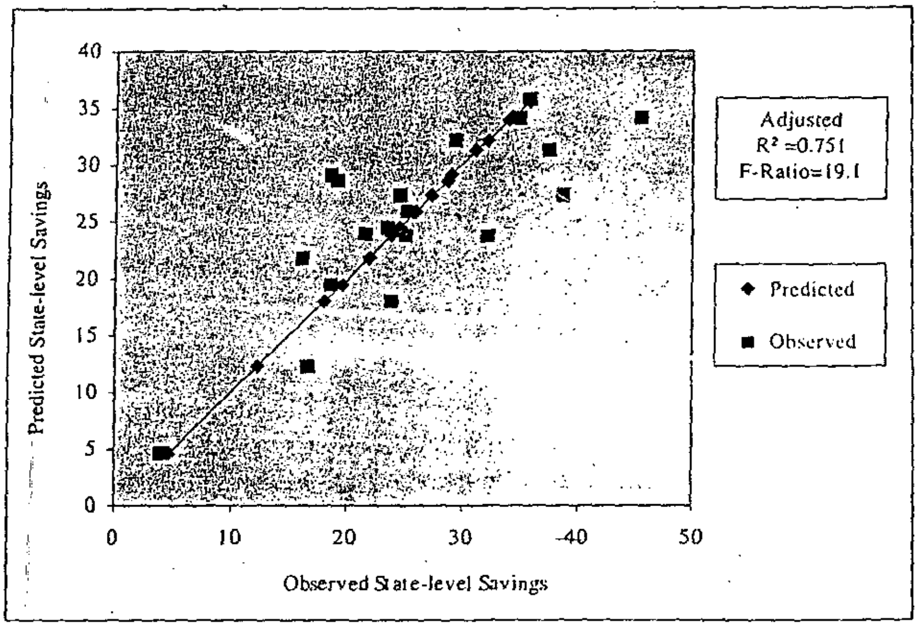
The state-level evaluation results were used to produce the estimate of national savings for 1996 discussed below (Section A). This estimate was developed by summarizing and integrating the findings of the state-level evaluations (Berry, 1997). The results are only for homes heating with natural gas, the only fuel for which all of the state-level evaluations provided results. Three of the thirteen states with evaluations conducted since 1990 had evaluated their Program more than once in the last seven years.

The approach chosen to estimate the 1996 national savings was to use regression modeling to develop the best linear equation for predicting savings. The data from the 17 recent state-level evaluations (1990-1995) were used to develop this predictive tool. Then the parameters of the best predictive model were applied to the appropriate average national input values for each predictor in the equation. For example, the average heating degree days for the available evaluations was 5,942. Nationally, the population weighted 30-year average of heating degree days is 4,499. Therefore, the national average of 4,499 heating degree days was used as the input to the regression model used to predict national savings. For the most part, national input values were taken from the National Evaluation, which was based upon a representative national sample. Details of model development and of the rationale for selecting specific national input values are given in Berry (1997).

A. Three Methods Show Trend Toward Higher Savings

Regression Analysis. **The key finding of the Metaevaluation's regression analysis is that, in the last seven years, improved practices have produced 80% higher average energy savings per dwelling.** The most recent comprehensive evaluation of the Program was based on an analysis of changes in pre- and post-weatherization energy consumption for a representative national sample of homes weatherized in 1989. This National Evaluation found that dwellings that heated primarily with natural gas, which made up over 50% of the national sample, had average savings of 17.3 Mbtu per dwelling, which was 18.3% of space heating consumption, or 13.0% of the total consumption of natural gas for all end

Predictive Value of Fit for the Three-Variable (Pre-Weatherization Consumption, Year, Audit Type) Regression Model



Literature Review Findings on Central Tendencies Characterizing the Percentage of Energy Savings in 1981-1989 and in 1990-1996

	n	Median	Mean	Interquartile Range	Range
1980-89	25	12%	13%	12-16%	6-23%
1990-96	17	20%	22%	18-24%	13-34%

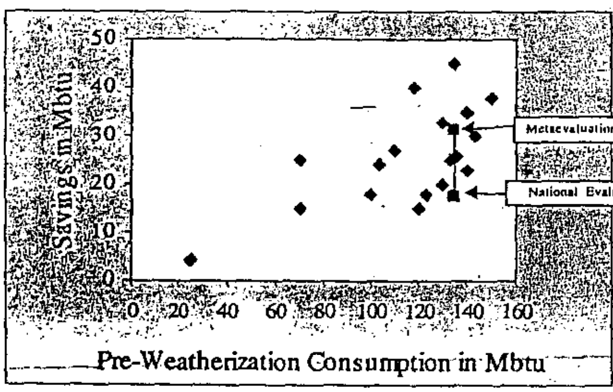
Upward Trends in Energy Savings in Ohio, Vermont, and Iowa

Ohio			Vermont			Iowa		
	Mbtu	Percent		Mbtu	Percent		Mbtu	Percent
1990-91	20.5	12.6%	1992-93	18	17.8%	1992-93	25.2	18.6%
1993-94	29.3	20.4%	1993-94	24.5	20.1%	1993-94	n/a	n/a
1994-95	31.0	22.5%	n/a	n/a	n/a	1995	27.3	21.7%

uses (Brown, Berry, Balzer, and Faby, 1993). The Metaevaluation of state-level evaluations of the Program, which developed a regression-based national estimate of savings, indicated that savings in 1996, in homes using natural gas as the primary heating fuel, were 31.2 Mbtu, which was 33.5% of natural gas space heating consumption, or 23.4% of the total consumption of natural gas for all end uses (Berry, 1997).

Literature Review Findings. In addition to the regression modeling results summarized above, two additional types of evidence (from a literature review and from comparisons within the same state over time) demonstrate the trend toward increased Program energy savings.

At Same Levels of Pre-Weatherization Consumption, Most Evaluations Completed Since 1990 Show Higher Savings Than in 1989



Six years before conducting the 1996 Metaevaluation, ORNL completed a similar task in preparation for the National Evaluation. That task was a literature review (which was completed in 1990) and is presented in Section 1.4 of Brown et al., (1993). Comparisons of findings from the 1990 and 1996 literature reviews show a trend toward increased savings. The 1990 literature review concluded that the state-level evaluations available at that time (covering the years of 1981-1989) showed typical energy savings (expressed as the percentage reduction in the total consumption of the primary heating fuel) of between 12% and 16%, with a range of 6% to 23% savings in various locations. The 1990 literature review also concluded that a number of demonstration projects indicated that the Program could potentially achieve much greater savings (25% to 40%). The similarity in findings from that literature review (i.e., expected average savings of 12% to 16%) and the results of the National Evaluation (13.0% of the total consumption of natural gas for all end uses or 18.3% as a percentage of consumption for space heating) created confidence that a review of the state-level evaluations conducted since 1990 would also yield a reasonably accurate current estimate of national savings. The 1996 review of state-level evaluations covering weatherizations performed in 1990 through 1996 showed typical savings of 18% to 24% (expressed as the percentage reduction in the total consumption of the primary heating fuel), with a range of savings from 13% to 34%.

1996 PROGRAM IMPROVEMENTS/NONENERGY BENEFITS

Some Reasons for Improved Program Performance in 1996

Shift From Priority Lists to Advanced Audits
- No advanced audits in 1980's
- 37 States used advanced audits in 1996

More Use of Blower-Door Directed Air Sealing

Increased Targeting of Dwellings With High Potential for Savings

Revised DOE Regulations That Promote More Cost-Effective Tailoring of Measures to the Specific Needs of Individual Dwellings and Regions
- Removed barriers to heating system efficiency measures
- Allowed cooling measures
- Promoted use of advanced audits

Nonenergy Benefits are Numerous and Important

Affordable Housing
- maintain or enhance residential property values
- extend the lifetime of low-income housing
- decrease homelessness and mobility

Improving Comfort, Health, and Safety
- improve livability and thermal comfort of homes
- prevent fires
- reduce CO hazards from defective and unvented heating systems

Impacts on Household Budgets
- increase resources for nonenergy expenditures

Utility Benefits
- reduce utility arrearages
- reduce utility terminations and reconnections

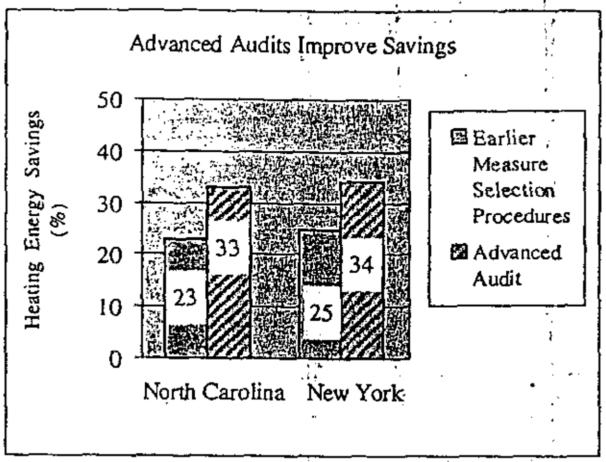
Employment and Economic Benefits
- increase economic output
- increase employment
- generate tax revenues

Environmental Benefits
- reduce emissions of combustion by products

Trends within States. Three states for which savings could be compared over time -- Iowa, Ohio, and Vermont -- all showed significant increases in savings. The trend toward increased savings over time in these states is unmistakable.

B. Reasons for Increases in Program Savings

Several reasons exist for the trend toward higher savings. Three important technical improvements are discussed below.



Advanced audits had not yet been introduced in 1989. Today 37 states use them. Two demonstration studies, one in New York and one in North Carolina, have shown the superior energy savings achieved with the use of advanced audit procedures (New York State Energy Research and Development Authority and New York State Department of State, 1993; Sharp, 1994). In North Carolina the introduction of an advanced audit increased heating energy savings from 23% to 33%. In New York, savings increased from 25% to 34%.

Blower-door directed air sealing is another important technology that has contributed to the trend toward increased savings. In 1989 only a few states used this technology; now most do. With the use of blower doors to guide air sealing, investments in air infiltration reduction will produce higher savings.

Targeting high-energy consumers is a Program management technique that produces higher savings. More agencies use this practice today. Many studies have shown that high pre-weatherization consumption is the best predictor of high energy savings (Brown et al., 1993; Columbia Gas of Ohio, 1995; Pennsylvania Public Utility Commission, 1994, Berry, 1997).

Additional reasons to expect a trend toward higher energy savings relate to the implementation of Program regulations designed to capture opportunities for improvement. Among the **revised DOE regulations** issued in 1994 were changes that promote the use of advanced audits and permit the use of **cooling efficiency measures** such as air conditioner replacements, ventilation equipment, and screening and shading devices.

C. Nonenergy Benefits of Weatherization

Most of the state-level evaluations did not address the issue of the nonenergy benefits of weatherization at all. Only one, the Iowa evaluation, gives much attention to nonenergy benefits. The Iowa evaluation notes that the potential benefits of weatherization include:

- improved client safety and health;
- reduced utility collection costs and write-offs;
- improved property value, longevity, and maintenance of affordable housing;

Summary of 1994 Regulatory Changes Governing DOE's Weatherization Program

	OLD RULES	NEW RULES[a]
Weatherization materials and measures	Services provided include: -air sealing -caulking and weather stripping -furnace and boiler tune-up, repair, and replacement -cooling system tune-up and repair -replacing windows and doors and adding storm windows and doors -insulating attics, walls, and foundations -client education	Added the following: -replacement air conditioners -ceiling, attic, and whole-house fans -evaporative coolers -screening -window films
Materials requirement	40% of funds must be spent on materials	Waiver of 40% requirement may be granted if an advanced audit procedure is used
Rental unit requirements and protections	Owner permission 66% of eligibility required for large multifamily units and 50% eligibility required for duplexes and four-unit buildings Weatherization benefits to accrue primarily to low-income tenants	Expanded renters protection -benefits and no rent increase even for renters paying for energy through rent -States may require financial participation from landlords
Eligibility and targeting	Up to 125% of poverty, or the state may elect to use LIHEAP eligibility criteria Special consideration given to the elderly and persons with disabilities	Special consideration also given to families with young children
Reweatherization	Allowed reweatherization of unit partially weatherized from September 30, 1975 to September 30, 1979	Cut-off date for reweatherization extended to September 30, 1985

[a]The final version of the new DOE rulemaking was published in the Federal Register of March 4, 1993.

- reduced environmental impacts from energy production and transport; and
- additional economic activity and jobs for Iowa.

Only the economic activity and job creation benefits were quantified in the Iowa study. Using an input-output analysis, the study concluded that each million dollars of Program spending produces about $240,000 worth of additional economic activity. This additional economic activity supports 5.6 additional jobs (The Statewide Low-Income Collaborative Evaluation (SLICE) of Iowa, 1994). The Iowa study did not assign a specific dollar value to any additional nonenergy benefits. However, it concluded that even conservative estimates of these nonenergy benefits would significantly increase the cost effectiveness of the Program.

In the National Evaluation, an effort was made to quantify the dollar value of some nonenergy benefits. The highest dollar values were assigned to employment and environmental benefits (Brown, Berry, Blazer, and Faby, 1993). The methods used to estimate the dollar value of the range of nonenergy benefits varied. These methods are explained in Chapter 6 of Brown et al. (1993). The final estimate of the net present value of all of nonenergy benefits that were monetized was set at $976 per dwelling in 1989 dollars. This is the estimate that is used in the next section to estimate Progam cost effectiveness from the societal perspective, which is the only perspective that includes nonenergy benefits.

D. Cost-Effectiveness Results

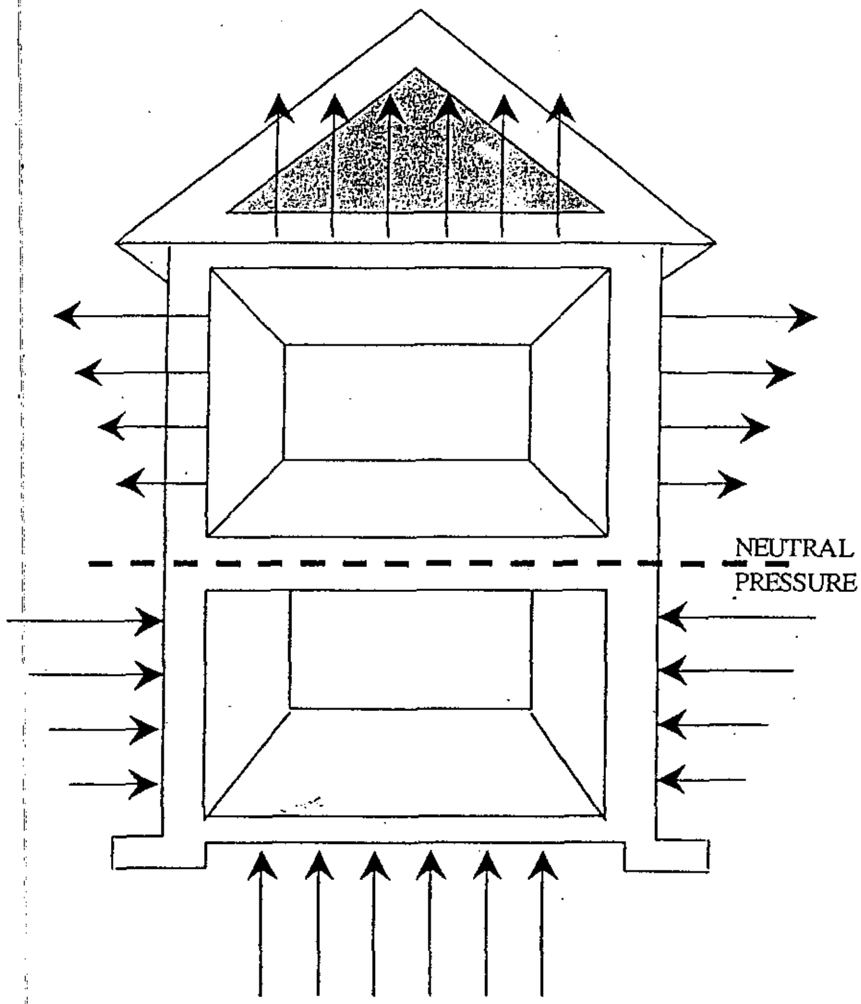
Because of the higher average national savings estimated for the Program in 1996, cost-effectiveness estimates also increased: The National Evaluation used three perspectives[1] for estimating cost effectiveness:

- the program perspective, which compares energy benefits to total costs;
- the installation perspective, which compares energy benefits to installation costs; and
- the societal perspective, which compares energy and nonenergy benefits to total costs.

[1] In the National Evaluation, three perspectives were used to develop benefit/cost ratios: the program perspective, the installation perspective, and the societal perspective. The program perspective compares the discounted value of energy savings to total program costs (including labor, materials, overhead, administrative, and all other categories of both fixed and variable costs). The installation perspective compares the discounted value of energy savings to installation-related program costs (i.e., *installation labor and materials costs*). The societal perspective compares the discounted value of both energy and nonenergy benefits (such as employment and environmental benefits) to total program costs (including labor, materials, overhead, administrative, and all other categories of both fixed and variable costs). All three perspectives used an assumed measure lifetime of 20 years and a discount rate of 4.7%. To make the 1996 benefit/cost ratios comparable to the National Evaluation ratios the same definitions and assumptions were used.

AIR INFILTRATION/EXFILTRATION

Stack Effect In Two-Story House



Very leaky houses are uncomfortable and have high energy bills, so finding and curing infiltration problems is a high priority for weatherization operations. The rate of air infiltration in a home depends on many factors, the most important being the size and location of holes in the thermal envelope and the difference in temperature between inside and outside. Warm air inside a dwelling gives rise to "stack effect" infiltration as it tries to escape from the top of the envelope, sucking in cold air at the bottom. Wind and leaks in duct systems can also have a major effect on infiltration, but these effects are not usually as constant over the heating season as is stack-effect infiltration, which is at its worst on coldest days.

Note that in the middle of the heated envelope there is a neutral pressure zone where neither infiltration nor exfiltration occurs due to stack effect. This explains why caulking and weatherstripping in mid-envelope tends to save less energy than careful attention to the bottom and top of the envelope, where these natural driving forces are greater.

Benefit/Cost Ratio for Gas-Heated Dwellings in 1989 and 1996

PERSPECTIVE	BENEFITS INCLUDED	COSTS INCLUDED
PROGRAM	Energy Savings Only	All Costs
	1989 Benefit/Cost Ratio = 1.06 1996 Benefit/Cost Ratio = 1.79	
	BENEFITS INCLUDED	COSTS INCLUDED
INSTALLATION	Energy Savings Only	On-Site Installation Costs
	1989 Benefit/Cost Ratio = 1.58 1996 Benefit/Cost Ratio = 2.39	
	BENEFITS INCLUDED	COSTS INCLUDED
SOCIETAL	Both Energy and Nonenergy Benefits	All Costs
	1989 Benefit/Cost Ratio = 1.61 1996 Benefit/Cost Ratio = 2.40	

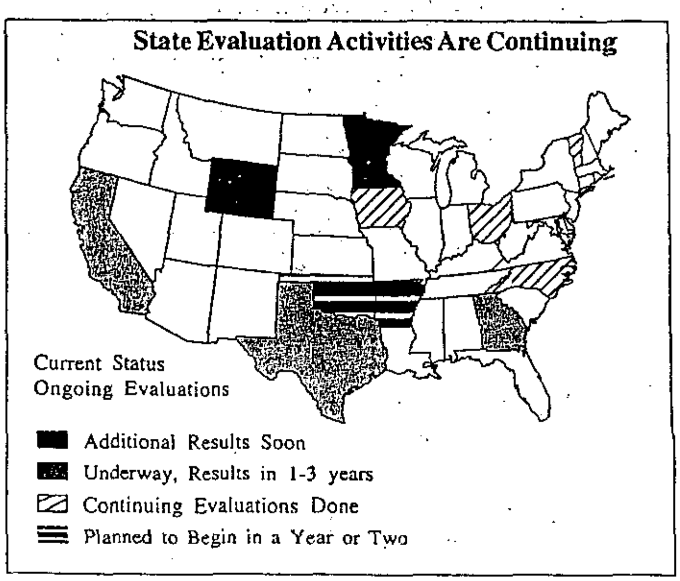
E. Conclusions from the 1996 Metaevaluation

All aspects of the Metaevaluation point to improved performance during the past seven years. **In spite of funding reductions, technical advances have produced 80% higher energy savings on a per dwelling basis. Increases in energy savings were achieved through better training, audit tools, and management practices with little increase in costs.** The trend toward increased savings was demonstrated in three ways:

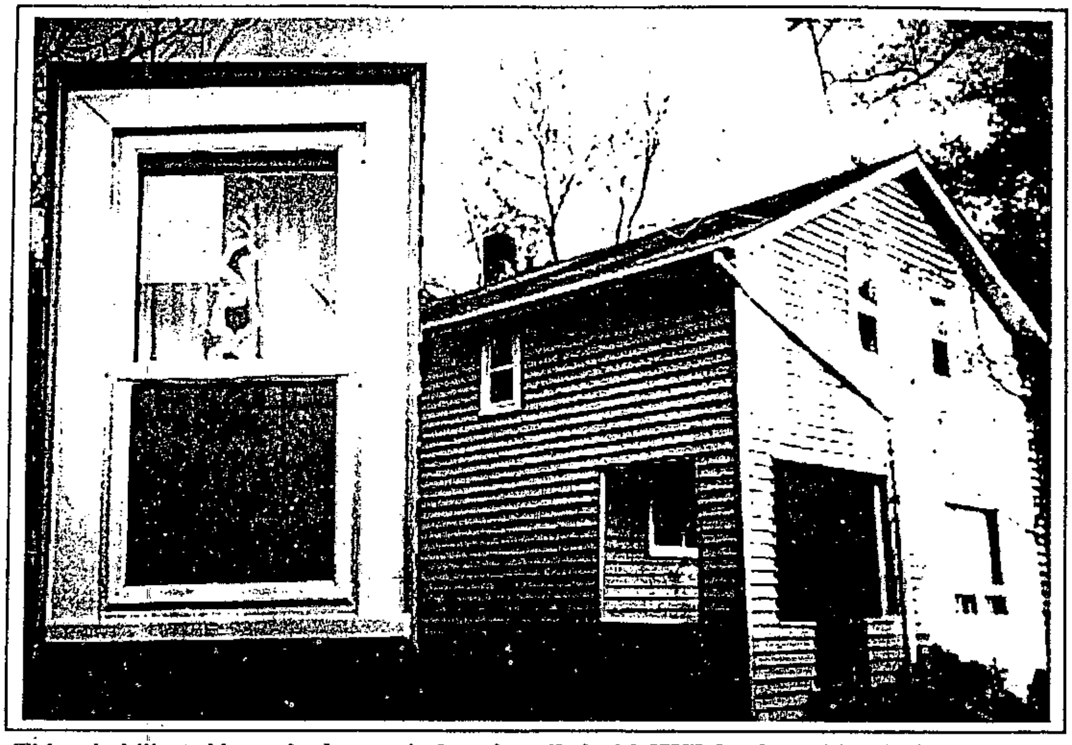
- regression modeling results obtained from a metaevaluation of 17 state-level evaluations;
- comparisons of a 1990 and a 1996 literature review of state-level evaluations; and
- comparisons of within state savings over time.

