Heating, Early Retirement – Replacement of a Heat Pump

See Table 2-120 through Table 2-124 for the energy savings (kWh) per heating load type associated with a central heat pump replacing another heat pump for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-120: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	392	466	602	724	781	835
2.0	523	621	802	965	1,041	1,113
2.5	653	776	1,003	1,207	1,301	1,391
3.0	784	931	1,203	1,448	1,561	1,669
3.5	915	1,087	1,404	1,689	1,822	1,948
4.0	1,045	1,242	1,604	1,931	2,082	2,226
5.0	1,307	1,552	2,006	2,413	2,602	2,782

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-121: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	225	267	345	415	448	479
2.0	300	356	460	554	597	638
2.5	375	445	575	692	746	798
3.0	450	534	690	830	895	957
3.5	524	623	805	969	1,045	1,117
4.0	599	712	920	1,107	1,194	1,276
5.0	749	890	1,150	1,384	1,492	1,596

Climate Zone 3: South Region, Houston Weather Data

Table 2-122: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	120	142	184	222	239	255
2.0	160	190	245	295	318	341
2.5	200	237	307	369	398	426
3.0	240	285	368	443	478	511
3.5	280	332	430	517	557	596
4.0	320	380	491	591	637	681
5.0	400	475	614	738	796	851

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-123: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	92	110	142	171	184	197
2.0	123	146	189	228	245	262
2.5	154	183	236	284	307	328
3.0	185	220	284	341	368	394
3.5	216	256	331	398	429	459
4.0	246	293	378	455	491	525
5.0	308	366	473	569	613	656

Climate Zone 5: West Region El Paso Weather Data

Table 2-124: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	227	269	348	419	451	483
2.0	302	359	464	558	602	644
2.5	378	449	580	698	752	805
3.0	453	539	696	837	903	965
3.5	529	628	812	977	1,053	1,126
4.0	604	718	928	1,117	1,204	1,287
5.0	756	898	1,160	1,396	1,505	1,609

Heating, Early Retirement – Replacement of an Electric Resistance Furnace

See Table 2-125 through Table 2-129 for the energy savings (kWh) per heating load type associated with a central heat pump replacing an electric resistance furnace for all five Texas climate zones.

Deemed Summer Demand Savings Tables

New Construction

Table 2-114 through Table 2-118 present the summer demand savings (kW) associated with a central heat pump being installed during new construction for all 5 Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-125: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.05	0.10	0.19	0.17	0.23	0.36
2.0	0.07	0.14	0.25	0.22	0.31	0.48
2.5	0.09	0.17	0.32	0.28	0.38	0.60
3.0	0.11	0.21	0.38	0.33	0.46	0.72
3.5	0.12	0.24	0.45	0.39	0.54	0.84
4.0	0.14	0.27	0.51	0.44	0.62	0.96
5.0	0.18	0.34	0.64	0.56	0.77	1.19

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-126: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.06	0.11	0.20	0.15	0.22	0.35
2.0	0.08	0.15	0.27	0.20	0.29	0.47
2.5	0.09	0.18	0.34	0.25	0.36	0.59
3.0	0.11	0.22	0.41	0.30	0.44	0.70
3.5	0.13	0.26	0.47	0.35	0.51	0.82
4.0	0.15	0.29	0.54	0.40	0.58	0.94
5.0	0.19	0.37	0.68	0.49	0.73	1.17

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 3: South Region, Houston Weather Data

Table 2-127: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.05	0.10	0.19	0.17	0.23	0.36
2.0	0.07	0.14	0.25	0.22	0.31	0.48
2.5	0.09	0.17	0.32	0.28	0.38	0.60
3.0	0.11	0.21	0.38	0.33	0.46	0.72
3.5	0.12	0.24	0.45	0.39	0.54	0.84
4.0	0.14	0.27	0.51	0.44	0.62	0.96
5.0	0.18	0.34	0.64	0.56	0.77	1.19

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-128: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.05	0.10	0.19	0.17	0.23	0.36
2.0	0.07	0.14	0.25	0.22	0.31	0.48
2.5	0.09	0.17	0.32	0.28	0.38	0.60
3.0	0.11	0.21	0.38	0.33	0.46	0.72
3.5	0.12	0.24	0.45	0.39	0.54	0.84
4.0	0.14	0.27	0.51	0.44	0.62	0.96
5.0	0.18	0.34	0.64	0.56	0.77	1.19

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 5: West Region El Paso Weather Data

Table 2-129: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.06	0.11	0.20	0.15	0.22	0.35
2.0	0.08	0.15	0.27	0.20	0.29	0.47
2.5	0.09	0.18	0.34	0.25	0.36	0.59
3.0	0.11	0.22	0.41	0.30	0.44	0.70
3.5	0.13	0.26	0.47	0.35	0.51	0.82
4.0	0.15	0.29	0.54	0.40	0.58	0.94
5.0	0.19	0.37	0.68	0.49	0.73	1.17

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Replace-on-Burnout

Table 2-130 through Table 2-134 present the summer demand savings (kW) associated with a central heat pump replacing on burnout an HVAC system for all 5 Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-130: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.15	0.20	0.29	0.26	0.32	0.45
2.0	0.20	0.26	0.38	0.35	0.43	0.60
2.5	0.25	0.33	0.48	0.43	0.54	0.75
3.0	0.30	0.39	0.57	0.52	0.65	0.90
3.5	0.34	0.46	0.67	0.61	0.76	1.06
4.0	0.39	0.53	0.76	0.69	0.87	1.21
5.0	0.49	0.66	0.95	0.87	1.08	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-131: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.16	0.21	0.30	0.25	0.32	0.45
2.0	0.21	0.28	0.40	0.33	0.43	0.60
2.5	0.26	0.35	0.51	0.41	0.53	0.75
3.0	0.31	0.42	0.61	0.50	0.64	0.90
3.5	0.37	0.49	0.71	0.58	0.74	1.05
4.0	0.42	0.56	0.81	0.66	0.85	1.21
5.0	0.52	0.70	1.01	0.83	1.06	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 3: South Region, Houston Weather Data

Table 2-132: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.15	0.20	0.29	0.26	0.32	0.45
2.0	0.20	0.26	0.38	0.35	0.43	0.60
2.5	0.25	0.33	0.48	0.43	0.54	0.75
3.0	0.30	0.39	0.57	0.52	0.65	0.90
3.5	0.34	0.46	0.67	0.61	0.76	1.06
4.0	0.39	0.53	0.76	0.69	0.87	1.21
5.0	0.49	0.66	0.95	0.87	1.08	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-133: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.15	0.20	0.29	0.26	0.32	0.45
2.0	0.20	0.26	0.38	0.35	0.43	0.60
2.5	0.25	0.33	0.48	0.43	0.54	0.75
3.0	0.30	0.39	0.57	0.52	0.65	0.90
3.5	0.34	0.46	0.67	0.61	0.76	1.06
4.0	0.39	0.53	0.76	0.69	0.87	1.21
5.0	0.49	0.66	0.95	0.87	1.08	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 5: West Region El Paso Weather Data

Table 2-134: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.16	0.21	0.30	0.25	0.32	0.45
2.0	0.21	0.28	0.40	0.33	0.43	0.60
2.5	0.26	0.35	0.51	0.41	0.53	0.75
3.0	0.31	0.42	0.61	0.50	0.64	0.90
3.5	0.37	0.49	0.71	0.58	0.74	1.05
4.0	0.42	0.56	0.81	0.66	0.85	1.21
5.0	0.52	0.70	1.01	0.83	1.06	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Early Retirement

Table 2-135 through Table 2-139 present the summer demand savings (kW) associated with a central heat pump replacing an HVAC system for all five Texas climate zones. These savings can be used with the replace-on-burnout energy savings in Table 2-130 through Table 2-134 to calculate summer demand savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-135: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.59	0.64	0.73	0.70	0.77	0.89
2.0	0.78	0.85	0.97	0.94	1.02	1.19
2.5	0.98	1.06	1.21	1.17	1.28	1.49
3.0	1.18	1.28	1.45	1.40	1.53	1.79
3.5	1.37	1.49	1.69	1.64	1.79	2.08
4.0	1.57	1.70	1.94	1.87	2.04	2.38
5.0	1.96	2.13	2.42	2.34	2.55	2.98

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-136: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.63	0.68	0.77	0.72	0.79	0.92
2.0	0.84	0.91	1.03	0.96	1.05	1.23
2.5	1.04	1.13	1.29	1.20	1.31	1.54
3.0	1.25	1.36	1.55	1.44	1.58	1.84
3.5	1.46	1.58	1.80	1.68	1.84	2.15
4.0	1.67	1.81	2.06	1.91	2.10	2.46
5.0	2.09	2.26	2.58	2.39	2.63	3.07

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 3: South Region, Houston Weather Data

Table 2-137: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.59	0.64	0.73	0.70	0.77	0.89
2.0	0.78	0.85	0.97	0.94	1.02	1.19
2.5	0.98	1.06	1.21	1.17	1.28	1.49
3.0	1.18	1.28	1.45	1.40	1.53	1.79
3.5	1.37	1.49	1.69	1.64	1.79	2.08
4.0	1.57	1.70	1.94	1.87	2.04	2.38
5.0	1.96	2.13	2.42	2.34	2.55	2.98

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-138: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.59	0.64	0.73	0.70	0.77	0.89
2.0	0.78	0.85	0.97	0.94	1.02	1.19
2.5	0.98	1.06	1.21	1.17	1.28	1.49
3.0	1.18	1.28	1.45	1.40	1.53	1.79
3.5	1.37	1.49	1.69	1.64	1.79	2.08
4.0	1.57	1.70	1.94	1.87	2.04	2.38
5.0	1.96	2.13	2.42	2.34	2.55	2.98