Each of these approaches pointed to significant increases in Program energy savings. As a result, Program benefit/cost ratios are even higher today than they were in 1989, with a 1996 societal benefit/cost ratio of 2.40.

The DOE will continue to monitor on-going state-level evaluation efforts and will conduct several cooperative state-level evaluations in the next few years. Results of additional state-level evaluations will be incorporated into the metaevaluation framework as they become available. Periodically updated metaevaluation results will be used to track Program performance.

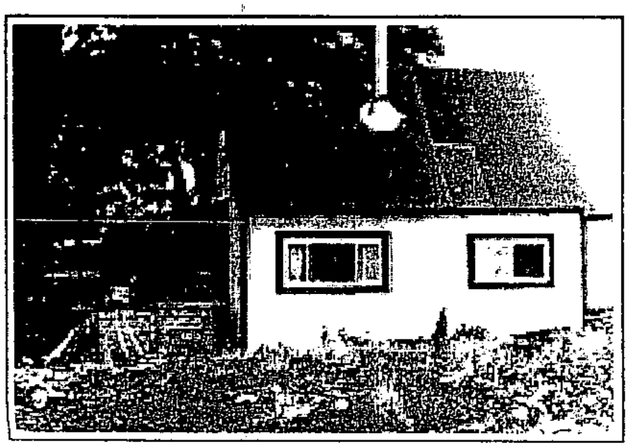


Housing Rehabilitation



This rehabilitated home had new windows installed with HUD funds, and insulation installed with DOE funds.

Before Weatherization



After Weatherization

This dilapidated home which received an impressive retrofit is one example of the substandard housing local agencies often serve. Holes in roofs, walls, and ceilings, and broken windows are common problems. Leveraged funds from non-DOE sources are often used to meet housing rehabilitation needs.

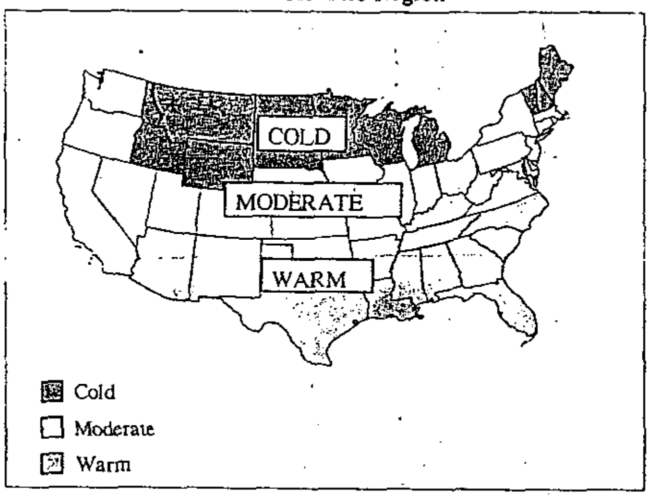
V. NATIONAL EVALUATION METHODS AND RESULTS FOR 1989

A. National Evaluation Process and Publications

The National Weatherization Evaluation was a comprehensive evaluation of the Weatherization Assistance Program, which was designed to accomplish the following goals:

- estimate energy savings and cost effectiveness;
- assess nonenergy impacts;
- describe the weatherization network;
- characterize the eligible population and resources; and
- identify factors influencing outcomes and opportunities for the future.

The National Weatherization Evaluation's Three Climate Region



Working groups with more than 30 nationally known evaluation specialists and conservation program professionals were formed to help define these goals. They gave guidance to the ORNL evaluation team in planning five major studies and in reviewing draft reports. The five studies were as follows:

Single-Family Study--this study estimated the national savings and cost effectiveness of weatherizing single-family and small multifamily dwellings that use natural gas or electricity for space heating.

Fuel-Oil Study--this study estimated the savings and cost effectiveness of weatherizing single-family homes in nine northeastern states that use fuel oil for space heating.

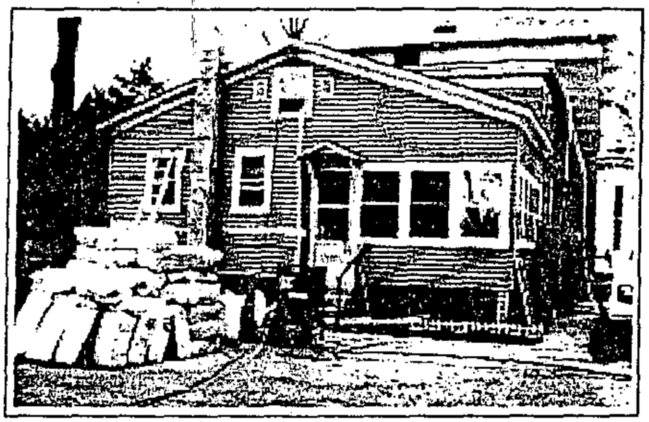
Multifamily Study--this study described the measures used, resources employed, and challenges faced in weatherizing large multifamily buildings.

Network Study--this study characterized the weatherization network's leveraging, capabilities, procedures, staff, technologies, and innovations.

Resources and Population Study--this study profiled low-income weatherization resources, the weatherized population, and the population remaining to be served.

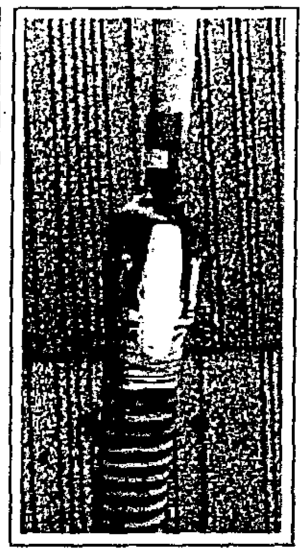
DENSE-PACK CELLULOSE

Installing cellulose at high density has been found to be a powerful technique for installing insulation and achieving air sealing at the same time. Many crews find that the infiltration rates of some houses can be cut in half without using a tube of caulk. The secret is careful installation of high-density cellulose in wall cavities (and other places where it really counts) with a tube inserted directly where the insulation needs to go--and using power blowing machines to pack it in tightly.

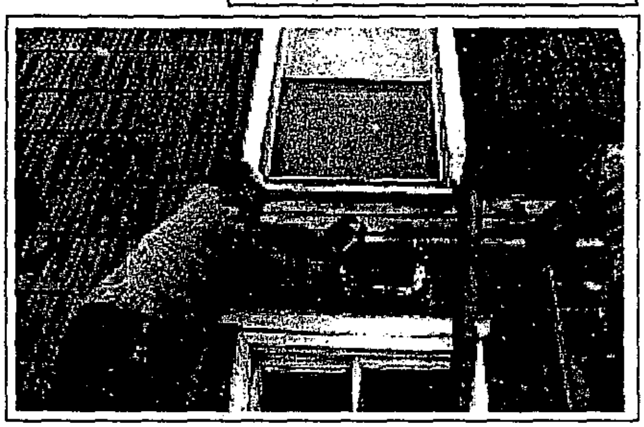


Powerful blowing machines make the job of installing cellulose insulation more efficient.

Installing insulation as the snow flies.

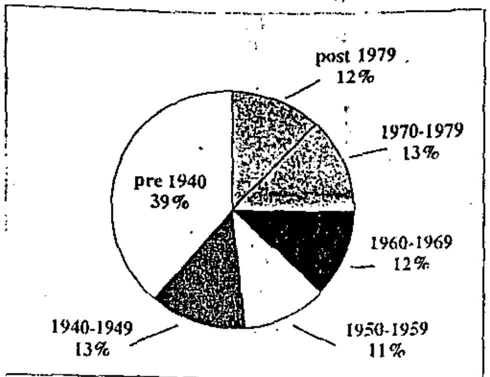


The small tube at the top is snaked into wall cavities, then slowly withdrawn as insulation fills them up. The result is a very tight fill.

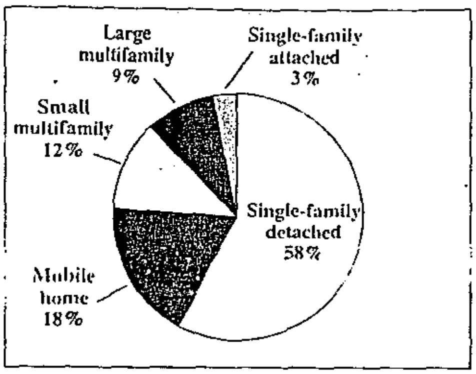


Preparation, insulation, and cleanup keeps two weatherization team members working for most of a day.

Wall preparation. Shingles are positioned for fast reattachment after insulation blowing.



Year of Construction of Dwellings Weatherized in 1989



Types of Dwellings Weatherized in 1989

The findings from each of these studies were documented in a series of eleven reports published between 1990 and 1994. References to these reports are at the end of this document.

B. Diversity of Dwellings and Agencies

Perhaps the most striking finding of the comprehensive National Evaluation was the diversity among local weatherization agencies across the country. Some agencies weatherized 15 homes in a year; others weatherized thousands. Some agencies achieved savings of 30 to 40 percent of pre-weatherization consumption. Others produced no measurable savings. Some agencies employed state-of-the-art procedures, used a variety of funding and technical resources, and performed sophisticated self-evaluations. Others followed the same procedures year after year, did not evaluate their impacts, and relied entirely on DOE for funding. With the downsizing of the Program in the last few years, many areas previously served by the smaller agencies have been incorporated into larger agency service areas.

The housing stock addressed by the Program also is diverse. Most low-income people live in homes built when energy was not an expensive commodity. Poor insulation and leaky construction have wasted energy from the start, and, inevitably, aging makes structures more energy inefficient, more expensive to heat, and often cold, unsafe, and unhealthy. Among the dwellings weatherized in 1989, 39 percent were more than 50 years old. On the other hand, only 12 percent were less than 10 years old.

Dwellings can be classified into five types. Each type has unique weatherization needs.

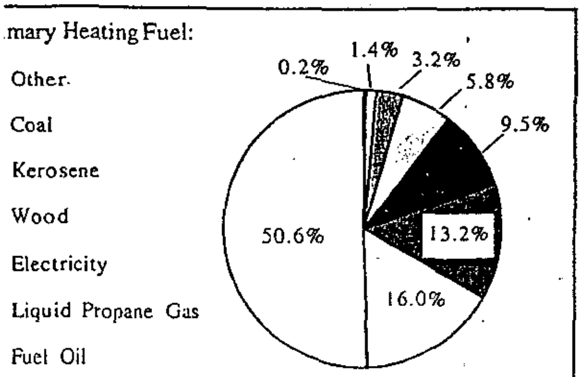
Single-family detached homes were the dominant type of structure weatherized by the Program in 1989 (representing 58 percent of the total). Half of these single-family detached units heated primarily with natural gas, and only 10 percent heated with electricity. Elderly occupants resided in 40 percent of these houses, a higher concentration than for any other dwelling type. The vast majority of these houses (73 percent) were owner-occupied.

Single-family attached dwellings (often called row houses) comprised the smallest housing-type category (3 percent of the weatherized population). Almost all were centrally heated (93 percent). As a class, these were the oldest buildings, with a mean age of 56 years. They also tended to have higher-income occupants and were located almost entirely in the moderate region.

Mobile homes comprised 18 percent of the weatherized population. They were by far the "newest" units, with an average age of only 17 years. These homes were more likely than any other housing to be heated with a nonmetered fuel (mainly propane) and were 78 percent owner-occupied. Mobile homes were occupied by individuals with the lowest incomes.

Net average annual energy savings (by fuel type) per dwelling for dwellings weatherized in 1989 (based on a billing analysis of a representative national sample of homes) *Estimated average annual savings per dwelling heated with natural gas in 1996 (based on a regression model developed from 17 state-level evaluations of natural gas savings conducted between 1990 and 1995)*			
Primary heating fuel	Percent of space heating consumption	Percent of total fuel consumption	Net savings (Mbtu/year)
Natural gas 1989 National Evaluation	18.3%	13.0%	17.3 Mbtu/year
1996 Metaevaluation (estimated from regression model)	***33.5%***	***23.4%***	***31.2 Mbtu/year***
Electricity	35.9%	12.2%	18.9 Mbtu/year
Fuel Oil (Northeast)	17.7%	17.7%	22.4 Mbtu/year
All fuels*	18.2%	13.5%	17.6 Mbtu/year

*includes estimates for propane, wood, kerosene, and other fuels



Distribution of Weatherized Dwellings by Primary Heating Fuel

Small multifamily dwellings (those located in buildings with 2 to 4 units) comprised 12 percent of the weatherized population. They were heated primarily with natural gas (73 percent) and were typically renter-occupied (82 percent). Compared to single-family detached homes, they were only half as likely to have an elderly or handicapped occupant.

Large multifamily dwellings comprised 9 percent of the weatherized population and represented a distinct building type. They were located almost entirely in the moderate and cold regions (approximately half are located in New York City), and they tended to be older than the single-family dwellings weatherized by the Program (52 percent vs. 38 percent were built before 1940). This type of dwelling is, for the most part, centrally heated by gas, electricity, or fuel oil.

C. Program Benefits

National Energy Savings in 1989

Equivalent 1989 Savings in Barrels of Oil

per day	1,650
per year	601,000
20-year lifetime	12 million

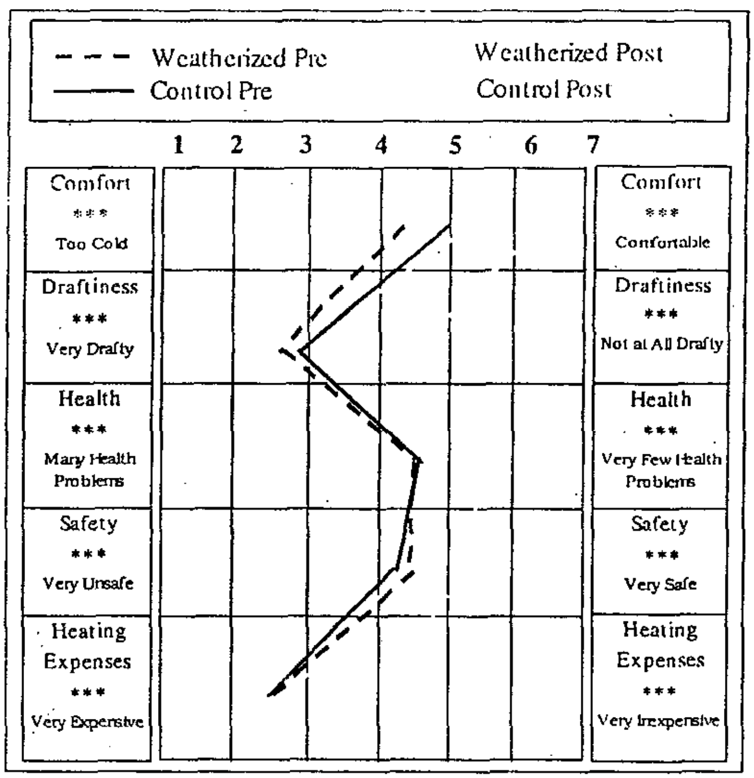
During Program Year (PY) 1989, the Program weatherized 198,000 single-family or small multifamily homes, resulting in net energy savings during the following year equivalent to 601,000 barrels of oil, or almost 1,650 barrels of oil per day.[2] Over the estimated 20-year lifetime of the weatherization measures, net savings from Program expenditures in 1989 are projected to be **69.7 trillion Btus, the energy equivalent of 12 million barrels of oil.** These estimates are based on measured reductions in the use of primary heating fuels after weatherization. Savings of supplemental heating fuels were not measured.

Gas-heated dwellings accounted for 50 percent of the dwellings weatherized by the Program in 1989. It is estimated that the Program, which addresses only space heating and sometimes water heating energy efficiency, saved 18.3 percent of the gas used for space heating. This represented 13.0 percent of total gas use, including water heating, cooking, and other gas-appliance uses. Variations in savings by dwelling type were significant. For example, single-family detached dwellings (the dominant dwelling type served by the Program) saved over 50 percent more natural gas per dwelling than did mobile homes.

Electrically heated homes represented only 10 percent of the dwellings weatherized under the Program during 1989. Weatherization of these dwellings saved 35.9 percent of the electricity used for space heating. This represented 12.2 percent of total electricity use. As with gas-heated homes, both single-family detached and small multifamily dwellings saved more electricity than did mobile homes.

[2]A barrel of oil is equal to 42 U.S. gallons and represented approximately two weeks of petroleum consumption per nerican in 1990. The equivalent number of barrel(s) of oil is, of course, a concrete way of expressing the 3,370 billion British rmal units (Btus) saved during 1990 due to weatherization work on single-family dwellings during Program Year 1989. In lity, of course, the savings occurred not only in gallons of oil, but also in hundreds of cubic feet (ccf) of natural gas, kilowatt-urs (kWh) of electricity, and other units of fuel. Where electricity is concerned, savings reported include the energy required generate electricity at its source.

Type of nonenergy impact	Value of the impact per dwelling
Increased property value	$126
Reduced incidence of fire	$3
Reduced arrearages	$32
Federal taxes generated from direct employment	$55
Income generated from indirect employment	$506
Avoided costs of unemployment benefits	$82
Environmental externalities	$172
Total	$976



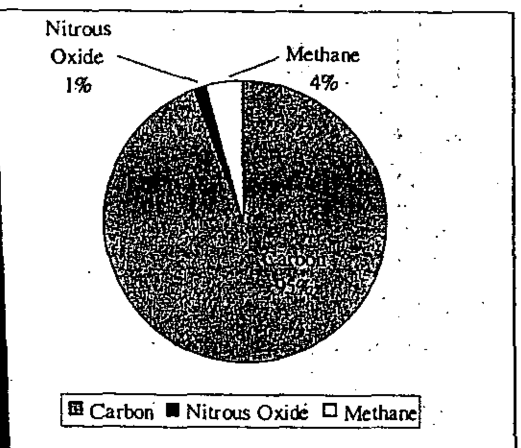
Occupant Perceptions of Nonenergy Benefits of Weatherization in Weatherized and Control Dwellings

The Fuel-Oil Study showed that an average single-family dwelling located in the Northeast and heated primarily by fuel oil saved 160 gallons of fuel oil in the first year following weatherization. This is equivalent to 22.4 million Btus, or 17.7 percent of total fuel-oil use. (Fuel oil is generally used only for space heating.)

Measured savings for gas, electricity, and fuel oil were combined with estimates of energy savings for dwellings that heated primarily with other fuels such as propane, wood, kerosene, and coal. The average savings for all single-family and small multifamily dwellings weatherized in 1989 was estimated to be 17.6 million Btus per year, 18.2 percent of the energy used for space heating and 13.5 percent of total energy use.

Nonenergy Benefits

The Program's weatherization activities have numerous benefits beyond reductions in energy consumption. Improvements to dwellings often raise the health, safety and comfort levels of occupants as well as increase the value of their homes. Reducing energy demand decreases the environmental impacts of energy production. In addition, lowering energy consumption produces a variety of economic benefits such as reduced energy burdens, more funds for other expenditures, and increased employment. In this section, information on selected nonenergy benefits is discussed.



ate change equivalent emission reductions of Program, by type of greenhouse gas.

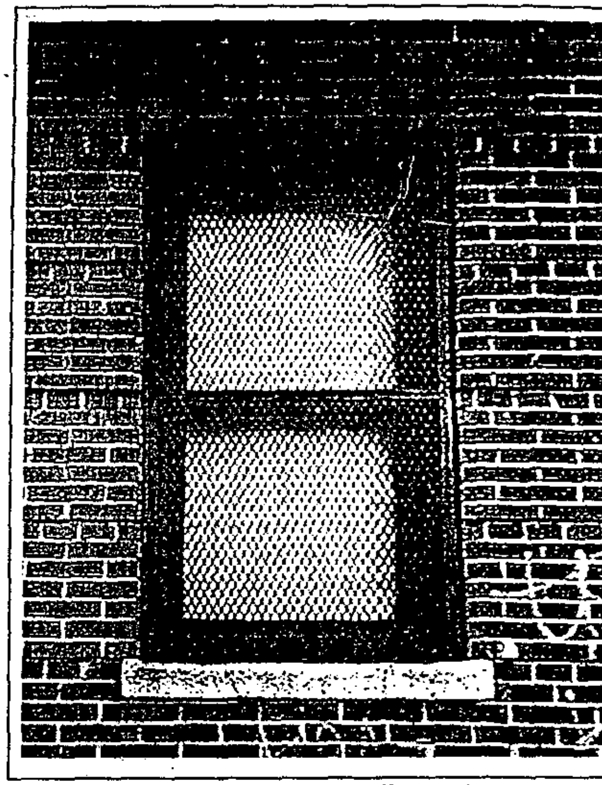
Occupants' perceptions of the health, safety and comfort of their homes were much improved after weatherization. Occupants of weatherized and control homes were asked to rate the comfort, draftiness, safety, and heating expenses for their homes. They also were asked to rate their own health (in terms of the incidence of illnesses, such as colds, flu, allergies, headaches, nausea, arthritis, which may be affected by the temperature, CO levels, or draftiness of the dwelling).

On every rating scale the weatherized group reported a highly significant and positive change after weatherization was completed. The control group, on the other hand, reported no change in any of the ratings. Thus, the weatherization clients experienced improvements in the comfort and safety of their homes, while the control group did not. The weatherized group also believed their homes became less drafty and their heating bills more affordable after weatherization. The control reported no changes. Finally, the weatherized group believed that there had been an improvement in their own health, while the control group did not. Although it is difficult to place a monetary value on these health, safety, and comfort benefits, occupants of weatherized dwellings recognize and appreciate them.

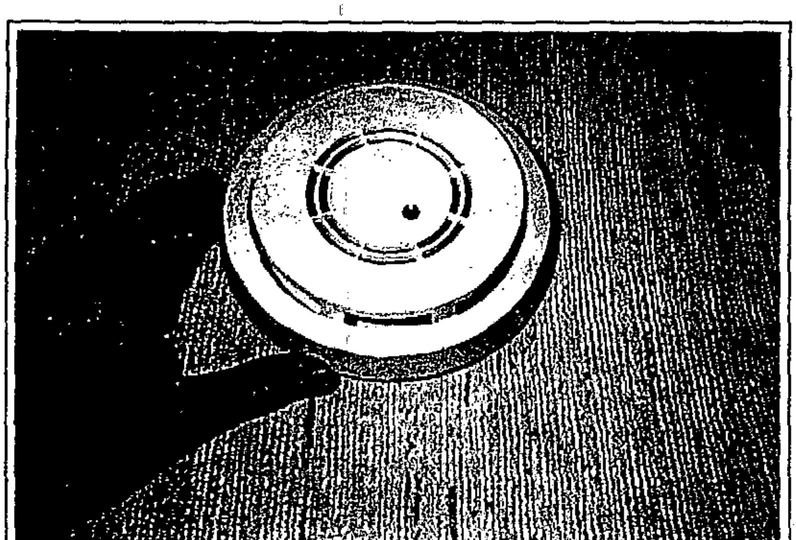
Environmental benefits from weatherization include the reduction of greenhouse gas emissions. The principal gases of concern from the perspective of global warming are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The following calculations are based on dwellings weatherized in 1989 that heated primarily with electricity, natural gas, fuel oil, LPG, or kerosene.