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 5: West Region El Paso Weather Data

Table 2-139: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.63	0.68	0.77	0.72	0.79	0.92
2.0	0.84	0.91	1.03	0.96	1.05	1.23
2.5	1.04	1.13	1.29	1.20	1.31	1.54
3.0	1.25	1.36	1.55	1.44	1.58	1.84
3.5	1.46	1.58	1.80	1.68	1.84	2.15
4.0	1.67	1.81	2.06	1.91	2.10	2.46
5.0	2.09	2.26	2.58	2.39	2.63	3.07

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Deemed Winter Demand Savings Tables

New Construction or Replace-on-Burnout of a Heat Pump

Table 2-140 through Table 2-144 present the winter demand savings (kW) associated with a central heat pump being installed during new construction or replacing a burned-out central heat pump.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-140: Winter Demand Savings for 8.2 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.14	0.19	0.21
2.0	0.07	0.11	0.11	0.18	0.25	0.29
2.5	0.08	0.14	0.14	0.23	0.32	0.36
3.0	0.10	0.16	0.16	0.28	0.38	0.43
3.5	0.12	0.19	0.19	0.32	0.44	0.50
4.0	0.13	0.22	0.22	0.37	0.51	0.57
5.0	0.17	0.27	0.27	0.46	0.63	0.71

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-141: Winter Demand Savings for 8.2 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.13	0.18	0.21
2.0	0.06	0.10	0.10	0.18	0.24	0.27
2.5	0.08	0.13	0.13	0.22	0.30	0.34
3.0	0.10	0.16	0.16	0.27	0.37	0.41
3.5	0.11	0.18	0.18	0.31	0.43	0.48
4.0	0.13	0.21	0.21	0.36	0.49	0.55
5.0	0.16	0.26	0.26	0.44	0.61	0.69

Climate Zone 3: South Region, Houston Weather Data

Table 2-142: Winter Demand Savings for 8.2 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.04	0.06	0.06	0.11	0.15	0.17
2.0	0.05	0.09	0.09	0.15	0.20	0.22
2.5	0.07	0.11	0.11	0.18	0.25	0.28
3.0	0.08	0.13	0.13	0.22	0.30	0.34
3.5	0.09	0.15	0.15	0.25	0.35	0.39
4.0	0.11	0.17	0.17	0.29	0.40	0.45
5.0	0.13	0.21	0.21	0.36	0.50	0.56

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-143: Winter Demand Savings for 8.2 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.03	0.05	0.05	0.09	0.13	0.14
2.0	0.04	0.07	0.07	0.12	0.17	0.19
2.5	0.06	0.09	0.09	0.15	0.21	0.24
3.0	0.07	0.11	0.11	0.18	0.25	0.28
3.5	0.08	0.13	0.13	0.21	0.29	0.33
4.0	0.09	0.14	0.14	0.25	0.34	0.38
5.0	0.11	0.18	0.18	0.31	0.42	0.47

Climate Zone 5: West Region El Paso Weather Data

Table 2-144: Winter Demand Savings for 8.2 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.13	0.18	0.20
2.0	0.06	0.10	0.10	0.17	0.24	0.27
2.5	0.08	0.13	0.13	0.22	0.30	0.33
3.0	0.09	0.15	0.15	0.26	0.36	0.40
3.5	0.11	0.18	0.18	0.30	0.42	0.47
4.0	0.13	0.20	0.20	0.35	0.47	0.53
5.0	0.16	0.25	0.25	0.43	0.59	0.67

Replace-on-Burnout – Replacement of Electric Resistance Furnace

Table 2-145 through Table 2-149 present the winter demand savings (kW) per heating load type associated with a central heat pump replacing an electric resistance furnace for all five climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-145: Winter Demand Savings for 3.41 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.05	2.08	2.14	2.19	2.21	2.24
2.0	2.73	2.78	2.85	2.92	2.95	2.98
2.5	3.42	3.47	3.57	3.65	3.69	3.73
3.0	4.10	4.16	4.28	4.38	4.43	4.47
3.5	4.79	4.86	4.99	5.11	5.17	5.22
4.0	5.47	5.55	5.70	5.84	5.91	5.97
5.0	6.84	6.94	7.13	7.30	7.38	7.46

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-146: Winter Demand Savings for 3.41 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.33	2.36	2.41	2.46	2.49	2.51
2.0	3.11	3.15	3.22	3.29	3.32	3.35
2.5	3.88	3.93	4.02	4.11	4.15	4.18
3.0	4.66	4.72	4.83	4.93	4.97	5.02
3.5	5.44	5.51	5.63	5.75	5.80	5.85
4.0	6.21	6.29	6.44	6.57	6.63	6.69
5.0	7.77	7.87	8.05	8.21	8.29	8.36

Climate Zone 3: South Region, Houston Weather Data

Table 2-147: Winter Demand Savings for 3.41 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1.94	1.97	2.01	2.05	2.07	2.09
2.0	2.59	2.62	2.68	2.74	2.76	2.79
2.5	3.24	3.28	3.35	3.42	3.45	3.48
3.0	3.89	3.94	4.03	4.11	4.14	4.18
3.5	4.53	4.59	4.70	4.79	4.84	4.88
4.0	5.18	5.25	5.37	5.48	5.53	5.57
5.0	6.48	6.56	6.71	6.84	6.91	6.97

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-148: Winter Demand Savings for 3.41 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1.66	1.69	1.72	1.76	1.77	1.79
2.0	2.22	2.25	2.30	2.34	2.36	2.38
2.5	2.77	2.81	2.87	2.93	2.96	2.98
3.0	3.33	3.37	3.45	3.52	3.55	3.58
3.5	3.88	3.93	4.02	4.10	4.14	4.17
4.0	4.44	4.49	4.60	4.69	4.73	4.77
5.0	5.55	5.62	5.74	5.86	5.91	5.96

Climate Zone 5: West Region El Paso Weather Data

Table 2-149: Winter Demand Savings for 3.41 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.27	2.30	2.36	2.41	2.43	2.45
2.0	3.03	3.07	3.14	3.21	3.24	3.27
2.5	3.79	3.84	3.93	4.01	4.05	4.08
3.0	4.55	4.61	4.72	4.81	4.86	4.90
3.5	5.31	5.38	5.50	5.61	5.67	5.72
4.0	6.07	6.14	6.29	6.42	6.48	6.53
5.0	7.58	7.68	7.86	8.02	8.09	8.17

Early Retirement – Replacement of a Heat Pump

See Table 2-150 through Table 2-154 for the winter demand savings (kW) associated with a central heat pump replacing another heat pump for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-150: Winter Demand Savings for 7.7 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.17	0.20	0.25	0.31	0.33	0.35
2.0	0.22	0.26	0.34	0.41	0.44	0.47
2.5	0.28	0.33	0.42	0.51	0.55	0.59
3.0	0.33	0.39	0.51	0.61	0.66	0.70
3.5	0.39	0.46	0.59	0.71	0.77	0.82
4.0	0.44	0.52	0.68	0.81	0.88	0.94
5.0	0.55	0.65	0.84	1.02	1.10	1.17

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-151: Winter Demand Savings for 7.7 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.16	0.19	0.24	0.29	0.32	0.34
2.0	0.21	0.25	0.32	0.39	0.42	0.45
2.5	0.26	0.31	0.41	0.49	0.53	0.56
3.0	0.32	0.38	0.49	0.59	0.63	0.68
3.5	0.37	0.44	0.57	0.68	0.74	0.79
4.0	0.42	0.50	0.65	0.78	0.84	0.90
5.0	0.53	0.63	0.81	0.98	1.05	1.13

Climate Zone 3: South Region, Houston Weather Data

Table 2-152: Winter Demand Savings for 7.7 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.13	0.15	0.20	0.24	0.26	0.28
2.0	0.17	0.21	0.27	0.32	0.35	0.37
2.5	0.22	0.26	0.33	0.40	0.43	0.46
3.0	0.26	0.31	0.40	0.48	0.52	0.55
3.5	0.30	0.36	0.47	0.56	0.60	0.65
4.0	0.35	0.41	0.53	0.64	0.69	0.74
5.0	0.43	0.51	0.67	0.80	0.86	0.92

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-153: Winter Demand Savings for 7.7 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.11	0.13	0.17	0.20	0.22	0.23
2.0	0.15	0.17	0.22	0.27	0.29	0.31
2.5	0.18	0.22	0.28	0.34	0.36	0.39
3.0	0.22	0.26	0.34	0.41	0.44	0.47
3.5	0.26	0.30	0.39	0.47	0.51	0.55
4.0	0.29	0.35	0.45	0.54	0.58	0.62
5.0	0.37	0.44	0.56	0.68	0.73	0.78

Climate Zone 5: West Region El Paso Weather Data

Table 2-154: Winter Demand Savings for 7.7 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.15	0.18	0.24	0.29	0.31	0.33
2.0	0.21	0.24	0.32	0.38	0.41	0.44
2.5	0.26	0.31	0.40	0.48	0.51	0.55
3.0	0.31	0.37	0.47	0.57	0.62	0.66
3.5	0.36	0.43	0.55	0.67	0.72	0.77
4.0	0.41	0.49	0.63	0.76	0.82	0.88
5.0	0.52	0.61	0.79	0.95	1.03	1.10

Early Retirement – Replacement of an Electric Resistance Furnace

See Table 2-150 through Table 2-154 for the winter demand savings (kW) associated with a central heat pump replacing an electric resistance furnace for all five Texas climate zones

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a central heat pump unit is 15 years based on the current DOE Final Rule standards for central heat pumps.[163]

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for Heat Pumps.[164]

Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

[163] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. Accessed 10/21/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

[164] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011.

- Decision/action type (early retirement, replace-on-burnout, new construction)
- Cooling capacity of the installed unit (tons)
- Seasonal Energy Efficiency Ratio (SEER) of the installed unit
- Heating Seasonal Performance Factor (HSPF) of the installed unit
- Climate zone of the site
- Type of unit replaced (e.g., electric resistance furnace, air source heat pump)
- Age of the replaced unit (Early Retirement only)
- Recommended: retired unit model number, serial number, and manufacturer (Early Retirement only)
- Recommended: photograph of retired unit nameplate (Early Retirement only)
- Recommended: customer responses to survey questionnaire for early retirement eligibility determination (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ACCA Manual J Residential Load Calculation (8th Edition)[165]

[165] https://www.acca.org/store/product.php?pid=172.

Document Revision History

Table 2-155: Central Heat Pump Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Low-income and Hard-to-Reach Market Transformation section merged with main measure as "Early Retirement" option. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Early retirement savings may be claimed through any appropriately designed program in accordance with EM&V team's memo, "Considerations for early replacement of residential equipment." Remaining useful lifetimes updated.
v3.1	11/05/2015	TRM v3.1 update. Revision of cooling savings to reflect heat-pump-specific performance curves. Extension of Early Retirement cooling savings tables to higher SEER values. Clarification around summer demand savings for single-stage and two-stage units.
v4.0	10/10/2016	TRM v4.0 update. Added RUL value for units with an age of one year. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years. Updated savings for 15.0-15.9 SEER range.

2.2.6 Room Air Conditioner Measure Overview

TRM Measure ID: R-HV-WA

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction, Early Retirement

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

The following deemed savings values are applicable in calculating an incentive for the installation of a high-efficiency room air conditioner in a newly-constructed home or a room air conditioner replaced with a higher efficiency room air conditioner in a dwelling occupied by a residential energy consumer.

Eligibility Criteria

Installed room air conditioners must be compliant with the current ENERGY STAR® specification for room air conditioners.

Utilities should refer to the January 2015 memo, "Considerations for early replacement of residential equipment,"[166] when designing programs that permit savings to be claimed for early retirement. In order to be awarded early retirement savings, the unit to be replaced must be functioning at the time of removal with a maximum age of 12 years.

Baseline Condition

For new construction and replace-on-burnout, the baseline is assumed to be a new room air conditioning unit with a CEER rating that is compliant with the current federal standard,[167]

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[166] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. "Considerations for early replacement of residential equipment." Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to Texas investor-owned utilities through the EM&V team's SharePoint.

[167] DOE minimum efficiency standard for residential room air conditioners. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41.

effective June 1, 2014. The new standard is stated in terms of the Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage. The new standard is stated in terms of the Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage.

For early retirement, the baseline efficiency is assumed to match the minimum federal standard efficiencies in place prior to June 1, 2014.

Table 2-156: Room Air Conditioner Baseline Efficiencies for New Construction, Replace-on-Burnout, and Early Retirement

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr.)	Federal Standard prior to June 1, 2014	Federal Standard as of June 1, 2014
			ER Baseline EER	NC/ROB Baseline CEER
No	Yes	< 8,000	9.7	11.0
		> 8,000 and < 14,000	9.8	10.9
		> 14,000 and < 20,000	9.7	10.7
		> 20,000 and < 25,000	8.5	9.4
		> 25,000	8.5	9.0
No	No	< 8,000	9.0	10.0
		> 8,000 and < 11,000	8.5	9.6
		> 11,000 and < 14,000	8.5	9.5
		> 14,000 and < 20,000	8.5	9.3
		> 20,000	8.5	9.4
Yes	Yes	< 20,000	9.0	9.8
		> 20,000	8.5	9.3
Yes	No	< 14,000	8.5	9.3
		> 14,000	8.0	8.7
Casement-only		All capacities	8.7	9.5
Casement-slider		All capacities	9.5	10.4

High-Efficiency Condition

ENERGY STAR® specifications effective October 30, 2015 are provided in Table 2-157 as the efficient condition.[168] Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

[168] ENERGY STAR® Program Requirements Product Specification for Room Air Conditioners: Eligibility Criteria Version 4.0. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.0%20Room%20Air%20Conditioners%20Specification.pdf. February 20, 2015.

Table 2-157: Room Air Conditioner Efficient Condition Specifications

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr.)	Minimum CEER as of October 30, 2015
No	Yes	< 8,000	12.1
		≥ 8,000 and < 14,000	12.0
		≥ 14,000 and < 20,000	11.8
		≥ 20,000 and < 25,000	10.3
		≥ 25,000	9.9
No	No	< 8,000	11.0
		≥ 8,000 and < 11,000	10.6
		≥ 11,000 and < 14,000	10.5
		≥ 14,000 and < 20,000	10.2
		≥ 20,000	10.3
Yes	Yes	< 20,000	10.8
		≥ 20,000	10.2
Yes	No	< 14,000	10.2
		≥ 14,000	9.6
Casement-only		All capacities	10.5
Casement-slider		All capacities	11.4

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Peak demand and annual energy savings for room air conditioners should be calculated as shown next.

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{Savings,C} = CAP \times \frac{1\,kW}{1,000\,W} \times AOH_C \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 59

Where:

CAP = *Rated equipment cooling capacity of the installed room air conditioner (Btu/hr.)*

AOH_C = *Annual operating hours for cooling (Table 2-158)*

$CEER_{Base}$ = *Combined Energy Efficiency Ratio of the baseline cooling equipment (Table 2-157)*

$CEER_{RAC}$ = *Combined Energy Efficiency Ratio of the installed room air conditioner*

Table 2-158: Room Air Conditioner Annual Operating Hours for Cooling[169]

Climate Zone	AOH_C
Climate Zone 1: Panhandle	820
Climate Zone 2: North	1,374
Climate Zone 3: South	1,308
Climate Zone 4: Valley	2,150
Climate Zone 5: West	1,204

Demand Savings Algorithms

$$kW_{Savings} = CAP \times \frac{1\,kW}{1,000\,W} \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right) \times CF$$

Equation 60

Where:

CAP = *Rated equipment cooling capacity of the installed room air conditioner (Btu/hr.)*

$CEER_{Base}$ = *Combined Energy Efficiency Ratio of the baseline cooling equipment (Table 2-157)*

[169] Association of Home Appliance Manufacturers (AHAM) Room Air Conditioner Cooling Calculator. http://www.cooloff.org/sub_cool.html.

$CEER_{RAC}$ = *Combined Energy Efficiency Ratio of the installed room air conditioner*

CF = *Coincidence Factor = 0.87 (default)*[170]

Early Retirement

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

1. **The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and**
2. **The remaining time in the EUL period (8 – RUL)**

Annual energy (kWh) savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.

Where:

RUL = *Remaining Useful Life (seeTable 2-159); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years*

EUL = *Estimated Useful Life = 8 years*

Table 2-159: Remaining Useful Life (RUL) of Replaced Room Air Conditioner

Age of Replaced Unit (years)	RUL (years)	Age of Replaced Unit (years)	RUL (years)
1	8.2	8	5.0
2	7.2	9	4.0
3	6.2	10	3.0
4	5.2	11	2.0
5	5.2	12	1.0
6	5.2	13[171,172]	0.0
7	5.2		

[170] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential air conditioners be sized at 115% of the maximum cooling requirement of the house. Assuming that the house's maximum cooling occurs during the hours of 4 to 5 PM, the guideline leads to a coincidence factor for residential HVAC measures of 1.0/1.15 = 0.87.

[171] RULs are capped at the 75th percentile of equipment age, 13 years, based on DOE survival curves. Systems older than 13 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[172] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. "Considerations for early replacement of residential equipment." Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to all Texas investor-owned utilities through the EM&V team's SharePoint.

Derivation of RULs

Room air conditioners have an estimated useful life of 8 years. This estimate is consistent with the age at which approximately 50 percent of the room air conditioners installed in a given year will no longer be in service, as described by the survival function in Figure 2-5.

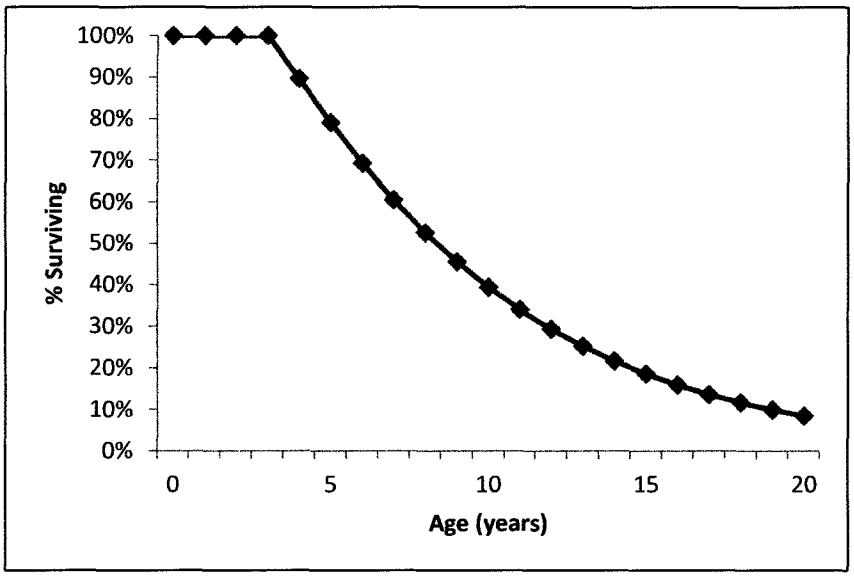

Figure 2-5: Survival Function for Room Air Conditioners[173]

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 2-5. The age of the room air conditioner being replaced is found on the horizontal axis, and the corresponding percentage of surviving room air conditioners is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