HEALTH AND SAFETY

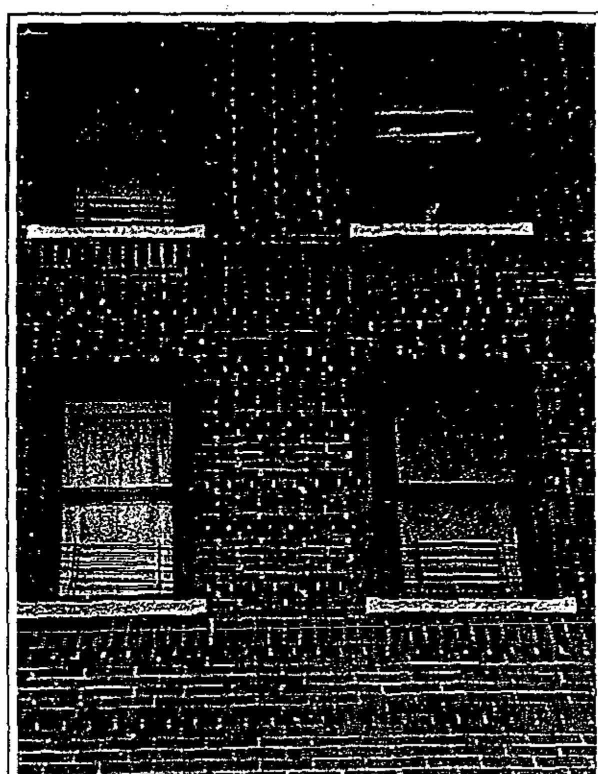
Testing for carbon monoxide ensures both furnace efficiency and safety.



Some weatherization crews install security measures on first-story windows.



Smoke alarm installations improve safety.

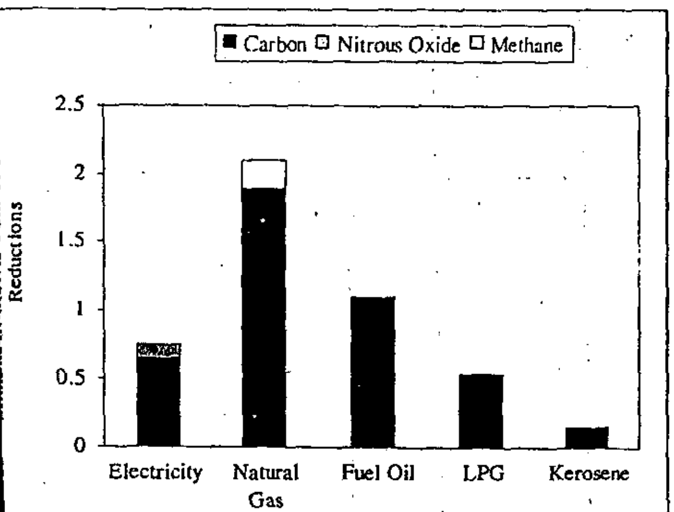


Higher-level windows receive grates to promote child safety.

Weatherizing a dwelling that heats primarily with natural gas reduces **carbon** emissions by 0.2489 metric tons per year. Weatherizing a dwelling heating with electricity reduces carbon emissions by 0.475 metric tons per year, assuming that emissions from electricity generation are equivalent to those from bituminous coal combustion. The carbon emission reductions per dwelling unit for fuel oil, LPG, and kerosene are 0.445, 0.263, and 0.306 metric tons of carbon, respectively. These estimates translate into CO_2 emissions 3.67 times higher because of the additional weight of the two oxygen atoms.

Methane has 35 times the warming potential of CO_2. If the entire cycle of production, transmission, distribution, and household end-use is included, a typical weatherized dwelling heated primarily with natural gas will reduce methane emissions (in CO_2 equivalents) by 0.090 metric tons per year. The emission reductions from the other types of heating fuels are much smaller.

Electricity generation is the only source of **nitrous oxide** emissions that is relevant to home heating. Weatherization yields an annual reduction in N_2O emissions of 0.173 metric tons per electrically heated dwelling, in CO_2 equivalents.



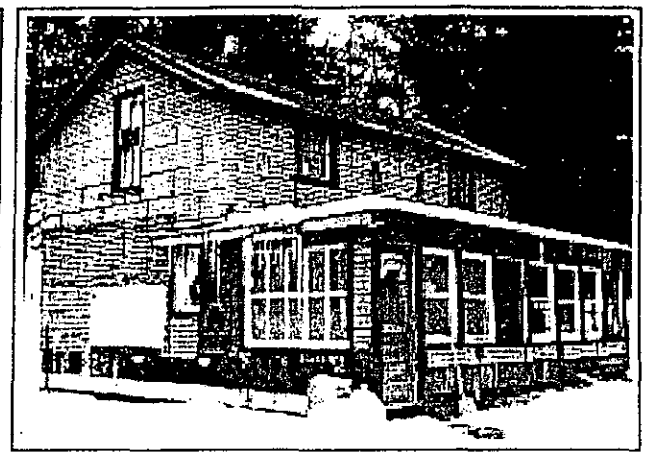
ate change equivalent emission reductions of all houses herized by the program in 1989 over the 20-year lifetime t measures, by type of heating fuel

The 1989 Program as a whole reduced the equivalent of more than 4 million metric tons of CO_2 over the 20 year lifetime of the measures in the 198,000 weatherized homes. The amount of CO_2-equivalent emission reductions due to various types of heating fuels and greenhouses gases are shown in the figure on this page. Since most of the dwellings weatherized by the 1989 Program were heated primarily with natural gas, these dwellings are responsible for the biggest share of the CO_2-equivalent reductions. They are also the only dwellings with a measurable methane impact. Carbon reductions account for the vast majority of the Weatherization Program's reductions of CO_2-equivalent greenhouse gas emissions. The next largest greenhouse gas impacted by the Program is methane.

The value of nonenergy benefits is often difficult to quantify. For the purposes of the evaluation, selected nonenergy benefits were assigned a dollar value, but the methods used to estimate their value varied.

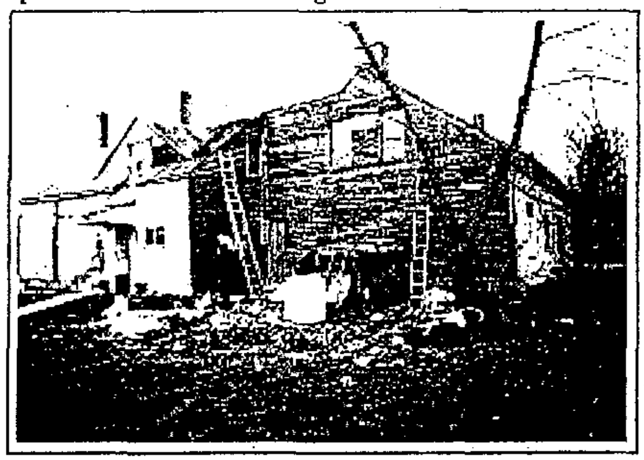
SINGLE-FAMILY DETACHED HOMES ARE FIFTY-EIGHT PERCENT OF TOTAL DWELLINGS WEATHERIZED

This farmhouse saved over 50 percent by air sealing, wall insulation, and furnace replacement.

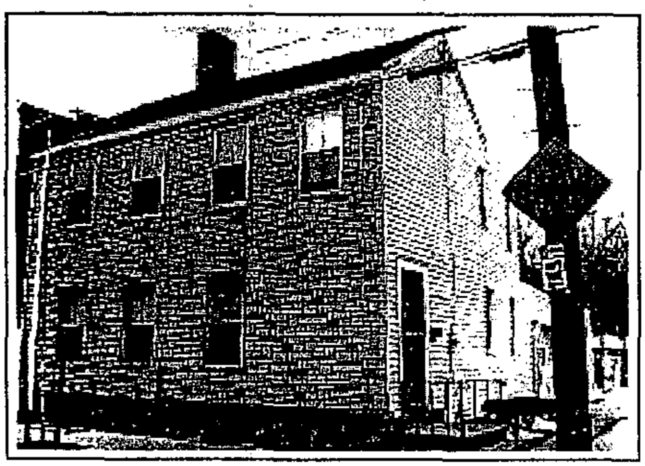


An uninsulated attic and air leakage between the porch and main structure are the main energy problems with this dwelling.

Joining the new to the old often causes trouble.



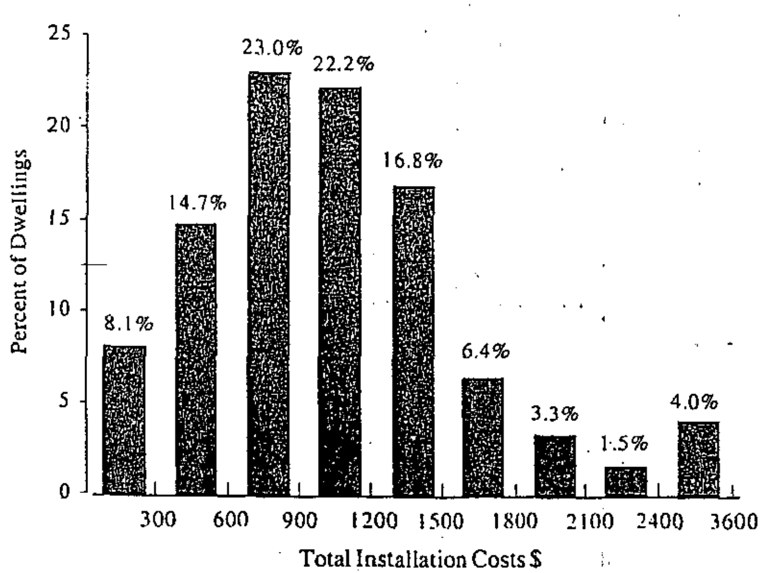
Movement of deteriorated foundation walls has opened large paths for air leakage.



Retrofit siding hides major holes that cause air leakage.

Built in sections over many years, this dwelling has major leaks between the main house and newer additions.

Estimates of environmental benefits relied on a literature review and on information about the proportions of weatherized dwellings using various fuel types and the average savings of different fuels. Estimates of employment benefits combined a literature review with data on Program employment, the skill levels of workers, and managers' judgments concerning the job market for weatherization workers. Data on Program expenditures for home repair were used to quantify the benefits associated with maintaining or enhancing property values and extending the lifetimes of dwellings. The monetary benefits of reducing the incidence of fires were quantified using insurance industry data. Estimates of reductions in arrearages were based on a literature review and data on payment histories collected on the dwellings included in the National Evaluation. For each benefit included in the estimate, we developed an average value per weatherized dwelling.



Installation Costs for Single-Family and Small Multifamily Dwellings Weatherized in 1989

Ultimately, the dollar value of nonenergy benefits resulting from the weatherization of single-family and small multifamily dwellings was estimated to be $976 per dwelling. The table on page 38 provides a summary of these nonenergy benefit estimates.

D. Cost Effectiveness

Cost effectiveness is a measure of how well a program works. To assess the cost effectiveness of the Weatherization Assistance Program, the market value of energy savings (and in some cases other benefits) was compared to the cost of installing the measures that produced them. Benefits and costs were discounted over the estimated life of the measures. Cost effectiveness was assessed only for single-family and small multifamily dwellings because estimates of program impacts were not available for large multifamily buildings, which comprised only 9 percent of the dwellings weatherized in 1989.

Program Costs

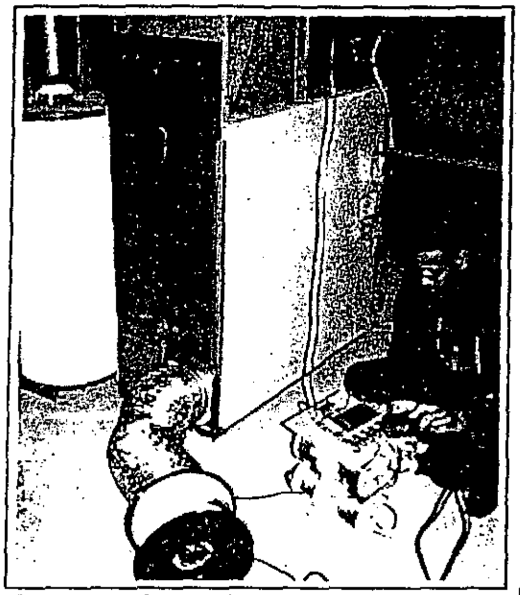
DOE regulations in 1989 required (subject to certain exceptions) that the average of all costs not exceed $1,600 per house. When the weatherization work is supplemented by non-DOE funds, average costs may exceed $1,600.

To provide a picture of costs that is reasonably consistent regardless of the sources of funds used, costs were grouped under two broad categories: (1) installation costs (i.e., labor and materials assignable to particular houses) and (2) overhead and management costs. Overhead and management costs include costs directly related to installation but not readily assignable to particular houses (e.g., vehicles, travel time, and field supervision), and program management (e.g., intake, inspections, training and general administration).

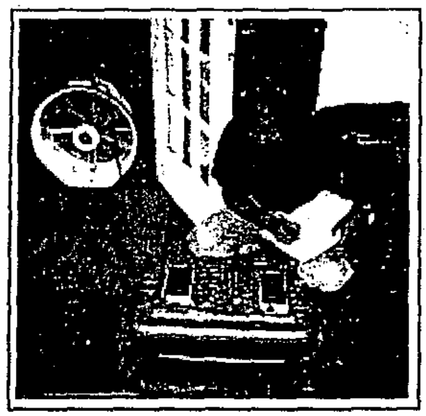
DISTRIBUTION SYSTEMS

Recent research has revealed that the distribu systems associated with central heating and conditioning units are themselves frequently le: The combination of loose houses and large hole return air systems results in inefficiency, unc fortable drafts, and high energy bills. The combi tion of **tight** houses and large holes in return systems can cause backdrafting of the products combustion from furnaces and hot water heat can dramatically increase the rate at which ra enters the dwelling--and can propel of these un sirable gases through the furnace's heat exchan directly into the main part of the dwelling.

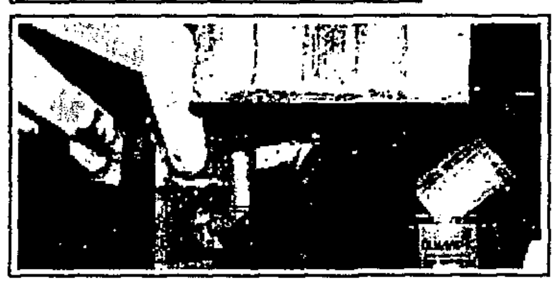
Duct problems can also negate the benefits other weatherization work. On the other ha sealing and balancing duct systems can raise furn system efficiency, lower overall air infiltration, sol moisture problems, enhance indoor air quality--a save energy.



The blower door and pressure-measuring gauges are useful both in quantifying duct leakage associated with duct work and in revealing the locus of significant leaks. Protocols for using both blower doors and the distribution system's own fan to quantify leaks are currently being developed, and several companies have recently developed small calibrated blowers useful in leak detection and quality control in duct sealing.

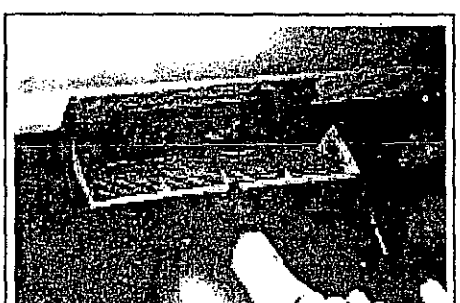


Permanent air sealing of the return air system is accomplished with a fiberglass mesh and special mastic.



A wooden return system on a gravity furnace is not only leaky but also immediately adjacent to sundry volatile organic compounds. When the furnace is fired, fumes from these compounds can be whisked from the basement into the living area.

This return air duct is the only one in the dwelling for a 100,000 Btu/hour furnace in a Philadelphia row house. Undersized by a factor of 20 when initially installed, it is now full of dirt. A $50 retrofit would save well over $100 each heating season.



Holes like these i supply ducts can quite wasteful--y they can be repaired quickly and cost effective

Installation costs for single-family and small multifamily dwellings weatherized in 1989 averaged $1,050. For not quite half (45 percent) of the dwellings, these costs fell within the $600 to $1,200 range. The chart on page 43 shows the range of costs.

Because of variations in record keeping, it proved difficult to specify overhead and management costs with the same degree of precision as installation costs. After approaching the problem from several perspectives, the evaluators settled on an average cost of $500 per single-family and small multifamily dwelling nationwide.

PERSPECTIVE	BENEFITS INCLUDED	COSTS INCLUDED
PROGRAM	Energy Savings Only	All Costs
	Benefit/Cost Ratio = 1.09	
INSTALLATION	Energy Savings Only	On-Site Installation Costs
	Benefit/Cost Ratio = 1.61	
SOCIETAL	Both Energy and Nonenergy Benefits	All Costs
	Benefit/Cost Ratio = 1.72	

tional Benefit/Cost Ratios for Fuel Types for the 1989 Program

The *evaluation examined cost effectiveness* in detail from three perspectives:

- The **program perspective:** the only benefit valued was net energy savings, and costs included installation, management, and overhead costs.
- The **installation perspective:** the only benefit valued was net energy savings and the only costs included were installation expenditures; and
- The **societal perspective:** benefits included both net energy and nonenergy benefits, and costs included installation, management and overhead.

National Cost Effectiveness

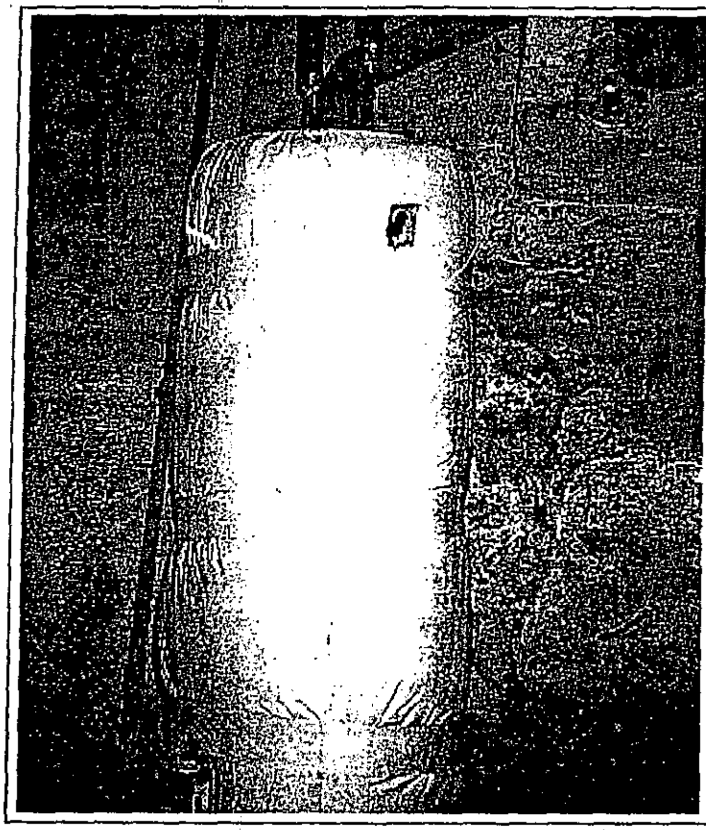
The results of each of the three perspectives used to measure cost effectiveness are described below.

The **program perspective** is the most conservative analysis because it includes all classes of costs (i.e., both installation costs and program overhead and management) but only the value of energy savings as a benefit. From this perspective, the national program is still cost effective. For gas-heated homes, the benefit/cost ratio is 1.06. For electrically heated homes, the ratio is 1.13, and for dwellings located in the Northeast heated primarily with fuel oil, the benefit/cost ratio is 1.48.

For the Program as a whole, including all fuel types, the program benefit/cost ratio is 1.09.

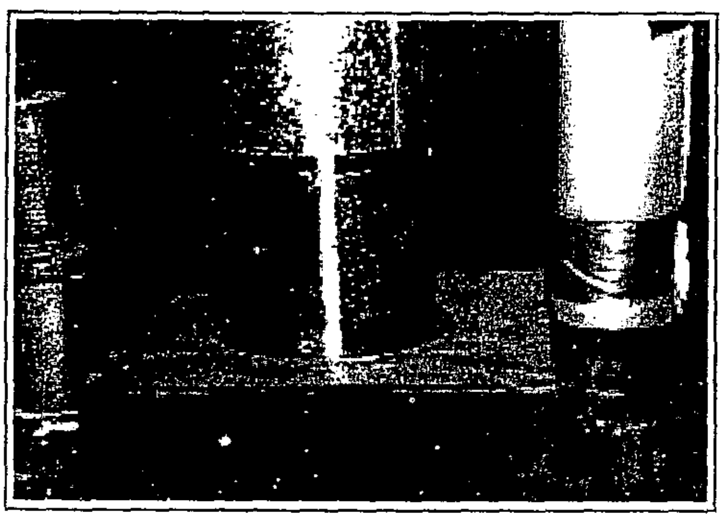
The **installation perspective** is the traditional approach used to evaluate weatherization programs. Nationally, for gas-heated dwellings, weatherization costs averaged $1,015 in 1989 dollars. Average energy

DOMESTIC HOT WATER

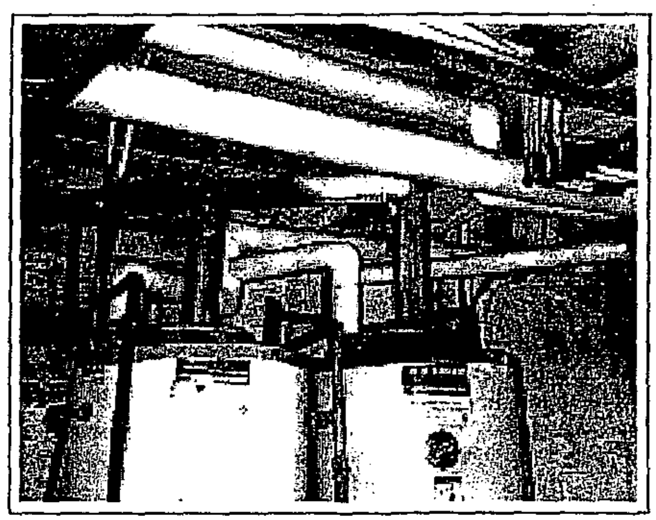


Well-insulated water heaters use less fuel.

Conserving energy used to heat water is usual a cost-effective undertaking. Stopping leaks wi minor plumbing repairs can result in substanti savings, as can installing low-flow devices lil shower heads and faucet aerators. Most weathe ization agencies report that the best results con from combining client education with gooc quality shower heads. Similarily, the installatio of tank insulation by weatherization agencies i frequently accompanied by turning down th thermostat on the water heater, an action that i often taken in conjunction with client educatio to promote sustained energy savings. Man agencies also install pipe insulation a few feet oi the cold water inlet side (to preven thermosiphoning during the standby cycle) anc 10 feet or more on the hot water side.