Energy Savings Algorithms

For the RUL time period:

$$kWh_{savings,ER} = CAP \times \frac{1\,kW}{1,000\,W} \times AOH_C \times \left(\frac{1}{EER_{ER}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 61

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

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[173] Department of Energy, Federal Register, 76 FR 22454, Technical Support Document: 8.2.2.6 Product Lifetime. April 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053.

$$kWh_{savings,ROB} = CAP \times \frac{1\,kW}{1,000\,W} \times AOH_C \times \left(\frac{1}{CEER_{ROB}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 62

Where:

CAP	=	*Rated equipment cooling capacity of the installed room air conditioner (Btu/hr.)*
AOH_C	=	*Annual operating hours for cooling (Table 2-158)*
$CEER_{ROB}$	=	*Combined Energy Efficiency Ratio of the replace-on-burnout baseline cooling equipment (Table 2-157)*
EER_{ER}	=	*Energy Efficiency Ratio of the early retirement baseline cooling equipment (Table 2-157)*
$CEER_{RAC}$	=	*Combined Energy Efficiency Ratio of the installed room air conditioner*

Summer Demand Savings Algorithms

To calculate demand savings for the early retirement of a room air conditioner, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL time period:

$$kW_{Savings,ER} = CAP \times \frac{1\,kW}{1,000\,W} \times \left(\frac{1}{EER_{ER}} - \frac{1}{EER_{RAC}}\right) \times CF$$

Equation 63

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$kW_{Savings,ROB} = CAP \times \frac{1\,kW}{1,000\,W} \times \left(\frac{1}{EER_{ROB}} - \frac{1}{EER_{RAC}}\right) \times CF$$

Equation 64

Deemed Energy Savings Tables

Replace-on-Burnout

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Early Retirement

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Summer Demand Savings Tables

Replace-on-Burnout

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Early Retirement

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Winter Demand Savings Tables

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a room air conditioning unit is 8 years based on the Technical Support Document for the current DOE Final Rule standards for room air conditioners.[174]

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 52852 Technical Support Document for Energy Conservation Standards for Room Air Conditioners.[175]

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[174] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 76 FR 22454 (April 21, 2011) and associated Technical Support Document. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053.

[175] Department of Energy, Federal Register, 76 FR 52852, Technical Support Document: 8.2.2.6 Product Lifetime. April 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41.

Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Decision/action type (Early Retirement, Replace-on-Burnout, New Construction)
- Cooling capacity of the installed unit (Btu/hr.)
- Combined Energy Efficiency Ratio (CEER) of the unit installed
- Climate zone of the site
- Age of the replaced unit (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for room air conditioners.
- Code of Federal Regulations, 10 CFR 430.32(b)

Document Revision History

Table 2-160: Room Air Conditioner Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Low-income and Hard-to-Reach Market Transformation section merged with main measure as "Early Retirement" option. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Early retirement savings may be claimed through any appropriately designed program in accordance with EM&V team's memo, "Considerations for early replacement of residential equipment." Remaining useful lifetimes updated. Updated EUL to align with median lifetime. New Construction permitted to claim savings. New ENERGY STAR® standards incorporated.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Added RUL values for units with an age of one to three years. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years.

2.3 RESIDENTIAL: BUILDING ENVELOPE

2.3.1 Air Infiltration Measure Overview

TRM Measure ID: R-BE-AI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling and Engineering Algorithms

Measure Description

This measure involves implementation of interventions to reduce the rate of air infiltration into residences with central air cooling and/or heating systems. Pre- and post-treatment blower door air pressure readings are required to confirm air leakage reduction.

Eligibility Criteria

Homes treated for air infiltration reduction must be centrally cooled with electric refrigerated air conditioning to claim cooling savings; to claim heating savings, homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump.

There is an upper limit of 5.2 CFM_{50} per square foot of house floor area for the pre-retrofit infiltration rate on eligible projects. For homes where the pre-retrofit leakage exceeds this limit, savings will be awarded against the leakage cap. At the utility's discretion, this cap may not apply to homes implementing the measure under low-income programs.[176] Utilities may require certification or competency testing of personnel who will perform the blower door tests.

Air leakage should be assessed through testing following Building Performance Institute (BPI) standards. In some limited cases, where testing is not possible or unsafe (e.g. due to potential presence of asbestos), visual assessment may be satisfactory. The air leakage testing should

[176] Low-income customers are income-eligible customers served through a targeted low-income energy efficiency program as described in 25.181(r). This may also apply to income-eligible customers served through a hard-to-reach program that is also delivered following the guidelines in 25.181(r).

not be conducted in homes where either evidence of asbestos or mold is present or suspected due to the age of the home.[177]

Utilities' program manuals should be consulted for health and safety considerations related to implementation of air sealing measures.

Only structures with electric refrigerated air conditioning systems are eligible.

Baseline Condition

The baseline for this measure is the existing leakage rate of the treated residence. The existing leakage rate should be capped to account for the fact that the deemed savings values per CFM_{50} leakage reduction are only applicable up to a point where the existing HVAC equipment would run continuously. Beyond that point, energy use will no longer increase linearly with an increase in leakage.

Baseline assumptions used in the development of these deemed savings are based on a 2013 Lawrence Berkeley National Laboratory (LBNL) analysis of air leakage measurements of US houses.[178] The LBNL study showed that approximately 95 percent of the home infiltration rates were below a normalized leakage rate of 2.0. Normalized leakage can be converted to CFM_{50}/ft^2 using Equation 65 through Equation 67.

$$NL = 1{,}000 \times \frac{ELA_4}{A \times 0.3048^2} \times \left(\frac{H \times 0.3048}{2.5\,m}\right)^{0.3}$$

Equation 65

$$Q_{50} = ELA_4 \Big/ \left(\sqrt{\frac{\rho}{2(4\,Pa)}} \times \left(\frac{4\,Pa}{50\,Pa}\right)^{0.65}\right)$$

Equation 66

$$CFM_{50,pre}/ft^2 = \frac{Q_{50} \times 60 \times 35.3147}{A}$$

Equation 67

Where:

NL = *Normalized Leakage = 2.0 from LBNL study*

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[177] The Building Performance Institute, Inc. (BPI) Standard Reference: Building Performance Institute Technical Standards for the Building Analyst Professional, v2/28/05mda, Page 1 of 17, states: "**Health and Safety**: Where the presence of asbestos, lead, mold and/or other potentially hazardous material is known or suspected, **all relevant state and federal (EPA) guidelines must be followed to ensure technician and occupant safety**. Blower door depressurization tests may not be performed in homes *where there is a risk of asbestos becoming airborne and being drawn into the dwelling.*"

[178] Chan, W.R., Joh, J., and Sherman, M. H. Analysis of air leakage measurements of US houses. Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory (LBNL), p. 616-625.

ELA_4	=	*Area of an orifice that would result in the same air-flow through the building envelope at a pressure difference of 4 Pa (m^2)*
A	=	*Average area of a home in Texas from RECS 2009 (ft^2) = 1,757 ft^2*
H	=	*Ceiling height (ft.) = 8.5 (default)* [179]
0.3048	=	*Constant to convert from feet to meters*
Q_{50}	=	*Leakage rate at 50 Pa (m^3/s)*
ρ	=	*1.2 kg/m^3 from LBNL study*
$CFM_{50,pre}/ft^2$	=	*Maximum per-square-foot pre-installation infiltration rate*
60	=	*Constant to convert from minutes to seconds*
35.3147	=	*Constant to convert from cubic meters to cubic feet*

Using the above approach, the maximum per-square-foot pre-installation infiltration rate is 5.2 CFM_{50}/ft^2. Therefore, to avoid incentivizing homes with envelope problems not easily remedied through typical weatherization procedures, or where blower door tests were improperly conducted, these savings should only be applied starting at a baseline CFM_{50}/ft^2 of 5.2 or lower.

High-Efficiency Condition

Blower door air pressure measurements must also be used to ensure that post-treatment air infiltration rates are not less than those set forth by the standard in Equation 68, based on floor area and number of bedrooms.[180] These calculated minimum CFM_{50} values assume two occupants for a one-bedroom dwelling unit and an additional person for each additional bedroom. Where higher occupant densities are known, the minimum rate shall be increased by 7.5 CFM_{Nat} for each additional person. A CFM_{Nat} value can be converted to CFM_{50} by multiplying by the appropriate N factor (Table 2-161).

$$\boldsymbol{Min\ CFM_{50}} = [\mathbf{0.03} \times \boldsymbol{A_{Floor}} + \mathbf{7.5} \times \boldsymbol{OCC}] \times \boldsymbol{N}$$

Equation 68

Where:

$Min\ CFM_{50}$	=	*Minimum final ventilation rate (CFM_{50})*
A_{Floor}	=	*Floor area (ft^2)*
OCC	=	*BR + 1, where BR is the number of bedrooms; if number of home occupants is known to exceed BR + 1, occupancy should be used instead*

[179] Typical ceiling height of 8 feet adjusted to account for greater ceiling heights in some areas of a typical residence.

[180] ASHRAE 62.2-2013. CFM_{Nat} values converted to CFM_{50} values by multiplying by appropriate N factor.

N = *N factor (Table 2-161)*

Table 2-161: N Factors[181]

Shielding	Number of Stories		
	Single Story	Two Story	3 or More Stories
Well shielded	22.2	17.8	15.5
Normal	18.5	14.8	13.0
Exposed	16.7	13.3	11.7

The maximum CFM reduction percentage[182] is capped at 40% for RSOP homes. It is important to note that the minimum ventilation rate specified earlier in this section still applies for cases where the maximum 40% CFM reduction cannot be achieved due to the post CFM value being limited by the minimum allowable post CFM value provisioned for safety reasons.

The TRM stipulates an upper limit of 5.2 CFM_{50} per square foot of house floor area for the pre-retrofit infiltration rate as part of eligibility criteria. For homes where the pre-retrofit leakage exceeds this limit, energy and demand savings must be calculated using the pre-measure-installation leakage cap. Therefore, when the pre-retrofit leakage is capped, energy and demand savings can only be claimed for a 40% reduction in CFM compared to the capped pre-CFM value. When the pre-retrofit leakage is not capped, energy and demand savings can only be claimed for a 40% reduction in CFM compared to the tested, actual pre-retrofit infiltration rate of the home.

The TRM requires all contractors to provide sufficient evidence such as pictures capturing the scope/type of retrofit implemented and blower door test readings for all RSOP homes that reach a CFM reduction percentage within the range of 30-40%. In the absence of any evidence, the TRM places a cap of 30% CFM reduction for calculating energy and demand savings.

At the utility's discretion, the cap of 40% CFM reduction and the ceiling of 5.2 CFM_{50} for pre-retrofit infiltration rate may not apply to homes implementing the measure under low-income programs.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings, which are expressed as linear functions of the leakage reduction achieved (in CFM_{50}).[183] Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each

[181] Krigger, J. and Dorsi, C.,"Residential Energy: Cost Savings and Comfort for Existing Buildings". A-11 Building Tightness Limits, p. 284. Use Zone 2 for Texas climate. http://www.waptac.org/data/files/Website_docs/Technical_Tools/Building%20Tightness%20Limits.pdf.

[182] CFM reduction percentage is calculated as: (pre CFM value – post CFM value) / pre-CFM value

[183] Model testing indicates a straight line relationship between demand and energy savings achieved and CFM50 reductions is appropriate with beginning and ending leakage rates within the ranges permitted by the measure.

climate zone were modified as follows: the base case air infiltration rate was set to 20 ACH_{50}. Results from running the base case model provide estimated hourly energy use for the prototypical home prior to treatment. Post-treatment conditions were simulated by setting the leakage rate to 3 ACH_{50}.

Deemed savings are presented as a function of the CFM_{50} reduction achieved, as demonstrated by blower door testing. The kWh and kW per CFM_{50} values represented by the V_E, V_S, and V_W coefficients are derived by taking the difference between annual energy use and summer and winter peak demand as estimated by the two model runs, and normalizing to the CFM_{50} reduction achieved. The pre- and post-treatment ACH_{50} values (20 and 3, respectively) are converted to CFM_{50} by multiplying the pressurized air-change rate by the volume of the model home and dividing by 60 (minutes/hour).

Deemed Energy Savings Tables

Table 2-162 presents the energy savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed energy savings for infiltration efficiency improvements.

$$\boldsymbol{Deemed\ Energy\ Savings} = \boldsymbol{\Delta CFM_{50}} \times \left(V_{E,C} + V_{E,H}\right)$$

Equation 69

Where:

ΔCFM_{50} = *Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*

$V_{E,C}$ = *Corresponding cooling savings value in Table 2-162*

$V_{E,H}$ = *Corresponding heating savings value in Table 2-162*

Table 2-162: Energy Savings V_E per CFM_{50} Reduction

Climate Zone	$V_{E,C}$: Cooling Savings	$V_{E,H}$: Heating Savings		
	Refrigerated Air	Gas Heat	Electric Resistance	Heat Pump
Zone 1: Panhandle	0.12	0.09	1.92	0.78
Zone 2: North	0.27	0.04	1.10	0.45
Zone 3: South	0.22	0.02	0.63	0.25
Zone 4: Valley	0.39	0.02	0.55	0.21
Zone 5: West*	0.07	0.03	0.88	0.34

Deemed Summer Demand Savings Tables

Table 2-163 presents the summer peak demand savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed summer demand savings for air infiltration improvements.

$$Deemed\ Summer\ Demand\ Savings = \Delta CFM_{50} \times V_S$$

Equation 70

Where:

ΔCFM_{50} = *Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*

V_S = *Corresponding value in Table 2-163*

Table 2-163: Peak Summer Demand Savings V_S per CFM_{50} Reduction

Region	Summer kW Impact per CFM_{50} Reduction
Climate Zone 1: Panhandle	1.64E-04
Climate Zone 2: North	2.10E-04
Climate Zone 3: South	1.90E-04
Climate Zone 4: Valley	2.24E-04
Climate Zone 5: West	9.40E-05

Deemed Winter Demand Savings Tables

Table 2-164 presents the summer peak demand savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed winter demand savings for air infiltration improvement:

$$Deemed\ Winter\ Demand\ Savings = \Delta CFM_{50} \times V_W$$

Equation 71

Where:

ΔCFM_{50} = *Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*

V_W = *Corresponding value in Table 2-164*

Table 2-164: Peak Winter Demand Savings V_W per CFM_{50} Reduction

Region	Winter kW Impact per CFM_{50} Reduction	
	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	9.42E-04	5.48E-04
Climate Zone 2: North	1.25E-03	6.93E-04
Climate Zone 3: South	8.61E-04	4.41E-04
Climate Zone 4: Valley	7.81E-04	3.60E-04
Climate Zone 5: West	2.92E-04	1.19E-04

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Example Deemed Savings Calculation

Example 1. A contractor uses a blower door test to estimate 12,000 CFM_{50} of pre-retrofit air leakage in a 2,200 square foot, 2-story, 3 bed-room home in Climate Zone 4 with a heat pump. The home is located in a well-shielded area. After identifying and sealing leaks, she performs another blower door test and measures 8,000 CFM_{50} of air leakage.

$$Max\ Initial\ Leakage\ Rate\ = 5.2 * 2{,}200 = 11{,}440\ CFM_{50}$$

$$Reported\ Initial\ Leakage\ = Min(12{,}000, 11{,}400) = 11{,}440\ CFM_{50}$$

$$Capped\ Post\ Retrofit\ Leakage\ = 11{,}400\ \text{x}\ (1 - \ 0.4) = 6{,}864\ CFM_{50}$$

$$Reported\ Post\ Retrofit\ Leakage\ = Max(8{,}000, 6{,}864) = 8{,}000\ CFM_{50}$$

$$Min.\ Post\ Retrofit\ Leakage\ (safety)\ = [0.03 \times 2{,}200 + 7.5 \times 4] \times 14.8 = 1{,}421\ CFM_{50}$$

$$\Delta CFM_{50} = (11{,}440 - 8{,}000) = 3{,}440$$

$$kWh\ savings = (0.39 + 0.21) \times 3{,}440 = 2{,}064\ \text{kWh}$$

$$Summer\ kW\ savings = 2.24x10^{-4} \times 3{,}440 = 0.77\ \text{kW}$$

$$Winter\ kW\ savings = 3.60x10^{-4} \times 3{,}440 = 1.24\ \text{kW}$$

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the DEER Final Report December 2008, the estimated useful life is 11 years for air infiltration reduction.

Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- The climate zone
- Pre-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Post-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Heating type (gas, resistance heat, heat pump)

- Square footage of the house
- Shielding level (well shielded, normal, exposed)
- Number of bedrooms
- Number of stories
- Number of occupants
- For RSOP homes that achieve a CFM reduction percentage of 30-40%: pictures capturing the scope/type of retrofit implemented and blower door test readings showing pre- and post-retrofit condition of the treated spot such as newly added door strip, caulking around window frame and recessed lighting fixtures.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003 Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.
- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-165: Air Infiltration Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions.
v3.0	4/10/2015	TRM v3.0 update. Revision of minimum ventilation requirements, pre-retrofit cap on infiltration levels, Climate Zone 5 savings values for homes with heat pumps, and tracking number of bedrooms and occupants in a house.
v3.1	11/05/2015	TRM v3.1 update. Provided clarification around effects of occupancy on minimum final ventilation.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Introduced new protocols related to maximum CFM reduction percentage and its associated documentation requirements. Added a new example for calculating savings.

2.3.2 Ceiling Insulation Measure Overview

TRM Measure ID: R-BE-CI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

Savings are estimated for insulation improvements to the ceiling area above a conditioned space in residences with central air cooling and/or heating systems.

Eligibility Criteria

Cooling savings in this measure apply to customers with electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings.

Baseline Condition

Ceiling insulation levels encountered in existing homes can vary significantly, depending on factors such as the age of the home, type of insulation installed, and level of attic use (equipment, storage, etc.). Deemed savings have been developed based on different levels of encountered (existing) ceiling insulation in participating homes, ranging from no insulation material (R-0) to the equivalent of about 6 inches of fiberglass batt insulation (R-22). The current average ceiling insulation level at participating homes is to be determined and documented by the insulation installer. Degradation due to age and density of the existing insulation should be taken into account.

In the event that existing insulation is or has been removed during measure implementation, the existing R-value for claiming savings shall be based upon the R-value of the existing insulation prior to removal.

For any reported pre-retrofit R-value that falls below R-5, the TRM requires all contractors to provide sufficient evidence including two pictures: 1) a picture showing the entire attic floor, and 2) a close-up picture of a ruler that shows the measurement of the depth of the insulation. In the absence of evidence demonstrating pre-retrofit ceiling insulation below R-5, the lowest level of pre-retrofit ceiling insulation that can be claimed is the R-5 to R-8 range.

High-Efficiency Condition

A ceiling insulation level of R-30 is recommended throughout Texas as prescribed by the Department of Energy. Accordingly, deemed savings are provided for insulating to R-30. Adjustment factors are provided to allow contractors to estimate savings for installation of higher or lower levels of post-retrofit insulation: contractors should estimate post-retrofit R-value according to the average insulation depth achieved across the area treated and the R-per-inch of the insulation material installed.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the default R-value of ceiling insulation (R-15 in most zones) was set at different levels, ranging from R-0 (no ceiling insulation) to R-22. These modifications are shown in Table 2-166.