A flue damper installed on this domestic hot water heater limits heat loss to the chimney during the off cycle.



The weatherization crew that insulated the tank and pipes entering and exiting from this hot water heater did an excellent job.

savings benefits were calculated to be worth $1,605. The resulting benefit/cost ratio, therefore, is 1.58. For electrically heated dwellings, average expenditures of $1,025 yield energy savings benefits of $1,728, producing a benefit/cost ratio of 1.69. For dwellings located in the Northeast heated primarily with fuel oil, average installation costs of $1,192 yielded energy saving benefits of $2,694, producing a benefit/cost ratio of 2.26.

For the 1989 Program as a whole, including all fuel types, the installation benefit/cost ratio is 1.61.

Benefit/Cost Ratios for Gas-Heated Homes

Perspective	1989	1996
Program	1.06	1.79
Installation	1.58	2.39
Societal	1.61	2.40

The **societal perspective** produces the highest benefit/cost ratios because it includes an estimated value of the nonenergy benefits of weatherization ($976), which exceeds the overhead and management costs of weatherization ($500). For gas-heated dwellings, the benefit/cost ratio is 1.61. For electrically heated dwellings, the benefit/cost ratio is 2.33. For fuel-oil-heated dwellings located in the Northeast, the benefit/cost ratio is 2.01.

For the Program as a whole, including all fuel types, the societal benefit/cost ratio is 1.72.

The bottom line is that the Program is a cost-effective government investment. Total costs (including materials, labor, overhead, and management) for all fuel types averaged $1,550 per single-family and small multifamily dwelling weatherized in Program Year 1989. The net current value of the energy saved per dwelling is $1,690 (in 1989 dollars). This results in a benefit/cost ratio of 1.09. When conservative values are included for some of the Program's various nonenergy benefits, the benefit/cost ratio increases to 1.72.

Because of the higher average national savings estimated for the Program in the 1996 Metaevaluation, cost-effectiveness estimates also increased. In 1989, the National Evaluation estimated the Program benefit/cost ratio for gas-heated homes from the program perspective as 1.06. Applying the same procedures and assumptions used in the National Evaluation to the 1996 savings estimate yields a benefit/cost ratio of 1.79. With the installation perspective, the 1989 result is 1.58, and for 1996 is 2.39. Societal ratios, which include the value of nonenergy benefits, were 1.61 in 1989, and 2.40 in 1996.

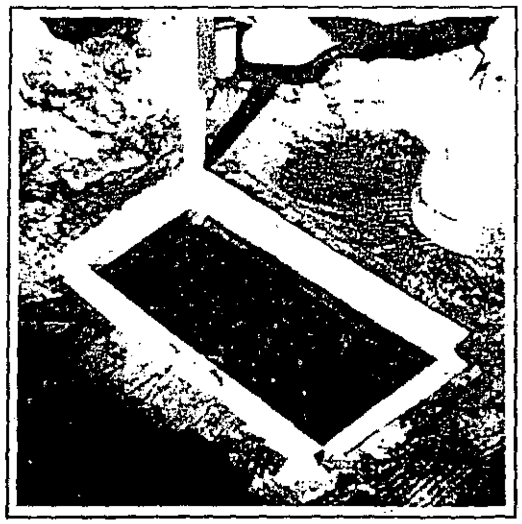
E. Performance by Climate Region in 1989

Performance indicators for the national Program mask a great deal of diversity. This diversity springs from regional differences and associated housing types and needs and from varying practices of weatherization agencies. The following sections discuss differences by region. Characteristics of the housing stock and local agencies account for much of the regional variation in weatherization practices and measures installed. These, in turn, provide important background for understanding regional variations in weatherization costs, energy savings, and cost effectiveness.

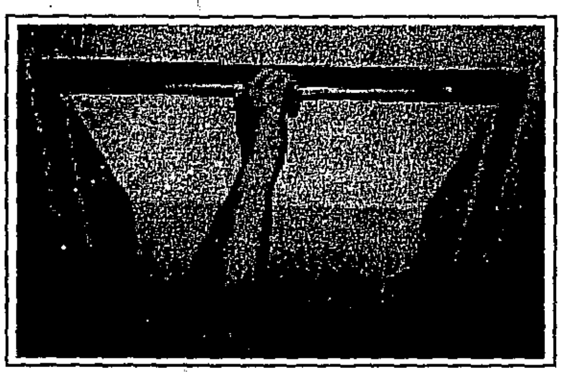
As a whole, the 1989 Program was most cost effective in the cold and moderate climate regions of the country, where program activity was

MOBILE HOME MEASURES

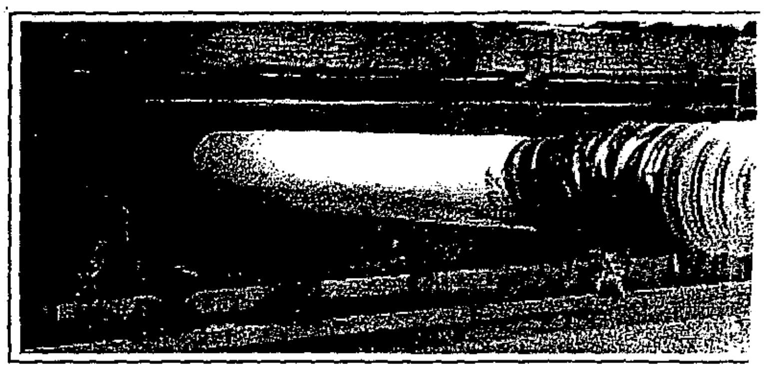
Many mobile homes have inconspicuous air leakage paths that can be clearly identified with blower doors. Successful weatherization work focuses on closing leaks at the bottom of the conditioned envelope, especially around the duct system. A recent Indiana study showed that 32 percent savings in mobile homes resulted from blower-door guided infiltration reduction and from blowing cellulose insulation in the belly board. A recent evaluation of the Vermont Weatherization Assistance Program provided evidence of substantial electricity savings from air sealing the water heater compartment of mobile homes, even when the electric water heater had already been jacketed.



The interface betwe[...] the riser in a supp[...] duct and the floor of a mobile home is frequently found to b[...] a source of air leaks both when the furna[...] fan is on and when i[...] is not. Here a techn[...] cian in Indiana uses [...] technique his agenc[...] developed to achie[...] a tight, lifelong seal

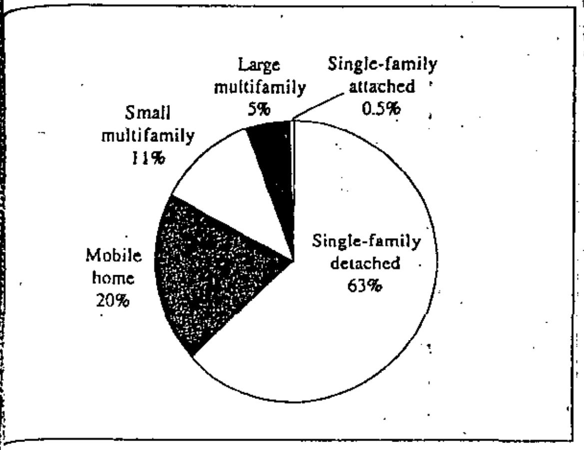


Sealing the opening to the evaporative cooler during winter months is routinely accomplished by weatherization technicians in Arizona, who find this a very cost-effective weatherization tactic with both mobile homes and site-built structures. Solar screens also result in significant savings in this semidesert climate.



A 30-foot-long plastic pipe is used to blow insulation between the belly board and the floor of a mobile home.

concentrated. In the warm climate region, where agencies were smallest and the low-income housing was most dilapidated, the Program saved less energy per dollar expended.

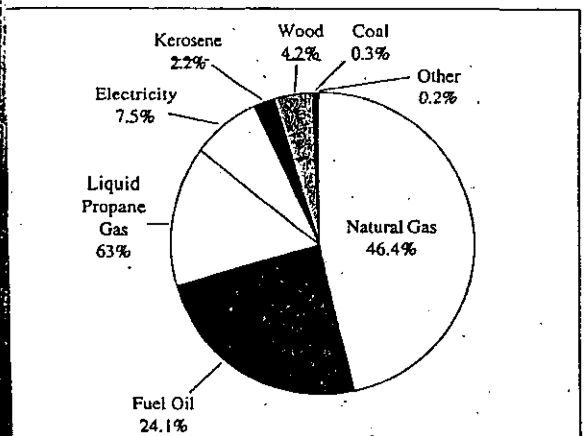


Types of Dwellings Weatherized in 1989 in the Cold Region

The Cold Climate Region

The cold climate region contains 11 states with an average of 7,444 heating degree days. In 1989, approximately 150 local agencies in this region weatherized more than 40,000 dwellings (18 percent of the total weatherized population).

Benefit/cost ratios were greater in this region than in any other region, ranging from 1.3 to 2.9 depending upon the perspective. This region also achieved the highest savings of any region, based on the Single-Family Study. For natural gas consumption, the first-year net savings of 235 ccf represented a 25 percent reduction in the gas used for space heating and an 18 percent reduction in total gas usage. Net electricity savings totaled 2,686 kWh for the first year, which was a 42 percent reduction in electricity use for heating and a 14 percent reduction in total electricity usage. Total costs averaged $1,576 per household, higher than the national average.



Types of Heating Fuels in Single Family and Small Multifamily Dwellings Weatherized in 1989 in the Cold Region

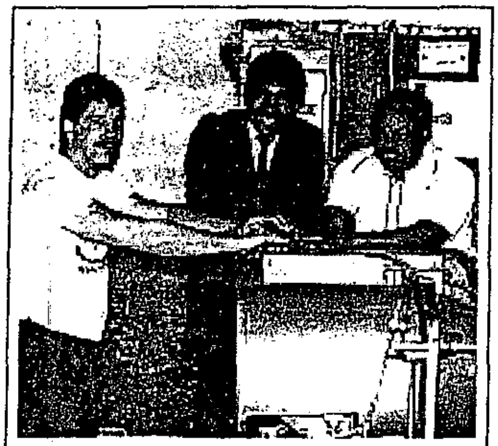
The majority of weatherized homes in the cold region are single-family detached (63 percent). Findings from the Single-Family Study show that this region has the oldest housing stock (averaging 45 years) and weatherizes dwellings that are on average larger than the other two regions (1,181 square feet). The primary heating fuel, as with all regions, is natural gas. This region, however, has a significantly higher portion of the population using fuel oil. A central heating system was found in 83 percent of the dwellings, the largest proportion of any region, and supplemental heating fuels were less common (24 percent of the weatherized single-family population). Two-thirds of these dwellings were owner-occupied, and they had the largest average number of occupants of any region.

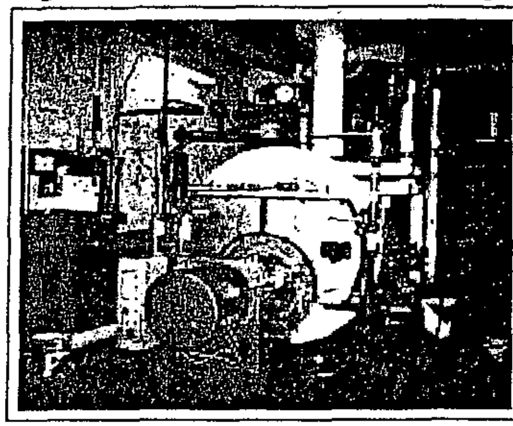
The cold region used the most rigorous methods for both client and weatherization measures selection. Integrated audits for measure selection were used over three times more frequently than the national average. The use of advanced diagnostic techniques was higher than in any other region. The Single-Family Study showed that blower door tests were performed almost twice as frequently as the national average. The cold climate zone had high installation rates for insulation, water heating, and space heating measures. In contrast, the cold region had relatively low installation rates for structural measures and windows and doors.

HEATING SYSTEMS

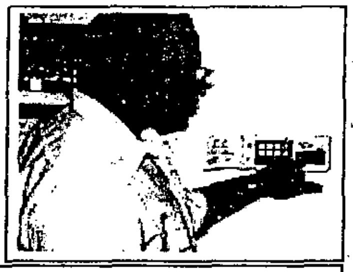
Furnace testing for safety and efficiency has recently become a routine part of many weatherization operations, yet there are still states which pay little attention to heating system work. Others do major work--when needed--ranging from switching to efficient oil burners to boiler replacement.

From left to right: A boiler technician, a local weatherization official, and an owner celebrate the recent installation of an energy-efficient boiler in a large multifamily building in Brooklyn. Owners in New York and some other states provide 25 percent or more of the cost of the work, thus leveraging scarce weatherization funds.

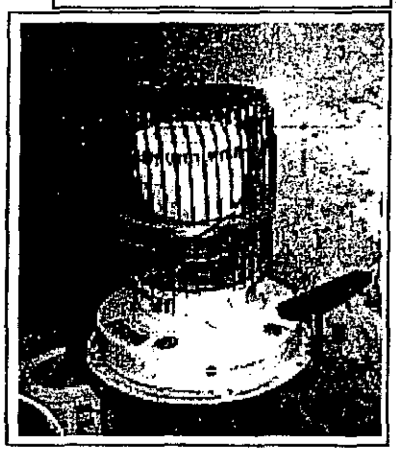




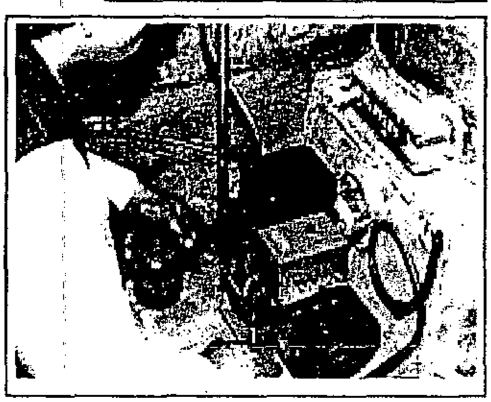
Modern multi-setback thermostats are cost-effective measures in many weatherization jobs.



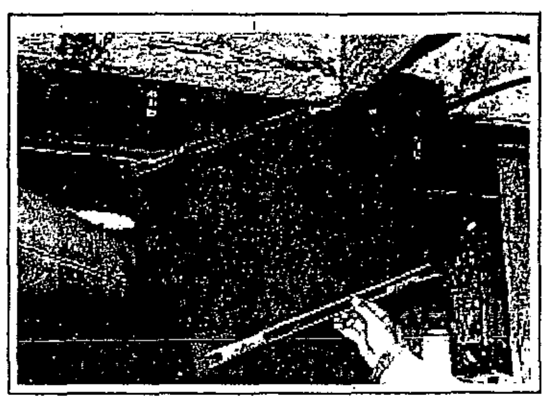
Kerosene heaters, like this one stored in the basement, contribute to poor indoor air quality. Education work with weatherization clients includes stern warnings about the hazards of these heaters--and the importance of getting rid of them entirely.



Many weatherization agencies use furnace testing equipment to measure the efficiency and safety of heating equipment.



An old boiler in a single-family dwelling in Philadelphia has plenty of life left in it, but its burner was inefficient and unsafe. This new burner assembly will save about 14 percent of the annual fuel oil bill.



Filthy return air filters, found frequently in the weatherization program, are both unhealthful and inefficient. Cleaning and tuning of furnaces, setting controls for efficiency, replacing filters--and empowering clients to do the job in the future--are routinely accomplished in most weatherization operations.

• **Installing attic insulation.** The 1989 evaluation clearly showed that the installation of insulation in attics never before insulated is particularly cost effective. Today advanced audits consistently recommend more attic insulation than was recommended by the priority list selection procedures used by most agencies in 1989.

• **Installing wall insulation.** During the time of the 1989 evaluation, only a few agencies had begun using the high-density installation technique (which accomplishes air sealing and insulation with a single operation). However, weatherization jobs that included high-density wall insulation showed even greater savings than those that used the older technique. More agencies are using high-density wall insulation techniques today.

• **Blower-door-assisted air sealing.** The payoff expected from blower-door-assisted air sealing was not discernible in the Single-Family Study in 1989. Because the effectiveness of blower-door-assisted air sealing has been demonstrated in small scale studies, this unexpected finding was attributed to the fact that blower doors were just being introduced into local agency procedures in 1989, when only 18 percent of completed dwellings received blower-door-assisted sealing. Today, many agencies offer training in blower door use, and many homes receive blower-door-assisted sealing. In fact, low-income weatherization agencies have become leaders in the application of blower doors and are generally convinced they save energy.

Recommended Practices

- Client education
- Resource leveraging
- Utility partnerships
- Housing rehabilitation funds

B. Promising Management Practices

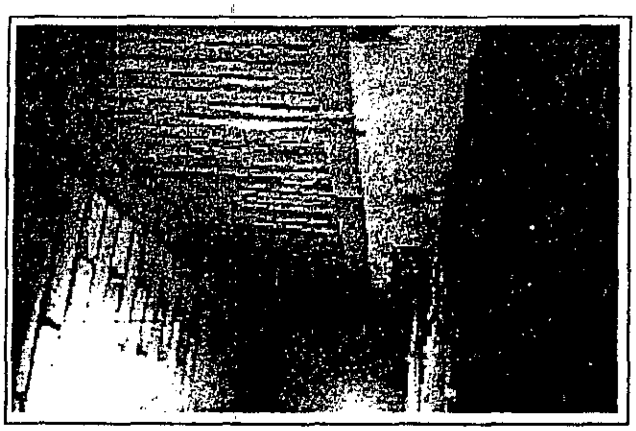
A handful of other practices employed by many weatherization agencies clearly make sense, but their impact could not be quantified in the 1989 evaluation. These include client education and resource leveraging. Some agencies are very active in providing client education and report good success in forming partnerships in which recipients of weatherization services participate in a number of concrete conservation activities in their homes.

Leveraging from utilities to accomplish the ends of demand-side management on the one hand and cost-saving conservation services for low-income families on the other has been an important opportunity for enhancing weatherization. Some agencies, for instance, provide electricity conservation services in conjunction with weatherization. These routinely involve removing inefficient incandescent lighting fixtures and replacing them with compact fluorescent lighting, and sometimes replacing inefficient refrigerators with efficient ones. Other utility partnerships have enabled capital-intensive investments such as energy-efficient replacement furnaces that otherwise might not be possible.

Still problematic for many local agencies is the extremely poor condition of many dwellings. The Program will be stronger when

This is a 12-inch fiberglass batt that has been on top of a small crack in the ceiling below for only one winter. The dirt is from the passing of massive amounts of air driven by stack-effect exfiltration.

Single-component foams in conjunction with rigid board stock cut to fit attic openings achieve tight, long-lasting attic sealing.



This space between the chimney interior framing is completely open to the attic. Sealing this at the level of the attic insulation is likely to save more energy than replacing every window in the dwelling. An experienced weatherization crew technician can thoroughly (and safely) seal this opening in 15 minutes with a material cost of $4.

Interior walls open to attics are commonplace—and must be sealed to prevent thermal siphoning. If this hole is not sealed during weatherization, the interior wall below is likely to be much colder in the winter than exterior insulated walls.

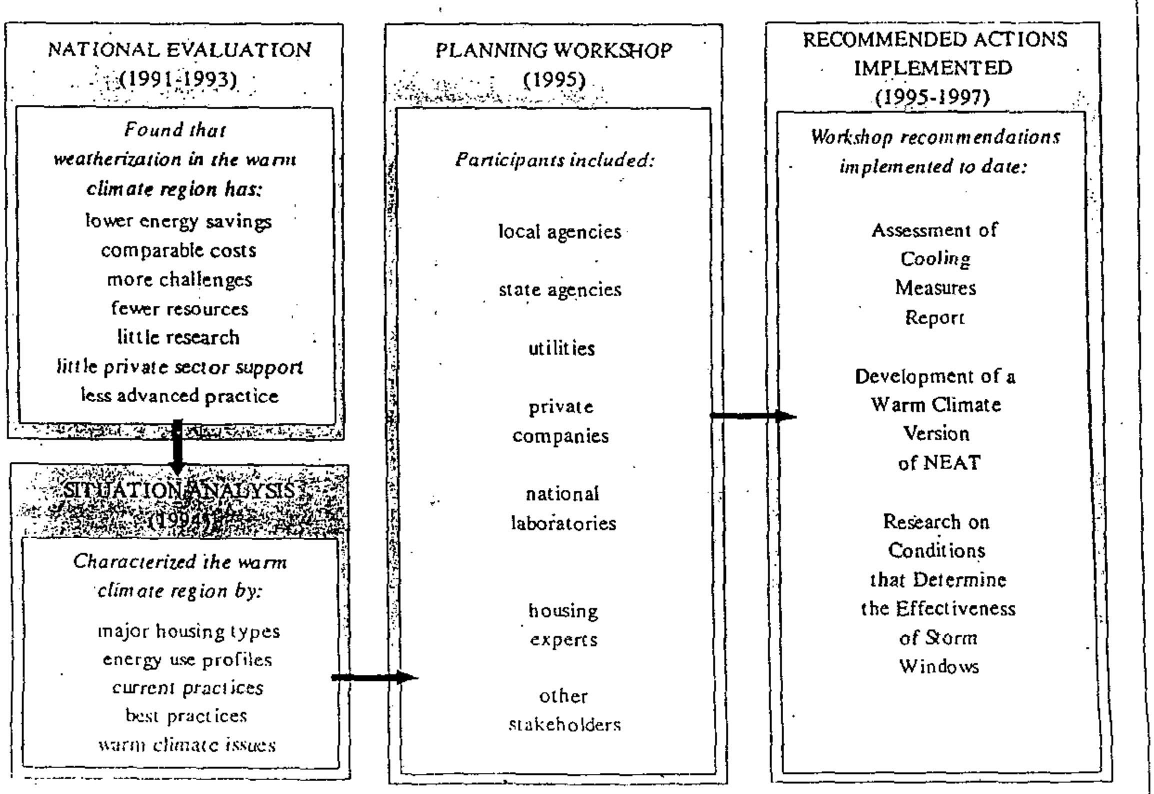
adequate housing rehabilitation funding allows local agencies to provide needed repairs and to devote a larger share of their DOE funds to energy-efficiency improvements.