The model runs are used to estimate peak demand and energy use in the modeled home at each of the base case ceiling insulation levels. The change-case models were run with the ceiling insulated to R-30.

Table 2-166: Residential Ceiling Insulation – Prototypical Home Characteristics

Shell Characteristic	Value	Source
Base Ceiling Insulation	R-0 R1-R4 R5-R8 R9-R14 R15-R22	Existing insulation level
Change Ceiling Insulation	R-30	Efficiency measure – R-30 retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs in Texas

Deemed Energy Savings Tables

Table 2-167 through Table 2-171 present the energy savings (kWh) associated with ceiling insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Climate Zone 1: Panhandle Region

Table 2-167: Climate Zone 1: Panhandle Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft)

Ceiling Insulation Base R-value	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
R-0	0.75	0.22	0.21	5.48	2.35
R-1 to R-4	0.62	0.18	0.18	4.60	1.97
R-5 to R-8	0.28	0.08	0.08	2.16	0.92
R-9 to R-14	0.15	0.04	0.05	1.17	0.50
R-15 to R-22	0.06	0.02	0.02	0.51	0.22

Climate Zone 2: North Region

Table 2-168: Climate Zone 2: North Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft.)

Ceiling Insulation Base R-value	Cooling Savings	Heating Savings		
		Gas Heat	Electric Resistance	Heat Pump
R-0	1.23	0.12	3.40	1.41
R-1 to R-4	1.01	0.10	2.87	1.18
R-5 to R-8	0.46	0.05	1.34	0.55
R-9 to R-14	0.25	0.03	0.72	0.30
R-15 to R-22	0.11	0.01	0.32	0.13

Climate Zone 3: South Region

Table 2-169: Climate Zone 3: South Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft.)

Ceiling Insulation Base R-value	Cooling Savings	Heating Savings		
		Gas Heat	Electric Resistance	Heat Pump
R-0	1.27	0.09	2.30	0.93
R-1 to R-4	1.04	0.07	1.96	0.79
R-5 to R-8	0.46	0.03	0.92	0.37
R-9 to R-14	0.24	0.02	0.50	0.20
R-15 to R-22	0.10	0.01	0.22	0.09

Climate Zone 4: Valley Region

Table 2-170: Climate Zone 4: Valley Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft.))

Ceiling Insulation Base R-value	Cooling Savings	Heating Savings		
		Gas Heat	Electric Resistance	Heat Pump
R-0	1.00	0.04	1.60	0.62
R-1 to R-4	0.78	0.04	1.35	0.52
R-5 to R-8	0.35	0.02	0.62	0.24
R-9 to R-14	0.18	0.01	0.33	0.13
R-15 to R-22	0.08	0.00	0.14	0.06

Climate Zone 5: West Region

Table 2-171: Climate Zone 5: West Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft.)

Ceiling Insulation Base R-value	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
R-0	1.17	0.38	0.12	3.44	1.43
R-1 to R-4	0.96	0.32	0.10	2.95	1.22
R-5 to R-8	0.43	0.15	0.05	1.40	0.57
R-9 to R-14	0.23	0.08	0.03	0.75	0.31
R-15 to R-22	0.10	0.03	0.01	0.33	0.13

Scale Down/Up Factors for Energy Savings: Insulation to Below or Above R-30

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing more or less than R-30 insulation. Scale down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale up factors are provided for the case when insulating to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the energy savings.

$$\boldsymbol{Energy\ Savings\ (kWh) = \{R30\ Savings/ft^2 + [S_{D/U} \times (R_{Achieved} - 30)]\} \times A}$$

Equation 72

Where:

R30 Savings/ft² = *Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from Table 2-172 through Table 2-173*

$S_{D/U}$	=	*Project-appropriate scale-down or scale-up factor from either Table 2-172 or Table 2-173.*
$R_{Achieved}$	=	*Achieved R-value of installed insulation (e.g. for R-28, $R_{Achieved} = 28$)*
A	=	*Treated area (ft^2)*

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved energy savings per square foot of treated ceiling area.

Table 2-172: Energy Scale Down Factors: Ceiling Insulation to less than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02
2	6.66E-03	n/a	7.11E-04	2.00E-02	8.20E-03
3	6.22E-03	n/a	4.67E-04	1.38E-02	5.47E-03
4	4.92E-03	n/a	2.44E-04	9.04E-03	3.47E-03
5	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved energy savings per square foot of treated ceiling area.

Table 2-173: Energy Scale Up Factors: Ceiling Insulation to greater than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03
2	4.45E-03	n/a	4.82E-04	1.33E-02	5.47E-03
3	4.00E-03	n/a	2.97E-04	9.19E-03	3.66E-03
4	3.24E-03	n/a	1.62E-04	5.99E-03	2.30E-03
5	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03

Deemed Summer Demand Savings Tables

Table 2-174 through Table 178 present the summer demand savings (kW) associated with ceiling insulation for the five Texas climate zones.

Climate Zone 1: Panhandle Region

Table 2-174: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation to R-30 Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Refrigerated Air	Evaporative Cooling
R-0	1.15E-03	3.44E-04
R-1 to R-4	9.78E-04	3.04E-04
R-5 to R-8	4.50E-04	1.47E-04
R-9 to R-14	2.33E-04	7.16E-05
R-15 to R-22	1.02E-04	2.87E-05

Climate Zone 2: North Region

Table 2-175: Climate Zone 2: North Region – Residential Ceiling Insulation to R-30 Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Demand Savings (kW/sq. ft.)
R-0	1.27E-03
R-1 to R-4	1.10E-03
R-5 to R-8	5.17E-04
R-9 to R-14	2.67E-04
R-15 to R-22	1.15E-04

Climate Zone 3: South Region

Table 2-176: Climate Zone 3: South Region – Residential Ceiling Insulation to R-30 Conditioning Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Demand Savings (kW/sq. ft.)
R-0	1.44E-03
R-1 to R-4	1.21E-03
R-5 to R-8	5.51E-04
R-9 to R-14	2.87E-04
R-15 to R-22	1.22E-04

Climate Zone 4: Valley Region

Table 2-177: Climate Zone 4: Valley Region – Residential Ceiling Insulation to R-30 Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Demand Savings (kW/sq. ft.)
R-0	8.70E-04
R-1 to R-4	7.16E-04
R-5 to R-8	3.40E-04
R-9 to R-14	1.79E-04
R-15 to R-22	7.95E-05

Climate Zone 5: West Region

Table 2-178: Climate Zone 5: West Region – Residential Ceiling Insulation to R-30 Deemed Summer Demand Savings (kW)

Ceiling Insulation Base R-value	Refrigerated Air	Evaporative Cooling
R-0	1.18E-03	3.33E-04
R-1 to R-4	1.01E-03	3.25E-04
R-5 to R-8	4.72E-04	1.53E-04
R-9 to R-14	2.38E-04	6.25E-05
R-15 to R-22	1.03E-04	2.09E-05

Scale Down/Up Factors: Insulation to Below or Above R-30

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved summer peak demand savings per square foot of treated ceiling area.

Table 2-179: Summer Peak Demand Scale Down Factors: Ceiling Insulation to less than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Refrigerated Air	Evaporative Cooling
1	6.41E-06	1.97E-06
2	7.30E-06	n/a
3	7.91E-06	n/a
4	5.20E-06	n/a
5	6.41E-06	1.97E-06

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved summer peak demand savings per square foot of treated ceiling area.

Table 2-180: Summer Peak Demand Scale Up Factors: Ceiling Insulation to greater than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Refrigerated Air	Evaporative Cooling
1	4.22E-06	1.89E-06
2	4.92E-06	n/a
3	5.92E-06	n/a
4	3.47E-06	n/a
5	4.22E-06	1.89E-06

Deemed Winter Demand Savings Tables

Table 2-181 through Table 2-185 present the winter demand savings associated with ceiling insulation for the five Texas climate zones.

Climate Zone 1: Panhandle Region

Table 2-181: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	7.83E-05	2.25E-03	1.15E-03
R-1 to R-4	6.35E-05	1.90E-03	9.84E-04
R-5 to R-8	2.51E-05	8.74E-04	4.53E-04
R-9 to R-14	1.37E-05	4.56E-04	2.38E-04
R-15 to R-22	4.72E-06	1.95E-04	1.01E-04

Climate Zone 2: North Region

Table 2-182: Climate Zone 2: North Region – Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	6.02E-05	2.49E-03	1.62E-03
R-1 to R-4	5.35E-05	2.11E-03	1.41E-03
R-5 to R-8	2.79E-05	9.84E-04	6.60E-04
R-9 to R-14	1.45E-05	5.13E-04	3.51E-04
R-15 to R-22	6.42E-06	2.23E-04	1.52E-04

Climate Zone 3: South Region

Table 2-183: Climate Zone 3: South Region -
Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	8.08E-05	1.96E-03	1.08E-03
R-1 to R-4	6.85E-05	1.65E-03	9.43E-04
R-5 to R-8	2.91E-05	7.71E-04	4.49E-04
R-9 to R-14	1.39E-05	4.01E-04	2.35E-04
R-15 to R-22	5.36E-06	1.74E-04	1.03E-04

Climate Zone 4: Valley Region

Table 2-184: Climate Zone 4: Valley Region –
Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	5.28E-05	1.60E-03	7.50E-04
R-1 to R-4	4.48E-05	1.36E-03	6.47E-04
R-5 to R-8	2.18E-05	6.31E-04	3.03E-04
R-9 to R-14	1.13E-05	3.28E-04	1.57E-04
R-15 to R-22	5.71E-06	1.44E-04	6.95E-05

Climate Zone 5: West Region

Table 2-185: Climate Zone 5: West Region –
Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	3.28E-05	9.12E-04	3.91E-04
R-1 to R-4	2.56E-05	8.13E-04	3.45E-04
R-5 to R-8	1.14E-05	3.72E-04	1.57E-04
R-9 to R-14	5.38E-06	1.79E-04	7.54E-05
R-15 to R-22	2.26E-06	7.41E-05	3.11E-05

Scale Down/Up Factors for Demand Reduction: Insulation to Below or Above R-30

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing more or less than R-30 insulation. Scale down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale up factors are

provided for the case when insulating to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the summer peak demand savings.

$$\textbf{Demand Savings (kW)} = \{\textbf{R30 Savings/ft}^2 + [S_{D/U} \times (R_{Achieved} - 30)]\} \times A$$

Equation 73

Where:

R30 Savings/ft²	=	*Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from Table 2-172 and Table 2-173*
$S_{D/U}$	=	*Project-appropriate scale-down or scale-up factor from either Table 2-172 or Table 2-173*
$R_{Achieved}$	=	*Achieved R-value of installed insulation (e.g. for R-28, $R_{Achieved} = 28$)*
A	=	*Treated area (ft²)*

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved winter peak demand savings per square foot of treated ceiling area.