C. The Warm Climate Weatherization Initiative

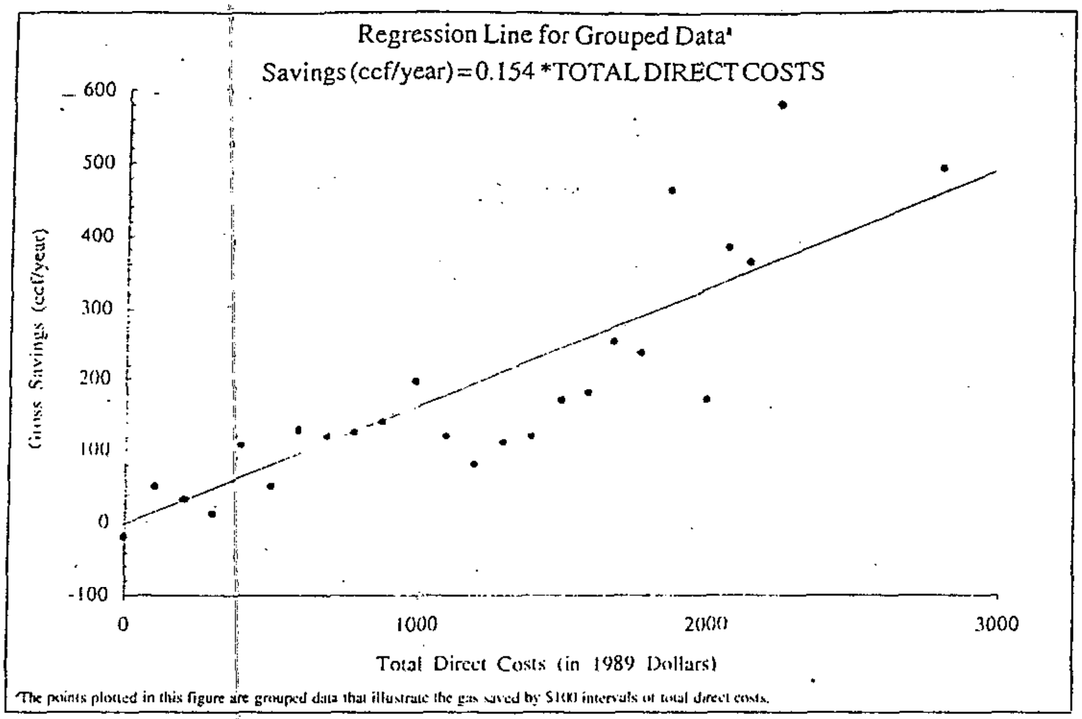
The lower-than-average savings in the warm climate region suggested the need for efforts designed to identify and implement ways of increasing energy savings from weatherization in warm climates. In addition, studies had decisively shown that improved procedures in warm climates could produce dramatic improvements in savings. The results of a 1993 ORNL study, for example, showed that the use of an advanced audit procedure more than doubled the amount of energy savings in North Carolina homes. A similar study in Virginia found that savings more than doubled with the implementation of improved procedures.

Although some improvements were already being adopted, DOE believed that it was important to accelerate the pace of change. Therefore, DOE decided to sponsor the Warm Climate Weatherization Initiative. This Initiative was designed to identify, develop, test, and transfer into widespread use a set of technological and programmatic approaches that can further increase the energy saved by weatherizing low-income homes in warm climates.

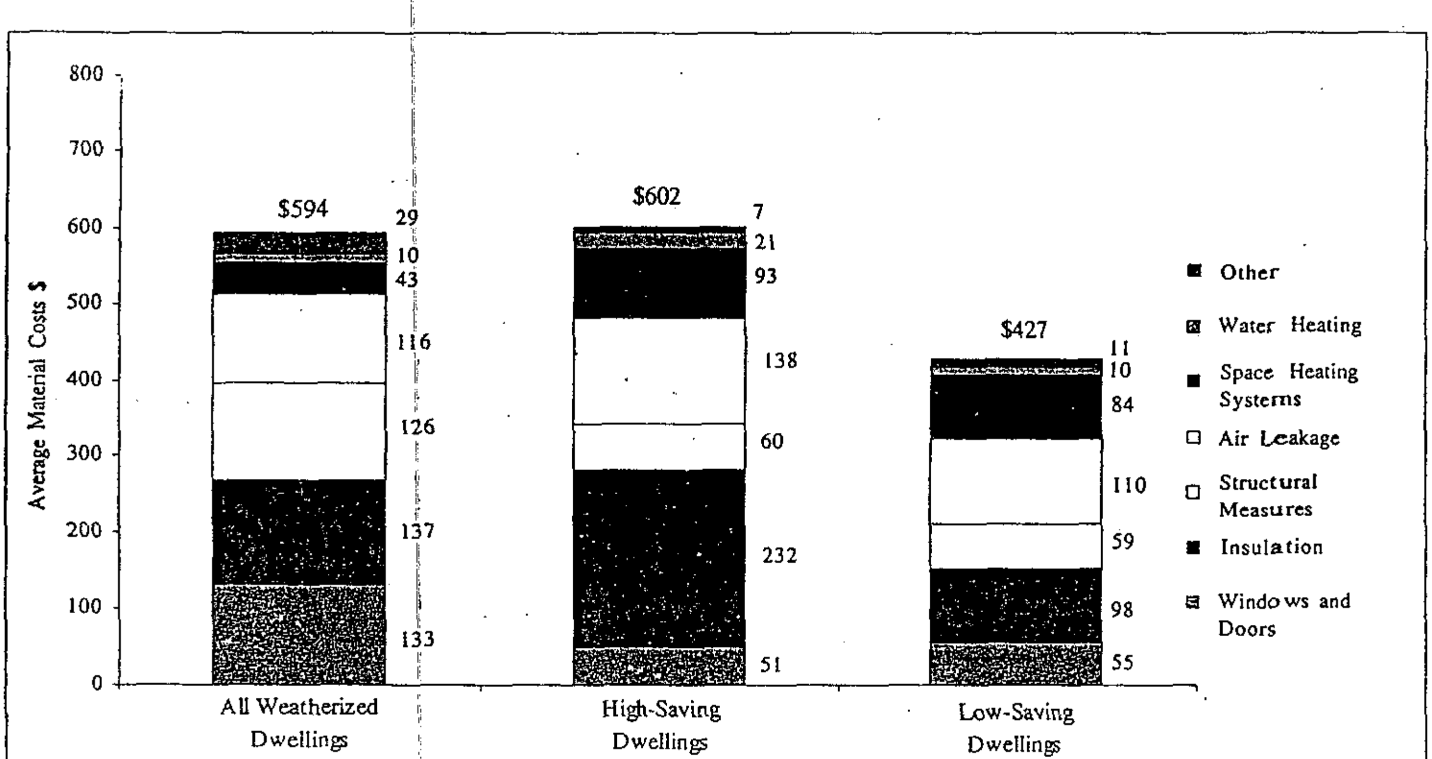
Overview of the Warm Climate Weatherization Initiative



RELATIONSHIP OF COSTS TO SAVINGS



Relationship of Amount Invested in Weatherization Measures to Energy Savings



Average Material Costs (in 1989 dollars): All Weatherized Dwellings vs. High- and Low-Saving Dwellings

The Warm Climate Initiative began with a Situation Analysis, in 1994, and a Planning Workshop, in 1995. The Situation Analysis, which was distributed prior to the Workshop, described current weatherization practices, housing conditions, energy end-use profiles, warm climate issues, and promising new technologies. The Workshop (which brought together Program representatives from all of the warm climate states, several local agencies, and DOE Headquarters, along with technical experts, and utility representatives) was asked to review the background information, identify the most important issues, and set an agenda for future research and improvements. Many of the Workshop recommendations have now been implemented. An ORNL report assessing cooling measures was completed in 1996, and research on the conditions that determine the effectiveness of storm windows produced preliminary results in the same year. Modifications to the National Energy Audit (NEAT) designed to improve its usefulness in warm climates are currently nearing completion. Furthermore, cooperative state-level evaluations in three warm climate states began in 1997.

VII. REMAINING OPPORTUNITIES

A. Additional Investments per Home

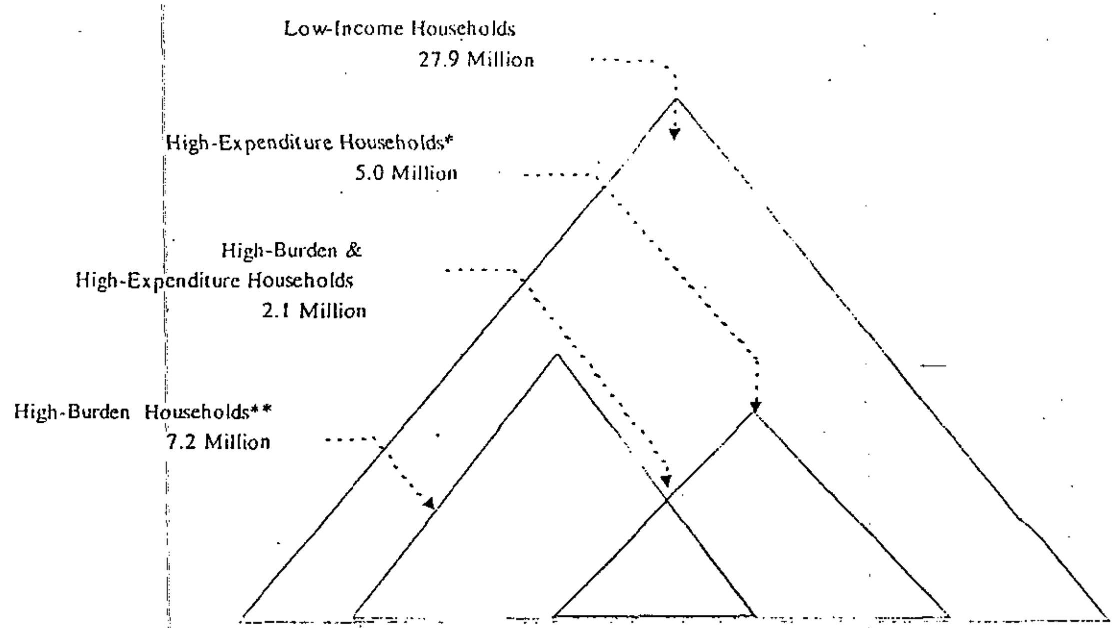
> **Many Opportunities for Additional Cost-Effective Investments**
>
> - Further reduce air leakage
> - Increase levels of insulation
> - Give more attention to heating systems and ducts
> - Use more leveraged funds for housing rehabilitation

In general, the amount invested in weatherizing a home is directly related to the magnitude of energy savings. A regression analysis of over 1,800 gas-heated homes showed that gas energy savings increased by 15 ccf/year with each additional $100 invested in labor and materials. The average rate of increase in energy savings did not diminish as investments increased from $1,000 to $3,000. In PY 1989, the average investment per house was about $1,000 for labor and materials. Houses that received larger investments, however, clearly saved more energy. For example, high-saving dwellings benefited from total expenditures for labor and materials of $1,192, which was 14% more than the national average of $1,050. Low-saving dwellings, however, received an investment of only $714 (or 68%) of the average national investment. Similarly, higher-saving agencies were more likely to obtain funds from non-DOE sources so that a higher average investment per dwelling was possible. These results suggest that there is a cost-effective potential for substantially increasing energy savings by increasing the average investment per dwelling.

The proportion of the funds invested in various types of weatherization measures also is an important determinant of energy savings. In high-saving dwellings, 38% of the total spent on materials was invested in insulation and 16% in heating systems. In low-saving dwellings, in contrast, 27% of the total spent on materials was invested in insulation and 3% in heating systems. In low-saving dwellings far larger proportions were spent on structural repairs (25% versus 7%) than in high-saving dwellings, and more was invested in windows and doors (15% versus 4%). Similarly, higher-saving agencies invested more in insulation and heating systems and less in windows and doors.

TARGETING NEEDY HOUSEHOLDS

LOW-INCOME HOUSEHOLDS AND SUBPOPULATIONS IN 1990



*averaging $1,233 in annual energy expenditures

**averaging 30.1% of their income

Targeting high-burden and high-expenditure households offers the opportunity to reduce utility bills of the neediest households and achieve sizable energy savings. The above diagram identifies 2.1 million program-eligible households that have both high energy expenditures (averaging $1,339 per year) and high energy burdens (averaging 30.4 percent of their income).

Many measures installed by the Program show significant opportunities for additional energy-efficiency improvements. Although the weatherized homes were clearly tighter than the control homes, approximately 80% of them still had air leakage rates that exceeded 1,500 cfm_{50} (a threshold above which more air-infiltration reduction is generally recommended). The R-values in weatherized homes were significantly higher than those in control homes. However, the R-values of the attic insulation in weatherized homes were still often below DOE-recommended levels. For example, about 26% of weatherized homes had attic R-values of less than R-19 and 63% had R-values of less than R-30. R-19 or less is below recommended levels in all climate regions in the U.S. and R-30 is below the recommended level for all except the hottest regions. The need for more frequent installations of attic and wall insulation was especially important in the warm climate region. The poor condition of heating systems and ducts in many homes also pointed to opportunities for additional savings (Berry and Brown, 1994).

Although many important and cost-effective energy-efficiency improvements are being implemented by the Program, more funding would make it possible to do much more. Because of the overhead costs involved in setting up work in each home, it would be most cost efficient to capture as many opportunities as possible during the DOE-sponsored installation. In addition, because a home will rarely be revisited at a later date, cost-effective measures that are not installed are likely to be long-term "lost opportunities." Leveraged funds from utilities and other sources are an important vehicle for providing more complete and comprehensive weatherization and for minimizing lost opportunities.

Many low-income homes need extensive structural repairs, which must be paid for with leveraged funds. For these homes, leveraging of housing rehabilitation funds to supplement DOE funds is an essential step in achieving structural integrity and energy efficiency.

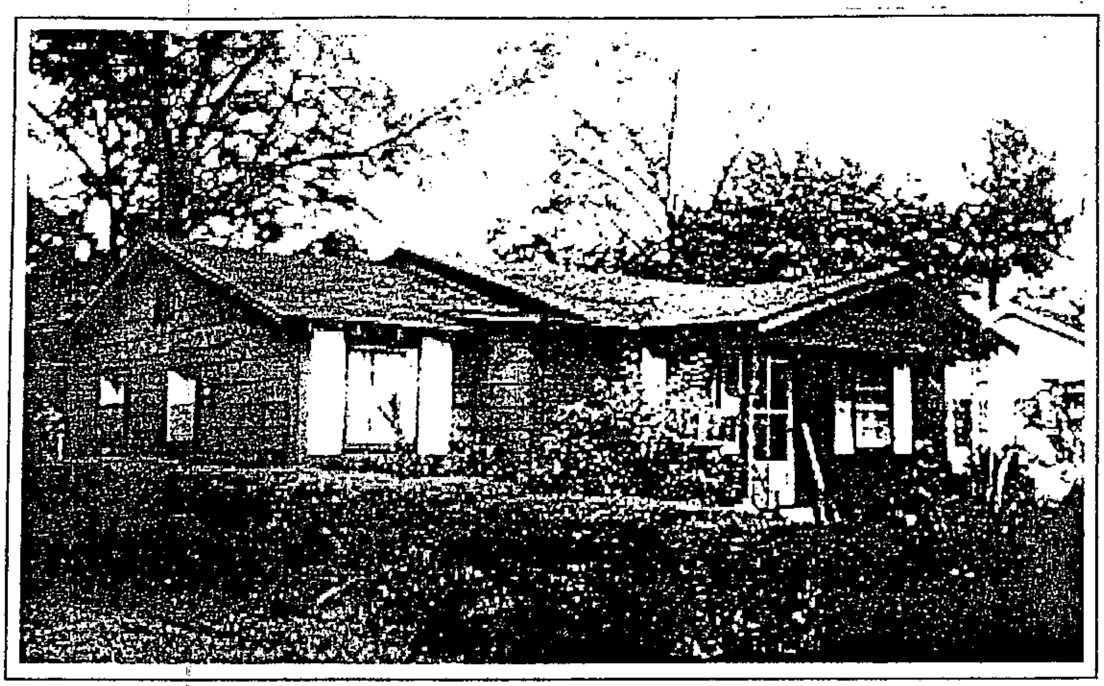
B. Targeting the Neediest Households

The Department of Health and Human Services has reported that, based on Energy Information Administration data, there were 29.1 million households with incomes near or below the federal poverty guidelines for weatherization eligibility in 1994. Given the large population remaining to be served by the Weatherization Program, it is critical for local agencies to focus resources on households with the greatest need for weatherization and with the largest potential for benefits.

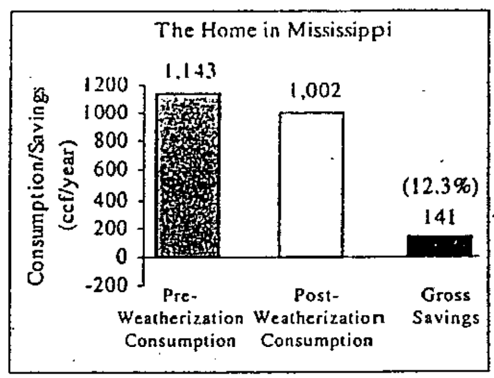
One strategy for targeting weatherization assistance funds is to identify households with both high energy expenditures and high energy burdens. High-expenditure households are good targets because high expenditures are correlated with high energy savings potential. High-burden households are good targets because they can least afford the costs of the energy they consume and they are the least likely to be able to make energy-saving investments in their homes.

The 1990 Residential Energy Consumption Survey (RECS) was used to estimate statistically the size and characteristics of the target groups

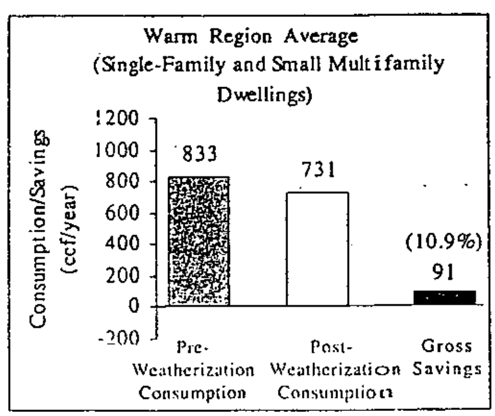
HIGH SAVINGS FROM ATTIC INSULATION



The core of this wood-framed home was built around 1955; since then, two small additions have been constructed, resulting in 1,277 square feet of living space and in a complicated roof-line prone to water and air leakage. Prior to weatherization, the home had no insulation in its attic, walls, or foundation, and its 14 wooden window frames and two wooden doors were rotten and leaky. The home was heated by two gas space heaters—one in the living room and the other in one of the four bedrooms. The 30-gallon water heater and the stove also used natural gas.



The weatherization agency spent $900 in materials and $400 in labor to weatherize this house. A state-wide priority list of measures was used to select the weatherization measures. The job involved blowing approximately 3" of loose-fill fiberglass insulation across the attic floor, adding two gravity vents for each of the bathrooms, repairing and replacing several windows, replacing one of the doors, and generally caulking and weatherstripping.



During the year after weatherization, the client used 1,002 ccf of natural gas, representing a decrease of 141 ccf (12.3%). The occupants judged their home to be noticeably less drafty after weatherization and much less expensive to heat.

that appear to have the greatest potential to benefit from weatherization assistance. The evaluation defined the groups as follows:

• **High-Expenditure Households**--those with the highest space heating costs per heating degree day and square foot relative to others in their climate zone and region. This group included 5.0 million low-income households which had average energy expenditures of $1,233 and an average energy burden of 19.2% of income.

• **High-Burden Households**--those with the highest energy burden (expenditures in proportion to income) relative to others in their climate zone and region. This group included 7.2 million low-income households which had average energy expenditures of $1,175 and an average energy burden of 30.1% of income.

• **High-Burden/High-Expenditure Households**--those that qualified in both categories above. This group included the 2.1 million households which had average energy expenditures of $1,339 and an average energy burden of 30.4% of income.

Several key characteristics help to define the High-Burden/High-Expenditure households. These households have very low incomes--they have an average income of $6,114 compared to $10,048 for all low-income households. A substantial share of these households represent vulnerable population groups--about 40% are elderly households and another 24% are single-parent households. In other ways, however, they are much like other low-income households--they occupy the same types of dwellings and they use the same types of fuels. Thus, in order to target these households, local agencies need to be particularly attuned to their client's expenditure and burden levels.

VIII. THE FUTURE OF WEATHERIZATION: THE NEXT STEPS

The various reports produced by the National Weatherization Evaluation presented a comprehensive profile of the weatherization procedures and measures that characterized high-performing agencies and high-saving dwellings. The following recommendations, which resulted from these findings, describe a series of next steps to enhance the Weatherization Program beyond its already strong foundation.

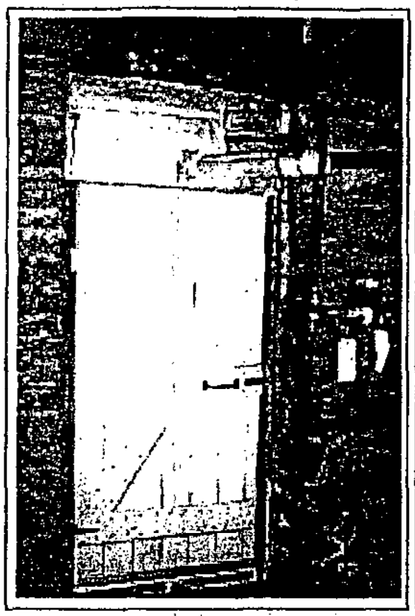
The Metaevaluation results, which showed an 80% increase in energy savings during the past seven years, suggest that substantial progress has already been made in implementing many of the National Evaluation's recommendations.

A. Service Delivery Procedures

• **Enhance the existing high quality of the weatherization work force through increased training and professional development.** High-performing agencies were characterized by experienced and well-trained employees. Improving the ability of the weatherization work force to employ diagnostic reasoning and principles from building science will result in even more cost-effective weatherization.

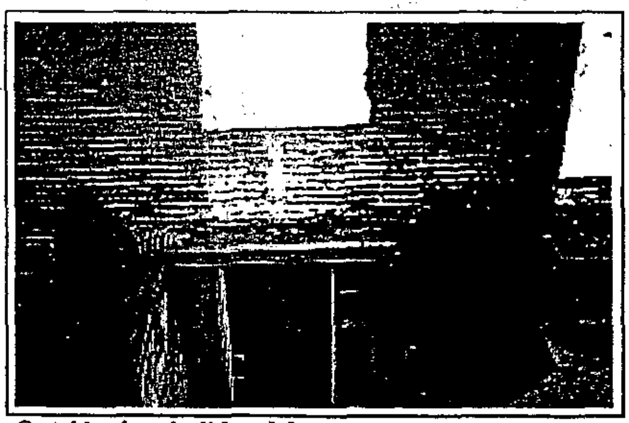
BASEMENTS

These photos illustrate a weatherization tactic used to block massive infiltration at the bottom of the heated envelope. Sometimes doors or even insulating walls have to be constructed to form an effective air barrier. Skilled weatherization crews can accomplish this job in two hours or less at a materials cost of only $60 or so.



A new bulkhead door and insulated sheathing isolate the area under a porch, thus solving a major infiltration problem.

Sealing a new basement partition wall.



Outside view, bulkhead doors open.

Inside view, new partition wall with weatherstripped access door.

Air sealing at sill plate with foam. This infiltration-stopping measure is necessary with most weatherization jobs.

Technology Transfer Efforts in the 1990's

- Development and promotion of advanced audits
- Warm Climate Initiative
- Development of mobile home audit
- Refined assessment methods for storm windows

• **Encourage agencies to direct their resources towards clients that have higher-than-average levels of energy burden.** This can be done either through the selection of clients that have a higher-than-average energy burden or the determination of investment levels based on the pre-weatherization energy burden. Both the Single-Family and the Fuel-Oil Studies found that energy savings are greatest in dwellings that consume large amounts of energy prior to weatherization. These same households also tend to spend a high proportion of their income on energy. By matching levels of investment with potential for savings, overall program cost effectiveness will improve.

• **Encourage the efforts of states to mobilize other resources to address the rehabilitation needs of low-income housing.** This will enable DOE resources to be focused more on energy-efficiency improvements. Most high-performing agencies have access to non-DOE funds to help pay for housing repairs. The Program will be stronger as more local agencies have access to non-DOE funds for housing rehabilitation while using DOE funds to improve energy efficiency.

• **Establish technology transfer mechanisms to promote replication of the success of high-performing agencies.** One striking finding of the Single-Family Study is the tremendous diversity among local agencies. A challenge to DOE's Weatherization Program is to help bring the less innovative and less advanced agencies up to the level of the high-performing agencies in their region. The promotion of advanced audits and the Warm Climate Initiative are two examples of successful recent technology transfer efforts. Additional research efforts that are nearing completion include the development of an audit designed specifically for mobile homes and the development of refined assessment methods for decisions about the installation of storm windows. When these improved tools are adopted by the Weatherization network, additional improvements in performance will result.

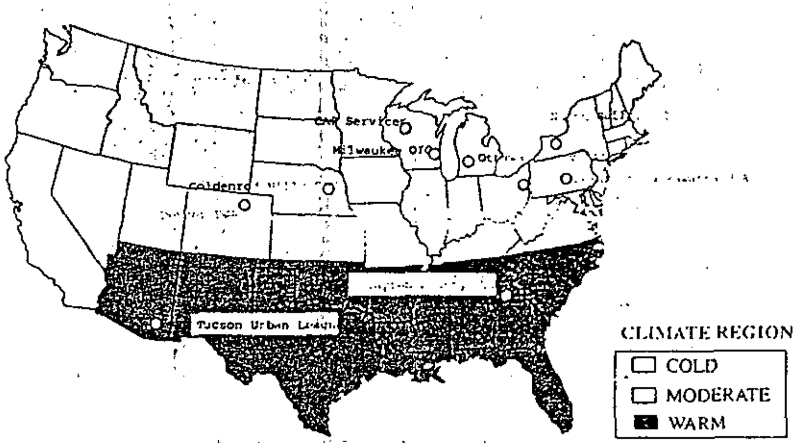
B. Weatherization Measures

• **Continue the Program's strong emphasis on attic, wall, and floor insulation.** High savings in both the Single-Family and Fuel-Oil Studies are associated with greater-than-average levels of investment in insulation. High-density wall insulation techniques that can achieve air sealing and insulation in the same operation appear to be especially effective. Advanced audits tend to increase the level of investment in both wall and attic insulation.

• **Further analyze the role of replacement windows and storm windows.** The Single-Family and Fuel-Oil Studies showed that large investments in windows are especially characteristic of dwellings and agencies that achieve lower-than-average energy savings. Yet at least one high-performing agency specialized in storm windows. Further, owner investments in the weatherization of large multifamily buildings tend to target storm windows. Preliminary research, conducted in 1996, has refined assessment methods for determining the conditions under which storm and replacement windows are a cost-effective Program expenditure. The findings from this research will be incorporated into future versions of the National Energy Audit.

KEYS TO SUCCESS

Case studies of ten high-performing local agencies demonstrate that there are many different formulas for the successful operation of a weatherization program. Each of the ten agencies employs a unique combination of useful and innovative approaches. At the same time, common features do exist. The following table summarizes the most notable characteristics that distinguish the ten high-performing agencies from other agencies. These noteworthy features range from agency and staff characteristics to client recruitment and selection practices; weatherization measures; resource leveraging; and cost controls.



Category	Characteristics of a Majority of the High Performers
Agency Characteristics	Large, multi-program community action agencies
Characteristics of Weatherized Housing	High levels of pre-weatherization energy use; older dwellings; more elderly occupants; fewer mobile homes; more central heating; fewer supplemental heating fuels
Weatherization Staff	Limited turnover and substantial weatherization experience
Delivery System	In-house crews supplemented by contractors for furnace work
Client Recruitment	Reliance on LIHEAP rosters for recruiting applicants
Selection of Clients and Investment Levels	Strong and increasing focus on high energy users
Blower Door Use	Limited use in 1989, extensive use in 1996, during the audit, while air sealing, and as part of the final inspection
Weatherization Measures	More first-time attic insulation and wall insulation; furnace retrofits and replacements; and water-heater measures
Leveraging Home Repairs	Access to housing rehabilitation funds from non-DOE sources
Cost Controls	Effective cost controls such as bulk purchasing & in-house fabrication of measures

• **Increase the emphasis on replacing inefficient space-heating systems.** High-performing agencies identified in the Single-Family Study replaced more space-heating systems than other agencies. In addition, they made greater use of instrumented analyses of furnaces and boilers to select measures that promote health, safety, and energy efficiency. System replacements and instrumented analyses were characteristic of high-saving homes in both the Single-Family and Fuel-Oil Studies.

• **Increase attention to heating system distribution systems.** Dwellings that received duct leakage control measures and distribution system diagnostics achieved above-average savings in the Single-Family Study.

• **Increase attention to water-heating measures.** Water-heating conservation measures are characteristic of high-saving homes in the Single-Family and Fuel-Oil Studies. Measures to consider should include domestic warm water tank and pipe insulation, water temperature reduction, low-flow showerheads, and aerators.

• **Select measures based on savings-to-investment ratios produced by audits.** The Program has successfully moved away from the use of prescriptive methods such as statewide priority lists for the selection of measures. Advanced audits that rank measures by savings-to-investment ratios, calculated for each individual house, were used in 37 states in 1996.

IX. CONCLUSIONS

Weatherization is a sound public program that has advanced technically during the past seven years. In spite of some impediments, such as reduced funding, **the Program is saving 80% more energy per dwelling and is more cost effective than in 1989.** Procedures and measures associated with higher energy savings and new technologies are the major sources of this progress.

Societal benefits resulting from the Program include:

- the creation of about 8,000 jobs (in 1996);
- cleaner air through reduced CO_2 and power plant emissions;
- reduced consumption of imported fuels through reduced residential consumption; and
- reduced demand on other social programs such as fuel assistance, housing and health care.

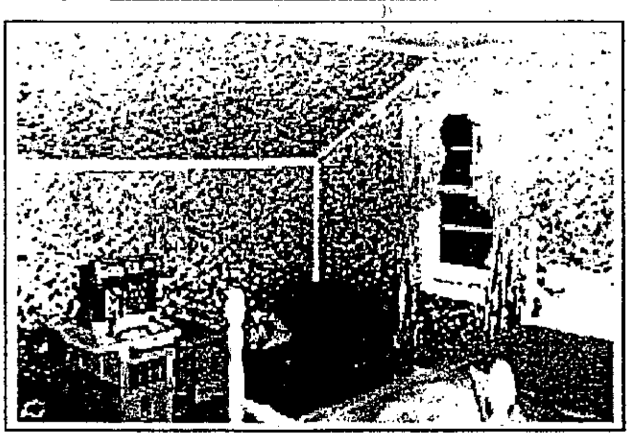
Other benefits include improvement of neighborhood housing conditions, and promoting the use of newly developed conservation tools, materials and techniques. Most importantly, alleviation of the high energy burden faced by low-income Americans enables them to gain increased financial independence and greater flexibility in spending for other essential items.

The table on page 73 compares the findings of the National Evaluation of the Weatherization Assistance Program, based on 1989 data, to the Metaevaluation of 17 state-level evaluations completed in 1996.

To sum up, the Weatherization Assistance Program Works!

PUTTING IT ALL TOGETHER

This home in rural New England had a weatherization job that reduced energy costs by more than 50 percent. After the knee wall on the second floor was accessed with a saw from the outside, extensive air sealing and insulation work were performed. (The access hole is now covered with a rectangular vent.) This weatherization job also included extensive repair of a leaky distribution system and other infiltration-stopping measures, including a new basement door. Although exterior aesthetics were not altered, the clients were overjoyed with a much more comfortable house--and a $600 per year saving on their oil bill.



Significant Findings of the 1989 National Weatherization Evaluation and the 1996 Metaevaluation for Gas-Heated Dwellings

Finding	1989 Value for Gas-Heated homes	1996 Value for Gas-Heated homes
Annual energy savings per dwelling (in Mbtus)	17.3	31.2
Energy savings as a percentage of energy used for space heating	18.3%	33.5%
Energy savings as a percentage of total gas consumption	13.0%	23.4%
Value of annual energy savings per dwelling in 1996 dollars	$107	$193
"Program" benefit/cost ratio*	1.06	1.79
"Installation" benefit/cost ratio**	1.58	2.39
"Societal" benefit/cost ratio***	1.61	2.40

*Based on energy-savings benefits and total weatherization costs.
**Based on energy-savings benefits and labor and materials costs.
***Based on energy-savings, employment, and other non-energy benefits and total weatherization costs.

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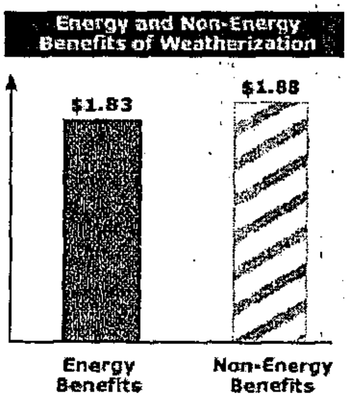

Each dollar of DOE investment in weatherization returns $3.71 in energy- and non-energy-related benefits.

Non-Energy Benefits of Weatherizati

There are substantial non-energy benefits from DOE's Weatherizat Assistance Program, according to a new study by Oak Ridge Natio Laboratory (ORNL). The study documents benefits to utility ratepa the economy, and the environment that are in addition to the ene benefits that reduce the energy bills of low-income families by inc the energy efficiency of their homes.

- **How to value non-energy benefits of weatherization?**
- **Read this and other reports by Oak Ridge National Lal**

How to value non-energy benefits of weatherization?

The U.S. Department of Energy (DOE) issued a press release on August 28, 2002 announcing a documenting considerable non-energy benefits from low-income weatherization. The report sum existing literature on how to value such benefits for participating households, utility ratepayers, economy, and the environment. While there is a large range of potential monetary values for th benefits, there is no question they are important for the communities that receive weatherizatio services.

Furthermore, ORNL's analyses are useful for developing overall cost-benefit ratios. Researchers that for every dollar of DOE investment, there are non-energy benefits worth $1.88.

These benefits are in addition to energy savings, which reduce energy bills an average of $275 p in more than 105,000 low-income homes in 2002. The cost-benefit ratio of energy reduction is $ each dollar of DOE investment. When the energy- and non-energy-related benefits are added to the DOE Weatherization Assistance Program returns $3.71 for every dollar invested by DOE.

Among others, the non-energy benefits of weatherization include:

- **For participating households**, there are reduced water consumption and accompanying and sewer fees, and an increase in property values.
- **For utility ratepayers**, there are reduced costs for bill collection and service shut-offs. A because weatherization addresses the safety of major appliances, the utility has fewer em calls.
- **For the local economy**, DOE's investment in energy efficiency generates a whole range c local home services industries. Nationwide, the Weatherization Assistance Program genera 8,000 jobs, which increases the tax base in communities throughout the country and indir supports other jobs. Furthermore, weatherization reduces the burden of unemployment pa for taxpayers and local businesses.
- **For national security**, weatherization decreases U.S. energy use the equivalent of 15 mi barrels of oil every year.

Exhibit (Schedule) 5

- **For the environment,** the reduction in energy consumption by low-income clients reduce need for combustion of fossil fuels and the resulting emissions into the atmosphere.

The report noted that there are additional benefits from weatherization that are not covered in t because a monetary value cannot be assigned to them.

Read this and other reports by Oak Ridge National Laboratory

Non-Energy Benefits from the Weatherization Assistance Program—A Summary of Findings from Literature (PDF 235 KB) Download Acrobat Reader.

Martin Schweizer and Bruce Tonn; Oak Ridge National Laboratory report number ORNL/CON-48 pp.; April 2002.

Recent Studies and Publications
The Oak Ridge National Laboratory (ORNL) Weatherization and SEP Support Program have publi dozens of reports over the past 17 years, many of which are available online. Some hard copies reports are also available from ORNL.

ORNL/CON-484

NONENERGY BENEFITS FROM THE WEATHERIZATION ASSISTANCE PROGRAM: A SUMMARY OF FINDINGS FROM THE RECENT LITERATURE

Martin Schweitzer
Bruce Tonn

OAK RIDGE NATIONAL LABORATORY

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ORNL/CON-484

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EXECUTIVE SUMMARY

The purpose of this project is to summarize findings reported in the recent literature on nonenergy benefits attributable to the weatherizing of low income homes. This study is a follow-up to the seminal research conducted on the nonenergy benefits attributable to the Department of Energy's national Weatherization Assistance Program by Brown et al. (1993).

For this review, nonenergy benefits were broken into three major categories: (1) ratepayer benefits; (2) household benefits; and (3) societal benefits. The ratepayer benefits can be divided into two main subcategories: payment-related benefits and service provision benefits. Similarly, there are two key types of household benefits: those associated with affordable housing and those related to safety, health, and comfort. Societal benefits can be classified as either environmental, social, or economic.

Fig. E.S. 1 presents point estimates of the average lifetime monetary value per weatherized home resulting from low income weatherization programs for the key benefit types listed above. These benefits represent net present value estimates (i.e., estimates of the current

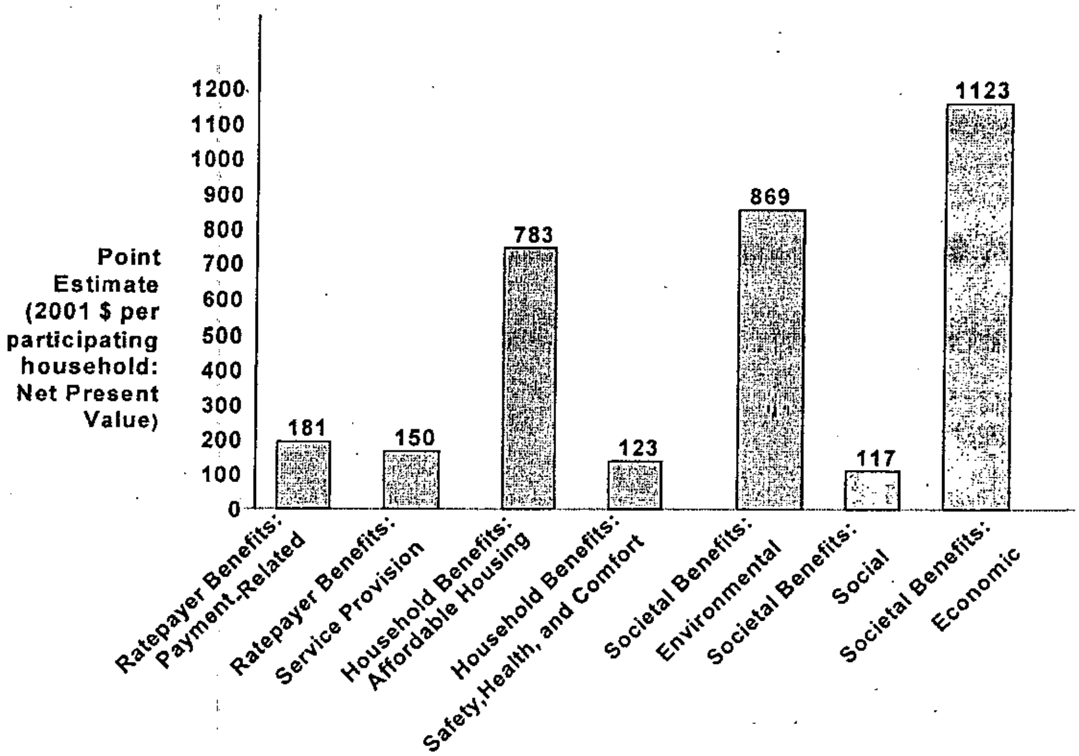

Fig. E.S.1 Summary of Nonenergy Benefits by Category and Subcategory

worth of all benefits expected over the lifetime of the weatherization measures), assuming a 20-year lifetime for installed energy efficiency measures and a 3.2% discount rate. Overall, societal benefits are estimated to be substantially larger than ratepayer and household benefits. *Ranges* for the societal benefits are also much greater than for the other two categories of nonenergy benefits. The total monetized value for all nonenergy benefit categories associated with weatherizing a home is estimated to be $3346, in 2001 dollars. This represents a national average which, like any point estimate, has considerable uncertainty associated with it. This figure is substantially higher than the total value of nonenergy benefits presented a decade ago in the national weatherization evaluation (Brown et al. 1993) because the current study quantified a much broader array of benefits than did the earlier work.

The net present value of $3346 for all nonenergy benefits is slightly greater than the average net present value of energy savings for houses heated by natural gas, which is $3174 in 2001 dollars. In comparison, the average total cost per weatherization is $1779, also in 2001 dollars. The "societal" benefit/cost ratio, which compares *all* benefits to *all* costs, is approximately 3.7. Low and high values for the societal benefit/cost ratio, using low and high nonenergy benefit estimates, are 2.0 and 52.5, respectively. It should be noted that the total monetized nonenergy benefit estimate is lower than it could be because the estimate does not contain some benefits that have not been expressed in monetary terms.

1. INTRODUCTION

1.1 BACKGROUND

The national Weatherization Assistance Program provides energy efficiency improvements for low-income residences throughout the country. The program is sponsored by the U.S. Department of Energy and is implemented by state and local agencies in all 50 states and the District of Columbia. Since its inception in 1976, the Weatherization Assistance Program has weatherized approximately five million dwelling units for their low-income occupants. Common weatherization measures include: caulking and weather stripping around doors and windows and sealing other unnecessary openings to reduce air infiltration; installing attic, wall, and floor insulation; and wrapping water heaters and pipes with insulating material. A national evaluation of the program conducted by Oak Ridge National Laboratory (ORNL) almost a decade ago (Brown et al. 1993) focused on energy and cost savings, but it also contained a detailed discussion of the nonenergy benefits associated with low-income weatherization activities. Since the time of the national evaluation, a substantial amount of research has been conducted to examine the nature and magnitude of the nonenergy benefits that result from weatherization programs. The purpose of this report is to use the findings from the large body of post-1993 research to update ORNL's previous estimates of the Weatherization Assistance Program's nonenergy benefits.

ORNL's national weatherization evaluation (Brown et al. 1993) identified an extensive range of nonenergy benefits associated with the Weatherization Assistance Program. A total of fifteen benefits were identified, but monetized values could be calculated for only about half of them. As shown in Table 1, all the monetized values combined had a net present value, over the lifetime of the weatherization measures installed, of $976 (in 1989 $).

1.2 METHODS

The primary research method used for this study was a comprehensive review of the literature on nonenergy benefits written since the national weatherization evaluation was completed in 1993. Many different articles and reports have been written about the nonenergy benefits of low-income weatherization activities since that time. Some present the findings from primary research conducted on the subject, usually focusing on a weatherization program operated by a given state or utility company (e.g., Magouirk 1995; Blasnik 1997; Hill et al. 1998). Others take a meta-analysis approach and report the findings from a number of studies conducted in different locations (e.g., Riggert et al. 1999; Riggert et al. 2000; Howat and Oppenheim 1999). One set of articles that was especially useful for this study (Skumatz and Dickerson 1997; Skumatz and Dickerson 1998; Skumatz and Dickerson 1999) focused on two

Table 1. Nonenergy Benefits Monetized in National Weatherization Evaluation (1993)

Nonenergy Benefit	Net Present Value of Benefit per Dwelling (1989 $)
Enhanced property value and extended lifetime of dwelling	126
Reduced fires	3
Reduced arrearages	32
Federal taxes generated from direct employment	55
Income generated from indirect employment	506
Avoided costs of unemployment benefits	82
Environmental externalities	172
Total of all nonenergy benefits	**$976**

low-income weatherization programs operated by Pacific Gas and Electric Company (PG&E), using primary data pertaining to those programs and also making use of important findings from a comprehensive review of studies performed by other researchers elsewhere in the country. Because much of the information analyzed by Skumatz and Dickerson came from a variety of locations, and because the PG&E programs they studied are very similar to other full-scale weatherization efforts undertaken throughout the country, the findings from the Skumatz and Dickerson articles are considered broadly applicable to DOE's Weatherization Assistance Program.

From a thorough review of the literature, we identified a complete set of nonenergy benefits and organized them into major categories and subcategories. Our approach was informed by the post-1993 articles and reports reviewed as well as by the ideas presented in the national weatherization evaluation (Brown et al. 1993). Then, a range of monetary values was identified for each nonenergy benefit, drawing from all recent studies that provided dollar values for nonenergy benefits and that employed methods that we considered reasonable and legitimate, even if the numbers themselves appeared to be somewhat extreme. In fact, many of the value ranges presented in this report are very broad.

After a range of monetized values was identified from the literature for all nonenergy benefits, we used our professional judgment to select a reasonable point estimate for each one to represent the average value of that benefit associated with weatherization efforts nationwide. Even where the entire continuum of possible values was very large, it was common for *most* of the suggested values to cluster around a fairly narrow range. In such cases, we tended to select a preferred point estimate that was close to the midpoint of the clustered values. Where one extremely high value led to an extended range, it was often the case that the clustered values and our point estimate fell toward the low end of that range. However, it is important to note the inherent uncertainty associated with any point estimate that is made. Clearly, a single point estimate for any given nonenergy benefit cannot represent the benefits associated with every weatherization effort in each separate locale because of the substantial variation that occurs among different programs and geographic areas. Even where, as in this report, a point estimate is based on a number of different studies and is intended to represent a national average, there is still good reason to be cautious. As the name implies, a point estimate is only an *estimate* of a savings value and is based on various assumptions about program operations and effectiveness rather than on systematic measurement, and subsequent weighting and averaging, of program outcomes throughout the country.

Nearly all of the nonenergy benefits addressed in this report occur everywhere, but a couple only apply to certain types of households (i.e., those receiving low-income rate subsidies or those using natural gas). In such cases, the magnitude of the benefits reported in the literature is adjusted downward to make it an average value for the entire nation. Of course, even where benefits do apply universally, the actual magnitude will vary from place to place, as noted above. When point estimates for all the benefits addressed in this report are aggregated, they represent the average benefit for a typical low-income U.S. household. However, that point estimate will not necessarily apply to each individual household. In cases where a particular benefit does not apply, the total value of all nonenergy benefits would tend to be lower than indicated in this report, provided that all other conditions affecting the magnitude of benefits are typical.