Table 2-186: Winter Peak Demand Scale Down Factors: Ceiling Insulation to less than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Gas Heat	Electric Resistance	Heat Pump
1	4.29E-07	1.21E-05	6.30E-06
2	3.97E-07	1.40E-05	9.55E-06
3	3.05E-07	1.10E-05	6.53E-06
4	3.19E-07	9.18E-06	4.32E-06
5	4.29E-07	1.21E-05	6.30E-06

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved winter peak demand savings per square foot of treated ceiling area.

Table 2-187: Winter Peak Demand Scale Up Factors: Ceiling Insulation to greater than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Gas Heat	Electric Resistance	Heat Pump
1	2.76E-07	7.85E-06	4.19E-06
2	2.57E-07	8.33E-06	4.80E-06
3	2.19E-07	7.33E-06	4.46E-06
4	1.72E-07	5.79E-06	2.72E-06
5	2.76E-07	7.85E-06	4.19E-06

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Example Deemed Savings Calculation

Example 1 (Scale Up). A home in Climate Zone 5 with evaporative cooling and an electric resistance furnace insulates 400 square feet from a baseline of R-1 to an efficient condition of R-38.

$$cooling\ energy\ savings\ per\ sq.ft. = 0.32 + 7.63x10^{-4} \times (38 - 30) = 0.33\ kWh/sq.\ ft.$$

$$heating\ energy\ savings\ per\ sq.ft. = 2.95 + 2.18x10^{-2} \times (38 - 30) = 3.12\ kWh/sq.\ ft.$$

$$kWh\ savings = (0.33 + 3.12) \times 400 = 1{,}381\ kWh$$

$$summer\ demand\ savings\ per\ sq.ft. = 3.25x10^{-4} + 1.89x10^{-6} \times (38 - 30)$$
$$= 3.41x10^{-4}\ kW/sq.\ ft.$$

$$Summer\ kW\ savings = 3.41x10^{-4} \times 400 = 0.14\ \text{kW}$$

$$winter\ demand\ savings\ per\ sq.ft = 8.13x10^{-4} + 7.85x10^{-5} \times (38 - 30)$$
$$= 8.76x10^{-4}\ kW/sq.\ ft.$$

$$Winter\ kW\ savings = 8.76x10^{-4} \times 400 = 0.35\ \text{kW}$$

Example 2 (Scale Down). A home in Climate Zone 3 with an air-source heat pump insulates 550 square feet from a baseline of R-5 to an efficient condition of R-28.

$$cooling\ energy\ savings\ per\ sq.ft. = 0.46 + 5.47x10^{-3} \times (28 - 30) = 0.45\ kWh/sq.ft.$$

$$heating\ energy\ savings\ per\ sq.ft. = 0.37 + 3.66x10^{-3} \times (28 - 30) = 0.36\ kWh/sq.ft.$$

$$kWh\ savings = (0.45 + 0.36) \times 550 = 446.4\ kWh$$

$$summer\ demand\ savings\ per\ sq.ft. = 5.51x10^{-4} + 7.91x10^{-6} \times (28 - 30)$$
$$= 5.35x10^{-4}\ kW/sq.ft.$$

$$Summer\ kW\ savings = 5.35x10^{-4} \times 550 = 0.29\ kW$$

$$winter\ demand\ savings\ per\ sq.ft. = 4.49x10^{-4} + 6.53x10^{-6} \times (28 - 30)$$
$$= 4.36x10^{-4}\ kW/sq.ft.$$

$$Winter\ kW\ savings = 4.36x10^{-4} \times 550 = 0.24\ kW$$

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[184] the Estimated Useful Life is 25 years for ceiling insulation.

Program Tracking Data & Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- The climate zone
- Base R-value of original insulation
- R-value of installed insulation
- Space cooling system type (evaporative cooling, refrigerated air conditioning)
- Space heating system type (gas, electric, heat pump)
- Square footage of ceiling insulation installed above a conditioned space
- Only for homes with a reported baseline R-value that is less than R-5:

  Two pictures: 1) a picture showing the entire attic floor, and 2) a close-up picture of a ruler that shows the measurement of the depth of the insulation.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.
- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

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[184] GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007). http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLife StudyLights&HVACGDS_1Jun2007.pdf

Document Revision History

Table 2-188: Ceiling Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRV v3.0 update. Provided savings tables for installation of insulation up to R-38. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air conditioning. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations. Clarified that no heating demand savings are to be claimed for homes with a gas furnace.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype simulation models and introduced new protocols for baseline and post-retrofit R-values, their associated savings estimations and documentation requirements.

2.3.3 Attic Encapsulation Measure Overview

TRM Measure ID: R-BE-CI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

Savings are estimated for bringing the attic into conditioned space by insulating and sealing the attic walls and roofs, eliminating leakage (to outside), and removing ceiling insulation, if present, to enhance air flow between the attic and the conditioned space directly below.

Eligibility Criteria

Cooling savings in this measure apply to customers with electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings.

Baseline Condition

The baseline condition is a vented, unfinished attic with some level of ceiling insulation. Ceiling insulation levels in existing construction can vary significantly, depending on the age of the home, type of insulation installed, and activity in the attic (such as using the attic for storage and HVAC equipment). Deemed savings have been developed based on different levels of encountered (existing) ceiling insulation in participating homes, ranging from no insulation material (R-0) to the equivalent of about 6 inches of fiberglass batt insulation (R-22). The average ceiling insulation level prior to the retrofit for at participating homes is to be determined and documented by the contractor. Degradation due to age and density of the existing insulation should be taken into account.

In the event that existing ceiling insulation is or has been removed during measure implementation, the existing R-value will be based upon the R-value of the existing insulation prior to removal.

High-Efficiency Condition

Attic walls and roof deck are insulated to either R-19 or R-38. Closed cell spray foam is recommended. Vents are sealed, as are obvious leaks. Ceiling insulation between the attic and the conditioned space is removed.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the default R-value of ceiling insulation (R-15 in most zones) was set at different levels, ranging from R-0 (no ceiling insulation) to R-22 to establish baseline energy use prior to encapsulation of the attic. These modifications are shown in Table 2-189.

The model runs calculated energy use for the prototypical home prior to encapsulating the attic. Next, change-case models were run to calculate energy use with the floor insulation measure in place with either R-30 or R-38 insulation.

Table 2-189: Residential Attic Encapsulation – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Base Attic Encapsulation	Vented Attic R-0 R1-R4 R5-R8 R9-R14 R15-R22	Typical construction practice throughout the state
Change Attic Encapsulation	Sealed attic with no ceiling insulation and either R-39 or R-38 roof deck insulation	Typical construction practice throughout the state

Deemed Energy Savings Tables

Table 2-190 through Table 2-194 present the energy savings (kWh) associated with ceiling insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are per square foot of installed insulation.

Climate Zone 1: Panhandle Region

Table 2-190: Climate Zone 1: Panhandle Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	R				
		Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.56	0.21	0.19	4.21	1.80
R-1 to R-4	R-19	0.44	0.18	0.16	3.43	1.46
R-5 to R-8	R-19	0.14	0.09	0.08	1.24	0.52
R-9 to R-14	R-19	0.02	0.05	0.04	0.36	0.14
R-15 to R-22	R-19	-0.06	0.03	0.02	-0.23	-0.11
R-0	R-38	0.63	0.23	0.21	4.54	1.94
R-1 to R-4	R-38	0.52	0.20	0.18	3.76	1.60
R-5 to R-8	R-38	0.22	0.11	0.09	1.57	0.66
R-9 to R-14	R-38	0.10	0.08	0.06	0.69	0.28
R-15 to R-22	R-38	0.02	0.06	0.04	0.10	0.03

Climate Zone 2: North Region

Table 2-191: Climate Zone 2: North Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	Cooling Savings	Heating Savings		
			Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.91	0.10	2.63	1.09
R-1 to R-4	R-19	0.71	0.08	2.15	0.88
R-5 to R-8	R-19	0.22	0.04	0.78	0.32
R-9 to R-14	R-19	0.03	0.02	0.23	0.09
R-15 to R-22	R-19	-0.10	0.01	-0.13	-0.06
R-0	R-38	1.04	0.11	2.83	1.17
R-1 to R-4	R-38	0.84	0.09	2.35	0.97
R-5 to R-8	R-38	0.35	0.05	0.98	0.40
R-9 to R-14	R-38	0.16	0.03	0.43	0.17
R-15 to R-22	R-38	0.04	0.01	0.07	0.02