Monetary values for the various nonenergy benefits provided in the recent articles and reports that we reviewed are generally treated as if they are in 2001 dollars. We consider this to be a reasonable approach because (1) most of the works reviewed were written during the last two or three years and inflation has been very modest during that period, and (2) the dollar values provided in the literature tend to be estimates and approximations and are not precise enough to warrant adjustment by a few percentage points. The principal exception to this is in the case of values that are taken from the national weatherization evaluation (Brown et al. 1993). Because the data in that study date from 1989, it was considered prudent to adjust the relevant numbers upward, using the inflation factors contained in the Consumer Price Index (Bureau of Labor Statistics 2001).

Many of the monetized values presented in the literature are listed in terms of dollars per participating household per year. We converted those annual benefits into net present value (NPV) per household, assuming that: (1) the useful life of the installed weatherization measures is 20 years (which is consistent with past evaluations of the Weatherization Assistance Program); and (2) the appropriate discount rate is 3.2 % (the rate suggested by the Office of Management and Budget for program evaluation). Based on these assumptions, a benefit that has an annual value of $10 per year would have a NPV of $146. We are aware that different parties are likely to apply different discount rates when calculating the value of a given investment. However, the 3.2% discount rate is used in this report for *all* categories of benefits to be consistent and to reflect the fact that this document is written from the perspective of the federal agency that sponsors the Weatherization Assistance Program.

1.3 SCOPE OF REPORT

The subsequent chapters of this report present key findings from our study of the nonenergy benefits associated with low-income weatherization efforts. In order to present a complete picture of the nonenergy benefits associated with weatherization programs, these benefits are described from three distinct perspectives: that of utility ratepayers; that of participating households; and that of society as a whole. It should be noted that a couple of the nonenergy benefits addressed in this report are discussed under more than one major category, to reflect the fact that there are different groups of beneficiaries. For example, "avoided shut-offs and reconnections" are discussed both from the ratepayer and the household perspective. The value of the benefit received by each set of actors in different, and double-counting is avoided because ratepayers and participating households receive different, and non-overlapping, values from the benefit in question.

Chapter 2 discusses the benefits received by utility companies and passed on to their ratepayers. These fall under the broad headings of benefits related to the payments that utilities receive from their customers and benefits related to the utilities' provision of services. In this chapter, as in the following ones, each individual benefit is described, a range of possible monetized values and a point estimate are given for each benefit, and a brief explanation is provided of the methods used to calculate the values.

In Chapter 3, benefits experienced by the low-income households that receive weatherization services are described. Such benefits can be grouped into two categories: affordable housing benefits and benefits related to the occupants' safety, health, and comfort.

Chapter 4 addresses societal benefits, which can be subdivided into environmental benefits, social benefits, and economic benefits.

Finally, Chapter 5 summarizes the full set of nonenergy benefits and their monetary values, examines the relative magnitude of the different types of nonenergy benefits, and compares the size of these benefits with the energy benefits generated by the Weatherization Assistance Program.

2. RATEPAYER BENEFITS

Utility ratepayers receive two distinct types of nonenergy benefits as a result of low-income weatherization efforts. Point estimates of the average lifetime monetary value associated with each type of benefit are shown in Fig. 1. The first type of benefit is related to the payments that utilities receive (or do not receive) from their customers and includes six different items: (1) avoided rate subsidies; (2) lower bad debt write-off; (3) reduced carrying cost on arrearages; (4) fewer notices and customer calls; (5) fewer shut-offs and reconnections for delinquency; and (6) reduced collection costs. The second type of benefit is related to the provision of services and has three components: (1) fewer emergency gas service calls; (2) transmission and distribution (T&D) loss reduction; and (3) insurance savings. While all of the benefits listed above initially accrue to utility companies, they tend to be passed on to the utilities' customers and are therefore classified in this report as ratepayer benefits. Each of these benefits is discussed in more detail below.

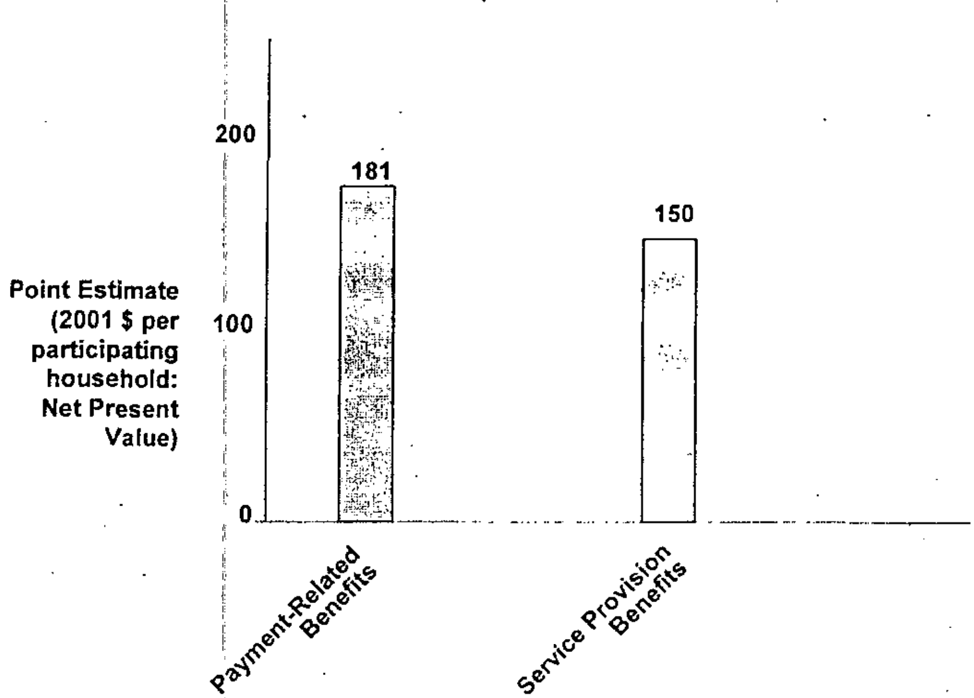

Fig. 1. Average Lifetime Monetary Value of Ratepayer Benefits, by Type

2.1 PAYMENT-RELATED BENEFITS

Rate Subsidies Avoided

Many utilities provide lower, subsidized rates for their low-income customers. Accordingly, each unit of energy consumed by low-income customers represents an expense for the utility and for its other customers, whose payments help subsidize the discount rate. When the amount of energy used by low-income customers is reduced as a result of a weatherization program, the number of subsidized units of energy sold decreases and the utility and its other ratepayers save money.

The literature reviewed for this study presented a number of different estimates of the dollar value of rate subsidies avoided as a result of low-income weatherization programs. Many of these estimates were presented in terms of annual savings per household but, as explained in Chapter 1, these were all converted to net present value over the lifetime of the measures installed. The estimated lifetime savings range from a low of $38 to a high of $467. However, the estimates of benefits found in the literature typically describe only those instances in which rate subsidies are available and used by low-income customers. In order to represent average savings across the nation as a whole, those savings numbers should be adjusted downward to reflect the proportion of low-income customers actually receiving such subsidies. Based on information compiled by the National Center for Appropriate Technology (2001), we know that only about 15% of low-income customers nationwide get rate subsidies. Accordingly, we multiplied the range of benefits presented in the literature by 0.15, resulting in an adjusted range of $6 to $70 (Table 2). Our preferred point estimate for this benefit is $21 but, as explained previously, any single estimate made for the entire low-income Weatherization Assistance Program is necessarily imprecise and the associated uncertainty must be recognized.

Table 2. Ratepayer Benefits: Payment-Related

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Rate subsidies avoided	6 - 70	21
Lower bad debt write-off	15-3462	89
Reduced carrying cost on arrearages	4-110	57
Fewer notices and customer calls	0-23	6
Fewer shut-offs and reconnections for delinquency	2-15	8
Reduced collection costs	Not Available	Not Available

The point estimate of $21 suggested above is derived from the midpoint of the range of possible dollar savings from avoided rate subsidies presented by Skumatz and Dickerson (1999) for the Low-Income Weatherization Program operated by PG&E. The savings estimate was calculated by taking the average rate subsidy received by participating households and multiplying it by the amount (in percentage terms) by which participants' energy use is likely to be reduced. We then adjusted this amount downward, as described above, to make it represent the average savings distributed over *all* low-income customers and not just those receiving rate discounts.

Lower Bad Debt Write-off

When customers cannot pay all or part of their bills for an extended period of time, the utility might have to write off the unpaid portion as bad debt. When the occupants of weatherized units experience reductions in their utility bills, they are better able to make their payments and the amount of bad debt written off is likely to decrease. Actually, there are two parts to this reduction in bad debt: a decrease in the average size of bad debt written off and a decline in the number of such accounts.

The range of possible dollar benefits presented in the literature for lower bad debt write-off was extremely broad, with a minimum NPV of $15 and a maximum of $3462 (Table 2). Although one very high value was noted, all the other benefit levels described in the literature clustered at the lower end of the range. We suggest a point estimate of $89, based on the findings from a well-designed study of the nonenergy benefits resulting from Public Service Company of Colorado's Energy $avings Partners Program (Magouirk 1995). That study measured the post-weatherization reduction in the *amount* of bad debt written off by participating households. In addition, the decrease in the *number* of accounts that were written off was measured. The two factors combined yielded the $89 NPV reported above. That number is near the high end of the range suggested by Skumatz and Dickerson (1999) for two California low-income programs but at the low end of the range suggested in an extensive study of the values of nonenergy benefits conducted for the state of California (TecMRKT Works et al. 2001).

Reduced Carrying Cost on Arrearages

Weatherization programs lower energy consumption for participating customers, thereby reducing the size of their energy bills and making it possible for them to pay a larger portion of those bills. This in turn reduces the amount of customers' bills that are in arrears. As these arrearages decline, the carrying costs borne by utilities (i.e., the interest on the amount in arrears) are also reduced.

According to the literature reviewed, the net present value of this benefit ranges from $4 to $110 (Table 2). As a point estimate, we chose $57, which is the midpoint of the savings calculated by Skumatz and Dickerson (1999) for two low-income programs in California. (PG&E's Low-Income Weatherization Program and its Venture Partners Pilot Program). The Skumatz and Dickerson study calculated savings based on likely program-induced reductions in arrearage balances, the magnitude of pre-weatherization arrearages in eligible households, and prevailing interest rates.

Fewer Notices and Customer Calls

As noted above, households that receive weatherization services tend to lower their energy consumption as a result, leading to lower energy bills, which are easier for them to pay. Consequently, utilities are required to send out fewer notices in response to late payments and will receive fewer customer calls regarding these situations. All of this results in a savings to utilities for staff time and materials.

As shown in Table 2, the NPV of this benefit reported in the literature ranges from $0 to $23. Our suggested point estimate is $6, which is at the high end of the range suggested by Skumatz and Dickerson (1999) but toward the lower end of the full range of benefits reported when other studies are included. The monetized benefits reported here represent a combination of the numbers calculated separately for late payment notices and for customer calls. An 18% reduction in the number of notices and calls was assumed, based on previous empirical findings on the incidence of reductions in the number of accounts written off for bad debt as a result of weatherization efforts (Magouirk 1995). This was multiplied by the annual cost per household of notices and customer calls to produce an estimate of savings per participant.

Fewer Shut-offs and Reconnections for Delinquency

As explained above, weatherized households are less likely to fall behind on their bill payments, meaning that they are less likely to have their utility service cut off for nonpayment. Because utilities incur costs to disconnect customers and to reconnect those households in the future, they experience a monetary savings as the result of customers being better able to pay their bills and retain service.

The net present value of this benefit ranges from $2 to $15 (Table 2). As a point estimate, we chose $8, which is the midpoint of the range of potential savings calculated by Skumatz and Dickerson (1999) for two PG&E low-income programs. This value is also very close to the benefits reported in several other studies of low-income weatherization efforts. The savings reported here were estimated based on the weatherization-induced reduction in the incidence of disconnections and the estimated costs of service shutoff and the portion of reconnection costs not covered by the customer.

Reduced Collection Costs

If fewer customer payments are delinquent, utilities spend less time and resources trying to collect what is owed them. However, it can be difficult to separate these reduced collection costs from the benefit associated with fewer late notices and customer calls, discussed above. A few of the reports reviewed for this study estimated collection costs *per incident* but did not put this in terms of the dollar value per all weatherized households. Because of the current lack of reliable estimates for this benefit, we will not attempt to assign it a monetary value.

2.2 SERVICE PROVISION BENEFITS

Fewer Emergency Gas Service Calls

As part of the home weatherization process, deteriorating or malfunctioning gas appliances can be serviced or replaced and new connectors can be installed. This proactive service reduces the subsequent need for utilities to make emergency service calls when appliances or connectors break or malfunction. By avoiding these emergency calls, utilities save staff time and resources, which constitutes a monetary benefit.

The literature reports that the NPV of this benefit ranges from $77 to $394. However, because this benefit can only occur where houses are fueled by natural gas, the reported values must be adjusted downward if they are to describe the nation as a whole. To reflect the fact that 50.9% of U.S. households are heated by natural gas (U.S. Energy Information Administration 2000), the numbers reported above were multiplied by 0.509, yielding an adjusted range of $39 to $201 for this benefit, as shown in Table 3. We suggest $101 as a reasonable point estimate. This number is at the midpoint of the range of values reported by Skumatz and Dickerson (1999) for two PG&E low-income programs and near the midpoint reported in the TecMRKT Works (2001) study (after their adjustment to reflect natural gas usage). The range of numbers reported in the Skumatz and Dickerson paper were calculated based on plausible ranges of service call costs and weatherization-induced reductions in the incidence of such calls (which dropped from 27% of households before weatherization to only 7% afterward, according to Magouirk, 1995).

Table 3. Ratepayer Benefits: Service Provision

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Fewer emergency gas service calls	39 - 201	101
T&D loss reduction	33-80	48
Insurance savings	0-2	1

Transmission and Distribution Loss Reduction

As a natural consequence of transporting electric power along transmission and distribution lines, a certain amount of energy is lost. These T&D losses are borne by the responsible utility and its customers. Because weatherization programs cause reductions in household electricity use, they likewise reduce the amount of electricity that must be transported and this results in a decrease in the T&D losses that occur. These savings often occur even in dwellings that are not electrically heated, because electricity usage for a number of purposes (e.g., furnace fans and pumps, air conditioning, lighting) can be affected by home weatherization measures.

The net present value of T&D loss reductions reported in the literature range from $33 to $88 (Table 3). Our suggested point estimate is $48, the midpoint of the possible benefit values reported by Skumatz and Dickerson (1999) for PG&E's Low Income Weatherization and Venture Partners Pilot Programs. The monetized value of the T&D losses reported here were calculated by multiplying the percentage of power that is typically lost through transmission and distribution (approximately 10%) by the avoided cost of power.

Insurance Savings

To the extent that the services performed by weatherization programs include the fixing of gas leaks and the repair or replacement of faulty appliances, the result is likely to be a reduction in the risk of household explosions and fires. This, in turn, would tend to lower the utility's insurance costs. Such cost savings are expected to occur whether the utility is self-insuring or buys coverage from another company.

The net present value of this benefit ranges from $0 to $2 (Table 3). As a point estimate, we chose $1, which is the midpoint of this range of potential savings values. The savings in insurance expenses reported here were estimated based on the magnitude of claims made in a typical year and the risk reduction associated with weatherization efforts. Skumatz and Dickerson (1999) assumed that the reduction in claims would fall by roughly the same factor that gas emergency calls would be reduced, as reported by Magouirk (1995).

3. BENEFITS TO HOUSEHOLDS

Low-income households that participate in weatherization programs are the recipients of two different types of nonenergy benefits. Point estimates of the average lifetime value of each are provided in Fig. 2. First, there are benefits that relate in some way to the affordability of low-income housing. These include: (1) water and sewer savings; (2) property value benefits; (3) avoided shut-offs and reconnections; (4) reduced mobility; and (5) reduced transaction costs. The other type of household benefit concerns the safety, health, and comfort of residents and has three components: (1) fewer fires; (2) fewer illnesses; and (3) improved comfort and related factors. Each of these household benefits is discussed in its own section, below.

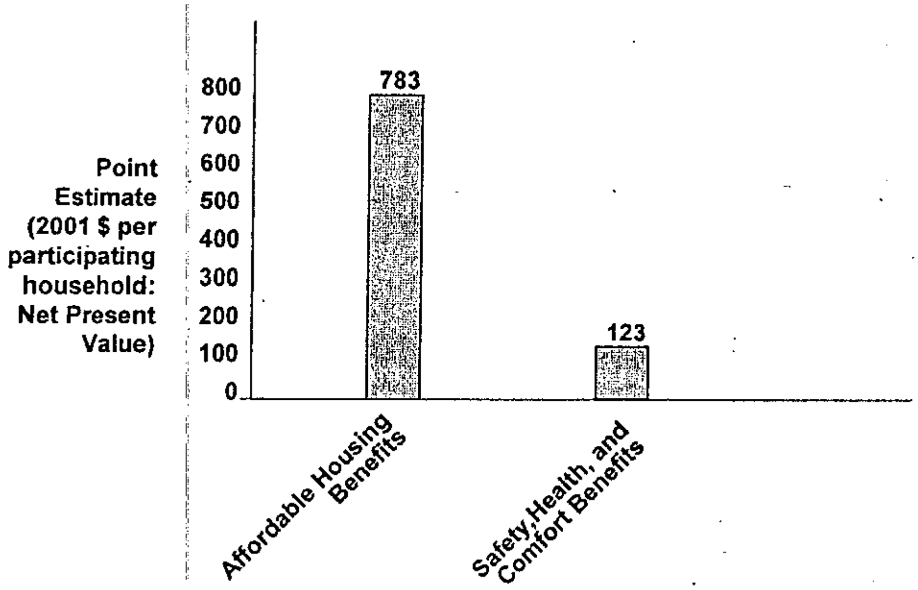

Fig. 2. Average Lifetime Monetary Value of Household Benefits, by Type

3.1 AFFORDABLE HOUSING BENEFITS

Water and Sewer Savings

Many of the homes serviced by a weatherization program receive low-flow showerhead and faucet aerator retrofits as part of the package of energy-efficiency measures installed. In addition to saving energy, these measures result in reduced household water use. Accordingly, households receiving these services save money on their water bills and, because sewer charges are generally based on the amount of water consumption, on their sewer bills as well.

A number of different estimates of the magnitude of water and sewer savings was presented in the literature reviewed for this study. Although most of those estimates were presented in terms of annual savings per household, they are presented here in terms of their net present value over the lifetime of the measures installed. The NPV of these savings ranges from $62 to $1607 (Table 4). Our best current estimate for this benefit is $271 but, as explained previously, there is substantial uncertainty associated with any point estimate made for the entire low-income Weatherization Assistance Program.

Table 4. Household Benefits: Affordable Housing

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Water and sewer savings	62-1607	271
Property value benefits†	0-5413	180
Avoided shut-offs and reconnections	0-52	17
Reduced mobility	0-1460	278
Reduced transaction costs	0-131	37

†occurs one time only in year weatherization is performed

The point estimate of $271 suggested above is based on information provided by Skumatz (2001) on average annual water savings per participating household resulting from the installation of faucet aerators and low-flow showerheads. This average household savings number was multiplied by the mean cost per gallon of water nationwide (U.S. Environmental Protection Agency 1997). The resulting number was updated to 2001 dollars using the multiplier suggested by the Consumer Price Index (Bureau of Labor Statistics 2001).

Property Value Benefits

In many cases, weatherization programs make some structural repairs and improvements to the houses they service in addition to installing energy efficiency measures. The structural improvements that are provided typically increase the property value of the homes receiving them. This represents a monetary benefit for the affected households that goes beyond the dollar savings associated with the energy efficiency improvements that are made. In addition, structural repairs can extend the useful lifetime of the affected dwellings and preserve the existing stock of affordable low-income housing.

According to the literature reviewed, the property value increase associated with home weatherization ranges from a minimum net present value of $0 to a maximum of $5413 (Table 4). Although one document (Riggert et al. 1999) suggests using the high value shown at the top of the range, all the other articles and reports reviewed for this study present values that cluster around the lower end of the scale. Those lower values are typically based on the assumption that the property value increase is equal to the cost of structural repairs made to the home in question. We suggest a point estimate of $180 for this benefit, based on the findings of the national weatherization evaluation (Brown et al. 1993). That study found that, in 1989, the average amount spent on materials for structural repairs nationally was $126. By adjusting that figure to 2001 dollars using the multiplier of 1.428 suggested by the Consumer Price Index (Bureau of Labor Statistics 2001), we get the $180 noted above.

Avoided Shut-offs and Reconnections

As explained in Chapter 2, weatherization programs result in decreased energy consumption for the homes serviced and this, in turn, means lower energy bills. Accordingly, weatherized households are less likely to fall behind on their bill payments and are less likely to have their utility service shut off for nonpayment. By avoiding service terminations, low-income customers experience a two-fold benefit. First, they get to retain the full use of their dwelling unit, the value of which is equivalent to the rent that would be "lost" if it were paid for a house (or portion of a house) that was unusable due to the lack of utility service. Also, the affected customers avoid having to pay a subsequent restart fee. While some authors include the perceived "value of service" experienced by the customer (i.e, how much it is worth to the customer to avoid a service disruption) as an additional benefit, this measure is not included here because of the difficulty of objectively assigning a dollar value to it.

The values for avoided shut-offs and reconnections presented in the literature range from $0 to $52 (Table 4). These numbers exclude the "value of service" benefit described in some studies, as noted above. A reasonable point estimate for this benefit is $17, which represents the upper end of the range given by Skumatz and Dickerson (1999) for lost rental value and cost to restart in their study of PG&E's Venture Partners Pilot Program. This value is considered reasonable to use here because a newer study (TecMRKT works et al. 2001) suggests a somewhat higher value for this benefit, putting the $17 figure roughly in the middle of the full range. Skumatz and Dickerson calculated lost rental value based on the likely reduction in termination rates and the assumed rent for a housing unit over a limited shut-off period. The cost to restart service was based on the projected reduction in termination rates and the restart costs per household, which include a reconnection fee and the value of lost work time.

Reduced Mobility

When household energy costs are high, less money is available for other purposes, including paying rent or making mortgage payments. This can be especially difficult for low-income households, where funds are very limited. In some cases, high energy costs can lead occupants to voluntarily move out of their current dwelling in favor of one with lower energy bills. In other instances, households with insufficient funds to cover all their expenses can be evicted for a failure to make housing payments or can be forced to move after utility service is discontinued. While the freedom to choose to be mobile is generally considered desirable, the mobility discussed here is associated with economic hardship and a lack of options. This kind of mobility, which is characterized by frequent and unwanted moves, can have the side effect of increasing school drop-out rates in the affected households. In turn, this can lead to a lifetime of lower earnings for those who prematurely terminate their education. By lowering household energy bills, weatherization programs can reduce mobility, thereby preventing some youth from dropping out of school and increasing their earning potential. That increase in earnings is a monetary benefit of weatherization that can be quantified.

The values for reduced mobility presented in the literature range from $0 to $1,460 (Table 4). Our suggested point estimate for this benefit is $278, which is the average of the point estimates presented by Skumatz (2001) for two different low-income weatherization programs. Skumatz calculated the value of reduced mobility based on: (1) the estimated effect of weatherization efforts on reducing the school drop-out rate; and (2) the estimated difference in lifetime earnings between high school graduates and drop-outs.

Reduced Transaction Costs

If they were not served by a weatherization program, some low-income households might choose to install certain energy-efficiency measures on their own. However, to do so, they would first have to become familiar with the needed retrofit measures and locate the necessary materials. The time and effort required for that represent a set of "transaction costs" for low-income households, and avoiding those transaction costs amounts to a benefit for those receiving weatherization services. By assigning a monetary value (approximating minimum wage) to the time saved by participants, the magnitude of transaction costs can be identified.

As shown in Table 4, the net present value of reduced transaction costs reported in the literature range from $0 to $131. Our suggested point estimate is $37, the midpoint of the possible benefit values reported by Skumatz and Dickerson (1999) for PG&E's Low Income Weatherization and Venture Partners Pilot Programs. The reduced transaction costs reported here were calculated based on the number of compact fluorescent lamps installed per household under the programs studied and the estimated reduced transaction costs per bulb. That monetized benefit was then doubled to reflect the fact that weatherization programs include many more measures than compact fluorescent bulbs alone. The resulting value seems conservative in light of the fact that home weatherization involves the installation of a number of different products (e.g., insulation, sealants, low-flow showerheads, storm windows, programmable thermostats) which consumers would have to locate and learn about if they were to perform the work themselves.

3.2 SAFETY, HEALTH, AND COMFORT BENEFITS

Fewer Fires

Many low-income homes have old and poorly-maintained space and water heating systems. These present a risk of fire resulting from gas leaks. Also, low-income households sometimes use dangerous supplemental heat sources like gas grills or electric space heaters, and this is especially problematic in those instances where the primary heating source is disconnected due to nonpayment. Weatherization programs can improve the operation of space and water heating systems and reduce the need for supplemental heating. As a result, fewer fires occur in weatherized homes, and this represents a real benefit to the affected households.

The net present value of fewer fires reported in the literature ranges from $0 to $555 (Table 5). We suggest using $68 as a point estimate for this benefit. This value of fewer fires over the lifetime of the weatherization measures installed is based on the annual per household value for this benefit presented by Brown et al. (1993) in the national weatherization evaluation, adjusted to 2001 dollars using the multiplier suggested by the Consumer Price Index (Bureau of Labor Statistics 2001). The study by Brown et al. estimated the number of fires prevented by the national Weatherization Assistance Program, using national statistics on the occurrence of fires and fire death rates, and attributed a value to the associated property damage and deaths based on residential fire-loss statistics and the projected value of future lifetime earnings.

Table 5. Household Benefits: Safety, Health, and Comfort

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Fewer fires	0-555	68
Fewer illnesses	0-2191	55
Improved comfort and related factors	Not Available	Not Available

Fewer Illnesses

Some authors have suggested that people living in houses with sufficient and continuous heat during the colder months of the year are likely to get fewer colds. When adults get fewer colds, it means that they experience fewer lost days of work and the accompanying loss of wages. In addition, when children are sick, a parent or guardian often has to miss work to care for them, again at the cost of lost wages. Accordingly, weatherization improvements that result in warmer and less drafty homes could lead to fewer illnesses and the monetary benefits that go along with that. It should be noted that tightening up homes could lead to increases in indoor air pollution and associated illnesses. However, properly conducted energy audits allow for adequate air changes in the home to minimize this risk.

The net present values reported in the literature for fewer illnesses range from a low of $0 to a high of $2191. We suggest a point estimate of $55. This value was calculated using the method described in Skumatz (2001). Skumatz developed a point estimate for the benefit of fewer illnesses associated with low-income weatherization efforts, based on survey findings regarding the number of lost workdays avoided and an assumed average wage earned by the affected workers.

Improved Comfort and Related Factors

Because houses tend to become warmer and less drafty after they are weatherized, their occupants are likely to experience increased comfort levels. In addition, the improvements made to homes during the weatherization process often make them less noisy and can improve their appearance. All of these represent benefits that are real but are very difficult to measure objectively. Some innovative work has been performed in this area, most notably in the form of survey research that asks respondents to characterize the value of various nonenergy benefits relative to the energy savings that they have received as a result of program participation (Skumatz et al. 2000). However, it is not clear whether the values calculated by such approaches, which assign a dollar value to a given benefit based on its perceived importance to the recipient, are either valid or reliable given the very hypothetical nature of the task set to the respondents. Accordingly, we will not attempt to assign a dollar value to comfort, noise, and aesthetic benefits at this time.

Improved indoor air quality is another benefit associated with weatherization programs. Faulty furnaces can release carbon monoxide into houses, with very negative health effects. Improvements to heating equipment made during the weatherization process can prevent such releases, and the installation of carbon monoxide monitors can alert household occupants to the presence of this dangerous gas. Despite its importance, we will not attempt to assign a monetary value to the benefit of improved indoor air quality because of the current lack of reliable estimates.

Weatherization providers are required to give a booklet on the hazards of lead-based paint (U.S. Environmental Protection Agency 2001) to households in which such paint could be present. This booklet presents information on the dangers of lead poisoning and how they can be reduced or eliminated. Because lead can have very adverse impacts on those exposed to it–especially children–educational efforts like the one described above can have the positive effect of protecting the health of household residents. Due to a lack of information on the monetary value of this benefit, we do not attempt to quantify its worth.

4.0 SOCIETAL BENEFITS

Following the literature, the *societal* nonenergy benefits attributable to weatherizing low income homes are broken into three categories: environmental, social and economic. Fig. 3 gives point estimates of the average lifetime monetary value associated with each of the three benefit types. The findings distilled from the literature are reported in sub-sections 4.1, 4.2, and 4.3, respectively.

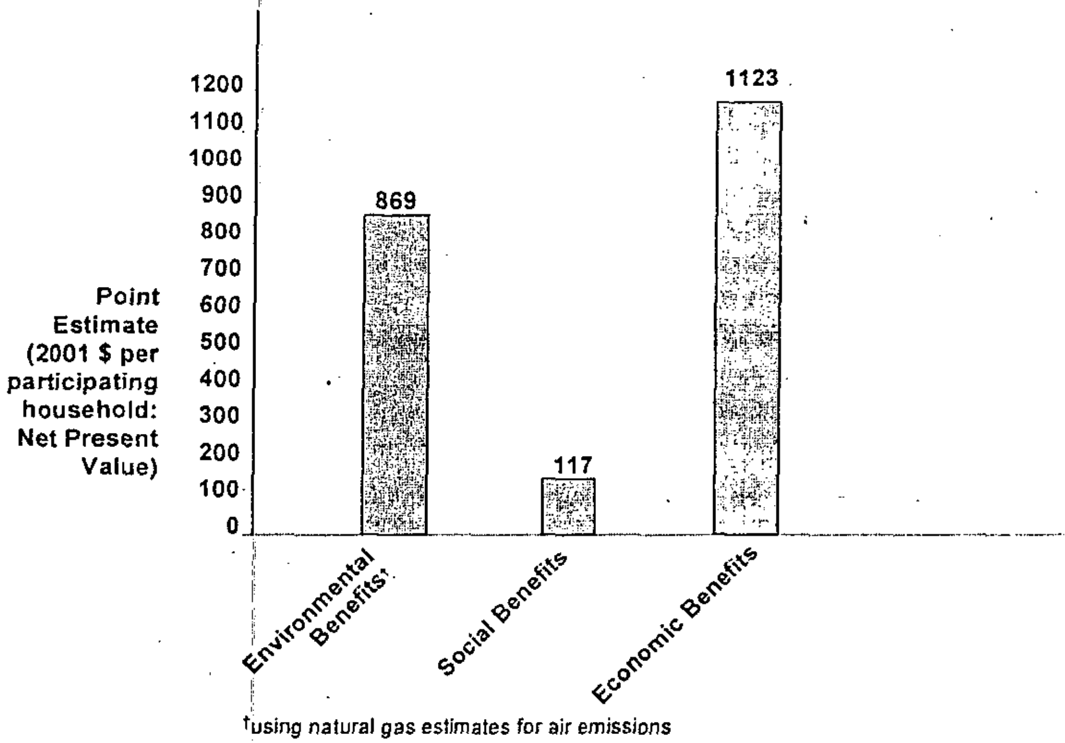

Fig. 3. Average Lifetime Monetary Value of Societal Benefits, by Type

4.1 ENVIRONMENTAL BENEFITS

Environmental benefits pertain to how the environment can be improved by weatherizing low income homes. The most frequently studied environmental benefits arise from the reduction of air pollutants due to the reduction in the burning of fossil fuels, either in the home (e.g., natural gas) or at central power stations to produce electricity. Other categories of environmental benefits quantified in the literature include less impingements upon fish around power plant water sources, and reduced water use and, subsequently, less sewage. Table 6 provides ranges and point estimates for these environmental benefits.

Table 6. Environmental Benefits

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Air Emissions - Natural Gas		
Carbon (CO_2)	40 - 32,189	102
Sulfur Oxides (SO_x)	.02 - 6015	23
Nitrogen Oxides (NO_x)	.02 - 2254	48
Carbon Monoxide (CO)	.21 - 758	46
Methane (CH_4)	.07 - 269	92
Particulate Matter (PM)	.01 - 6983	9
Subtotal	40 - 49,176	320
Air Emissions - Electricity		
Carbon (CO_2)	167 - 97,857	305
Sulfur Oxides (SO_x)	31 - 40,872	92
Nitrogen Oxides (NO_x)	11 - 17,290	523
Carbon Monoxide (CO)	36 - 81	39
Methane (CH_4)	.68 - 1.15	.91
Particulate Matter (PM)	.27 - 704	14
Subtotal	246 - 156,805	974
Other Benefits		
Heavy Metals (air emissions)	1.39 - 17,205	380
Fish Impingement	23.44 - 23.44	23.44
Waste Water and Sewage	3.36 - 657	146
Subtotal	28 - 17,885	549
Total†	68 - 67,061	869

† uses natural gas estimates for air emissions

With respect to air emissions, the literature contains a wide range of estimates for several factors that are needed to estimate benefits. These factors include (1) the number of pounds of pollutants emitted per unit of energy service delivered (e.g., lbs/ mmbtu), (2) average energy savings per weatherized home, (3) reductions in pounds of pollutants emitted per weatherization, and (4) value in dollars associated with reducing units of air pollutants (e.g., \$/ton of carbon dioxide emissions reduced). The approach followed to estimate the range of benefits was to take the lowest (highest) value for each factor to calculate the lower (upper) bound. The approach taken to develop a point estimate varied by each type of air emission. In general, mid-range and frequently mentioned estimates were used. Sources used for the environmental benefit review include: Brown et al. (1993), Berry (1997), Skumatz and Dickerson (1997, 1999), Skumatz (2000), Riggert et al. (1999), Riggert et al. (2000), Hill et al. (1999), Burtraw et al. (1997), Burtraw and Toman (1997), TecMRKT Works et al. (2001), Biewald et al. (1995), and National Research Council (2001).

The ranges in benefits associated with reducing air emissions are large and arise due to a host of methodological issues. Two key problems are related to choice of benefit estimation method and where studies had been conducted. The former problem is particularly acute with respect to valuing emission reductions. Generally, one of two methodological approaches is taken. One approach is to value emission reductions equal to the value of emission permits that are being traded in an emissions market (or the expected value for such permits if the market does not yet exist). This value approximates the cost faced by emitters for complying with emission reduction regulations. These values are attractive for benefit estimation exercises because they can be documented, if the market exists, or closely estimated, if the market does not yet exist.

The market valuation method tends to yield lower values for emission reductions than the second method, which calls for a comprehensive estimation of the benefits associated with emission reductions. In other words, a drawback to using the market values of emissions permits is that these values do not directly encompass important benefits accruable to society from the emissions reductions. For example, the market values do not reflect improvements to human health and ecosystems or decreasing rates of deterioration of the exterior of buildings and other materials exposed to the pollutants. Estimating all these benefits can lead to dramatically higher values for reducing harmful emissions to the air. The large ranges in benefits shown in Table 6 are mostly attributable to studies that adopted one or the other of the two methodologies. It must be noted that adopting a comprehensive benefits estimation methodology also increases the uncertainty in the valuation process because estimating health and ecosystem benefits is extraordinarily difficult. Because each method has significant strengths and weakness, neither has been universally accepted and wide ranges of benefits estimation can be expected to continue into the foreseeable future. In this study, we tended to favor the market valuation approach when generating point estimates of environmental benefits.

Where studies have been done is a second source of variation in the numbers presented in Table 6. This is because spatial factors can greatly impact the reductions in emissions per weatherized home. It is well known that the number of heating degree days, which vary across the country, is tightly correlated with energy savings and, ultimately, with air emission reductions due to weatherization. Thus, findings by studies done in California will be different from studies done in Vermont; both may not be generalizable to the entire country but a value somewhere in the range probably is. Cooling degree days also vary by climate zone but these savings are usually not included in energy savings estimates, and, conversely, not in air emission reduction estimates.

Fuel used for heating also varies across the country. Studies conducted in areas dominated by natural gas are different than studies done in areas more reliant on electricity. What types of fuels are used to generate electricity are also important, as coal types vary considerably and coal is considerably different from natural gas, for example. Generally, emission reduction estimates do not encompass homes that use multiple fuels for heating (e.g., electricity and wood are common in the Pacific Northwest). Impacts upon other energy end uses, such as air conditioning, are also not incorporated in these analyses. Studies done in limited market areas with unique fuel mixes and climate yield large ranges in results and this is also indicated in the ranges exhibited in Table 6.

It should also be noted that the environmental benefits listed in Table 6 are not comprehensive. Categories of environmental benefits not apparently quantified in the literature include reductions in water pollution (e.g., from run-offs from power plant sites, leaching of toxics into the groundwater from mining operations), land use changes (e.g., associated with extraction of natural resources), and solid waste (e.g., fly-ash from electric generation plants). The literature also does not include complete life cycle assessments that would encompass all pollutants associated with each phase of a home heating fuel (i.e., from extraction of raw materials to materials processing to consumption of the fuel to waste disposal issues) to allow comparison with the environmental implications associated with materials used to weatherize homes (e.g., assessing the life cycle emissions -- extraction, processing, manufacturing, transportation, use, and end-of-life disposal of insulation). For example, not included in this analysis are environmental costs associated with the production of fiber glass insulation, epoxy-based window caulking, double-pane windows, and other measures commonly installed in weatherized homes.

4.2 SOCIAL BENEFITS

Social benefits represent a catch-all category of benefits attributable to weatherization that are clearly not environmental or economic. In this sub-section we will focus on one such benefit that is discussed in the literature and for which the effects have been monetized: avoided unemployment benefits. This refers to the employment of people in the course of weatherizing homes who would have been unemployed otherwise. Sources for these benefits include Brown et al. (1993), Skumatz and Dickerson (1999), and Riggert et al. (1999). Other social benefits which have not been monetized include: social equity (Berry et al. 1997, National Consumer Law Center 1999), and improvement in community pride through improvement in the local housing stock.

The range for avoided unemployment benefits (Table 7) was developed by using the low and high estimates found in the literature. To establish a point estimate, the value reported by Brown et al. (1993) was adjusted to 2001 dollars based on the Consumer Price Index (Bureau of Labor Statistics 2001). Factors that impact the reliability of estimated benefits include the availability of jobs in various areas of the country and over time. In areas having numerous job opportunities, it is harder to argue that there are avoided unemployment benefits. However, since low income weatherizations are often conducted in economically distressed communities that typically do not benefit from national or even regional upturns in the economy, it can be more strongly argued that avoided unemployment benefits are valid.

Table 7. Social Benefits

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Avoided Unemployment Benefits†	0 - 183	117

† occurs one time only in year weatherization is performed

4.3 ECONOMIC BENEFITS

Weatherizing low income homes can yield a variety of economic benefits. One group of benefits is related to spending money on weatherization. These expenditures can directly result in new jobs and increases in personal income which can translate into increases in federal income tax collections. Additionally, weatherization expenditures can impact the local economy as a portion of every dollar prevented from leaving the community to import energy is spent within the community. This is known as the multiplier effect. Most studies only focus on the impacts within economically distressed areas and do not address the broader economy, where jobs and incomes may be lost, for example in energy production and distribution operations. Given the scale and scope of the energy production and distribution industries and the fact that energy consumption has continued to increase over time, it is highly unlikely that any job losses in those industries can be attributed to weatherization activities.

Of course, saving energy has national security implications, too, by reducing the need for energy imports. Lastly, it has been hypothesized that owners of rental units may benefit from the weatherization of rental units if the low income households save enough money on energy bills to better be able to pay their monthly rents.

Table 8 contains ranges and estimates for the economic-related factors listed above. Sources for these estimates include the Weatherization Network (1999), Nevin et al. (1998), Brown et al. (1993), TecMRKT Works et al. (2001), Riggert et al. (1999), Skumatz and

Dickerson (1997), Skumatz (2001 and 1998), Berry et al. (1997), Hill et al. (1998), RPM Systems (1995), Galvin (1999), National Research Council (2001), and Office of Transportation Technology (2001). Table 8 indicates that the direct and indirect economic benefits of low income weatherization programs can be quite significant.

Table 8. Economic Benefits

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Direct and Indirect Employment†	115 - 4354	801
Lost Rental	0 - 2.19	1.14
National Security	75 - 3286	321
Total	190 - 7642	1123

†occurs one time only in year weatherization is performed

Numerous factors impact the validity of the estimates contained in Table 8. As discussed above, the availability of jobs in an area impacts the job creation and increased federal benefits. The degree to which a local economy is sheltered from needing to import goods and services will impact the local multiplier effect, and housing availability will impact the lost rental benefit.

5. SUMMARY AND CONCLUSIONS

Table 9 summarizes the results of the literature review presented in the preceding three chapters. Overall, societal benefits are estimated to be substantially larger than ratepayer and household benefits. *Ranges* for the societal benefits are also much greater than for the other two categories of nonenergy benefits. The total point estimate for nonenergy benefits in all categories associated with weatherizing a home is $3346, in 2001 dollars. As explained in Chapter 1, this represents a national average figure which, like any point estimate, has substantial uncertainty

Table 9. Summary of Benefits for Each Major Category and Subcategory

Nonenergy Benefit Category/Subcategory	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Ratepayer Benefits		
Payment-Related Benefits	27-3680	181
Service Provision Benefits	72-283	150
Total for this Category	99-3963	331
Household Benefits		
Affordable Housing Benefits	62-8663	783
Safety, Health, and Comfort Benefits	0-2746	123
Total for this Category	62-11,409	906
Societal Benefits		
Environmental Benefits	68-67,061	869
Social Benefits	0-183	117
Economic Benefits	190-7642	1123
Total for this Category	258-74,886	2109
Total for All Benefit Categories	419-90,258	3346

associated with it. Actual benefits will be higher or lower in specific households and locales based on what programs exist, what fuels are used, the magnitude of energy savings, and other factors. More important than the precise dollar figures is the indisputable fact that nonenergy benefits represent a significant addition to the energy savings benefit achieved by the Weatherization Assistance Program.

The point estimate for total nonenergy benefits given above is substantially higher than the total value presented a decade ago in ORNL's national weatherization evaluation (Brown et al. 1993). The magnitude of all nonenergy benefits discussed in that study, when adjusted for inflation, is $1394 in 2001 dollars. The difference between that figure and the $3346 reported in this document is due almost entirely to the fact that our study quantified a much broader array of nonenergy benefits than was addressed in the earlier work. For instance, the only ratepayer benefit discussed in the national evaluation was the reduced carrying cost on arrearages. In contrast, our treatment of this topic also included avoided rate subsidies, lower bad debt write-off, fewer emergency gas service calls, transmission and distribution loss reduction, and several other factors. Similarly, our examination of household benefits included a number of factors—such as water and sewer savings, reduced mobility, and fewer illnesses—that were not considered in the earlier work. In the realm of societal benefits, our values are very similar to those presented in the earlier study for both social and economic factors. For environmental benefits, the values reported in this document are substantially higher than those presented in the earlier report but, once again, this is largely due to our treatment of additional factors. While Brown et al. only assessed the benefits of reductions in two types of air emissions, sulfur dioxide (SO_2) and NO_x, our study looked at a variety of other air emissions (e.g., CO_2, CO, CH_4) plus other environmental factors such as heavy metals and fish impingement. An additional explanation for the difference between the value of environmental benefits reported in the two documents is that our study was based on an updated, and substantially higher, amount of average household energy savings, which directly affects the magnitude of emissions reductions. In all nonenergy benefit categories, where our report dealt with the same specific benefits addressed by Brown et al., our values tended to be very similar.

The combined net present value of $3346 for all nonenergy benefit categories compares to an average net present value of energy savings of $3174 and an average total cost per weatherization of $1779, once again in 2001 dollars. The energy savings figure is based on the value of savings for houses heated by natural gas taken from a meta-evaluation of the Weatherization Assistance Program performed by ORNL (Berry et al. 1997) to update findings from the national evaluation. The value of annual energy savings reported in that study was inflated to account for future energy prices using long-term projections developed by the U.S. Energy Information Administration (2001) and discounted using the discount rate recommended by the Office of Management and Budget. The figure used here for weatherization costs represents *total* costs (including labor and materials as well as program overhead and management) for the average weatherized dwelling and was generated by taking the most recent available information from the Weatherization Assistance Program's grants management data system and adjusting the average cost per weatherized unit to 2001 dollars using the Consumer Price Index multiplier.

It is important to note that total estimated nonenergy benefits are slightly greater than the value of energy savings over the lifetime of the weatherization measures installed. The benefit/cost ratio for gas-heated houses, combining both energy and nonenergy benefits and comparing that figure to total costs (labor, materials, and overhead) for the average weatherized home, is approximately 3.7, meaning that $3.70 in benefits are realized for every dollar spent. This comparison of *all* benefits to *all* costs is referred to as the "societal perspective." Low and high values for the societal benefit/cost ratio, using low and high nonenergy benefit estimates, are 2.0 and 52.5, respectively.

Whatever assumptions are made, the total estimated value for all nonenergy benefit categories combined is lower than it could be, because the estimate does not contain some benefits that have not been monetized. It must also be noted that there are numerous uncertainties in the estimates reported above. The environmental benefit calculations in particular are subject to wide ranges in assumptions about air emissions prevented per weatherized home and the dollar values associated with reducing each air pollutant. In addition, nonenergy benefits in many different categories are likely to vary widely by climate, fuel type, and local economic conditions. In general, our point estimates are conservative and tend to be much closer to the lower than the upper end of the full range of values presented in the literature.

Potentially important future research projects on the subject of nonenergy benefits include the following: assessing subjective nonenergy benefits that participants receive from weatherization (e.g., improved comfort); following a panel of weatherized homes over time to assess the benefits of weatherization provided to successive occupants; and conducting comprehensive life cycle assessments to better understand all the environmental benefits and costs associated with energy use reductions and installation of energy efficiency measures.

6. ACKNOWLEDGMENTS

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