Climate Zone 3: South Region

Table 2-192: Climate Zone 3: South Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	Cooling Savings	Heating Savings		
			Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.96	0.08	1.81	0.73
R-1 to R-4	R-19	0.76	0.06	1.51	0.60
R-5 to R-8	R-19	0.24	0.03	0.58	0.23
R-9 to R-14	R-19	0.04	0.01	0.20	0.07
R-15 to R-22	R-19	-0.08	0.00	-0.05	-0.03
R-0	R-38	1.09	0.08	1.94	0.78
R-1 to R-4	R-38	0.88	0.07	1.64	0.65
R-5 to R-8	R-38	0.36	0.03	0.71	0.28
R-9 to R-14	R-38	0.17	0.02	0.33	0.13
R-15 to R-22	R-38	0.04	0.01	0.08	0.03

Climate Zone 4: Valley Region

Table 2-193: Climate Zone 4: Valley Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	Cooling Savings	Heating Savings		
			Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.67	0.03	1.26	0.48
R-1 to R-4	R-19	0.48	0.03	1.04	0.40
R-5 to R-8	R-19	0.09	0.01	0.39	0.15
R-9 to R-14	R-19	-0.05	0.00	0.13	0.05
R-15 to R-22	R-19	-0.15	0.00	-0.04	-0.02
R-0	R-38	0.77	0.04	1.34	0.52
R-1 to R-4	R-38	0.58	0.03	1.12	0.43
R-5 to R-8	R-38	0.19	0.01	0.47	0.18
R-9 to R-14	R-38	0.05	0.01	0.21	0.08
R-15 to R-22	R-38	-0.05	0.00	0.04	0.01

Climate Zone 5: West Region

Table 2-194: Climate Zone 5: West Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.90	0.37	0.10	2.71	1.13
R-1 to R-4	R-19	0.72	0.32	0.09	2.27	0.93
R-5 to R-8	R-19	0.25	0.16	0.04	0.89	0.36
R-9 to R-14	R-19	0.06	0.10	0.02	0.30	0.12
R-15 to R-22	R-19	-0.06	0.06	0.01	-0.07	-0.04
R-0	R-38	1.02	0.42	0.11	2.90	1.20
R-1 to R-4	R-38	0.84	0.36	0.10	2.46	1.01
R-5 to R-8	R-38	0.37	0.21	0.05	1.07	0.44
R-9 to R-14	R-38	0.19	0.15	0.03	0.49	0.20
R-15 to R-22	R-38	0.07	0.11	0.02	0.12	0.04

Deemed Summer Demand Savings Tables

Table 2-195 through Table 2-199 present the summer demand savings (kW) associated with ceiling insulation for the five Texas climate zones. Savings are per square foot of installed insulation.

Climate Zone 1: Panhandle Region

Table 2-195: Climate Zone 1: Panhandle Region – Residential Attic Encapsulation Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	9.70E-04	4.01E-04	1.04E-03	4.04E-04
R-1 to R-4	8.16E-04	3.66E-04	8.83E-04	3.69E-04
R-5 to R-8	3.44E-04	2.25E-04	4.11E-04	2.28E-04
R-9 to R-14	1.50E-04	1.57E-04	2.16E-04	1.61E-04
R-15 to R-22	3.29E-05	1.19E-04	9.93E-05	1.23E-04

Climate Zone 2: North Region

Table 2-196: Climate Zone 2: North Region – Residential Attic Encapsulation Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	1.06E-03		1.14E-03	
R-1 to R-4	9.08E-04		9.89E-04	
R-5 to R-8	3.86E-04		4.68E-04	
R-9 to R-14	1.62E-04		2.44E-04	
R-15 to R-22	2.63E-05		1.08E-04	

Climate Zone 3: South Region

Table 2-197: Climate Zone 3: South Region – Residential Attic Encapsulation Conditioning Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	1.26E-03		1.35E-03	
R-1 to R-4	1.06E-03		1.14E-03	
R-5 to R-8	4.65E-04		5.51E-04	
R-9 to R-14	2.29E-04		3.15E-04	
R-15 to R-22	8.20E-05		1.68E-04	

Climate Zone 4: Valley Region

Table 2-198: Climate Zone 4: Valley Region – Residential Attic Encapsulation Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	7.44E-04		7.99E-04	
R-1 to R-4	6.06E-04		6.61E-04	
R-5 to R-8	2.69E-04		3.25E-04	
R-9 to R-14	1.25E-04		1.81E-04	
R-15 to R-22	3.67E-05		9.19E-05	

Climate Zone 5: West Region

Table 2-199: Climate Zone 5: West Region – Residential Attic Encapsulation Deemed Summer Demand Savings (kW)

Ceiling Insulation Base R-value	R-19 Installed)		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	1.01E-03	3.22E-04	1.08E-03	3.44E-04
R-1 to R-4	8.58E-04	3.15E-04	9.32E-04	3.38E-04
R-5 to R-8	3.74E-04	1.62E-04	4.48E-04	1.84E-04
R-9 to R-14	1.64E-04	8.02E-05	2.38E-04	1.02E-04
R-15 to R-22	4.29E-05	4.29E-05	1.17E-04	6.52E-05

Deemed Winter Demand Savings Tables

Table 2-200 through Table 2-204 present the winter demand savings associated with ceiling insulation for the five Texas climate zones. Savings are per square foot of installed insulation.

Climate Zone 1: Panhandle Region

Table 2-200: Climate Zone 1: Panhandle Region – Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	7.75E-05	1.70E-03	8.70E-04	8.67E-05	1.82E-03	9.35E-04
R-1 to R-4	6.43E-05	1.39E-03	7.22E-04	7.34E-05	1.51E-03	7.87E-04
R-5 to R-8	2.99E-05	4.74E-04	2.47E-04	3.90E-05	5.94E-04	3.12E-04
R-9 to R-14	1.98E-05	1.00E-04	5.48E-05	2.89E-05	2.20E-04	1.20E-04
R-15 to R-22	1.17E-05	-1.34E-04	-6.79E-05	2.09E-05	-1.38E-05	-2.63E-06

Climate Zone 2: North Region

**Table 2-201: Climate Zone 2: North Region –
Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)**

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	4.97E-05	1.88E-03	1.21E-03	6.17E-05	2.01E-03	1.32E-03
R-1 to R-4	4.37E-05	1.55E-03	1.02E-03	5.57E-05	1.68E-03	1.13E-03
R-5 to R-8	2.08E-05	5.42E-04	3.55E-04	3.28E-05	6.70E-04	4.64E-04
R-9 to R-14	8.86E-06	1.21E-04	7.86E-05	2.09E-05	2.50E-04	1.87E-04
R-15 to R-22	1.59E-06	-1.39E-04	-9.90E-05	1.36E-05	-1.02E-05	9.55E-06

Climate Zone 3: South Region

**Table 2-202: Climate Zone 3: South Region -
Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)**

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	8.71E-05	1.59E-03	8.78E-04	9.55E-05	1.68E-03	9.34E-04
R-1 to R-4	7.61E-05	1.32E-03	7.58E-04	8.46E-05	1.41E-03	8.14E-04
R-5 to R-8	4.08E-05	5.29E-04	3.16E-04	4.93E-05	6.20E-04	3.72E-04
R-9 to R-14	2.73E-05	1.98E-04	1.25E-04	3.57E-05	2.89E-04	1.81E-04
R-15 to R-22	1.96E-05	-4.36E-06	6.84E-06	2.81E-05	8.67E-05	6.31E-05

Climate Zone 4: Valley Region

**Table 2-203: Climate Zone 4: Valley Region –
Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)**

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	4.67E-05	1.31E-03	6.23E-04	4.94E-05	1.38E-03	6.55E-04
R-1 to R-4	3.95E-05	1.10E-03	5.31E-04	4.21E-05	1.16E-03	5.63E-04
R-5 to R-8	1.90E-05	4.40E-04	2.24E-04	2.16E-05	5.08E-04	2.56E-04
R-9 to R-14	9.58E-06	1.69E-04	9.26E-05	1.22E-05	2.37E-04	1.25E-04
R-15 to R-22	4.57E-06	4.16E-06	1.43E-05	7.20E-06	7.22E-05	4.64E-05

Climate Zone 5: West Region

Table 2-204: Climate Zone 5: West Region –
Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	2.57E-05	6.66E-04	2.83E-04	3.08E-05	6.87E-04	2.92E-04
R-1 to R-4	1.93E-05	5.77E-04	2.42E-04	2.44E-05	5.98E-04	2.51E-04
R-5 to R-8	6.56E-06	1.83E-04	7.34E-05	1.17E-05	2.04E-04	8.31E-05
R-9 to R-14	1.18E-06	9.88E-06	5.10E-08	6.30E-06	3.09E-05	9.74E-06
R-15 to R-22	-1.60E-06	-8.35E-05	-3.96E-05	3.51E-06	-6.25E-05	-2.99E-05

Examples

Example 1. A contractor seals the attic and adds 900 square feet of R-38 insulation to the underside of the roof to a home in Climate Zone 3 with refrigerated air and a gas furnace, which has existing ceiling insulation estimated at R-7.

$$kWh\ savings = (0.36 + 0.03) \times 900 = 356.4\ \text{kWh}$$

$$Summer\ kW\ savings = 5.51x10^{-4} \times 900 = 0.50\ \text{kW}$$

$$Winter\ kW\ savings = 4.93x10^{-5} \times 900 = 0.04\ \text{kW}$$

Example 2. A contractor seals the attic and adds 1,200 square feet of R-38 insulation to the underside of the roof to a home in Climate Zone 4 with an air-source heat pump in which existing ceiling insulation is demonstrated to be only R-4.

$$kWh\ savings = (0.58 + 0.43) \times 1{,}200 = 1{,}207.2\ \text{kWh}$$

$$Summer\ kW\ savings = 6.61x10^{-4} \times 1{,}200 = 0.79\ \text{kW}$$

$$Winter\ kW\ savings = 5.63x10^{-4} \times 1{,}200 = 0.68\ \text{kW}$$

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[185] the Estimated Useful Life is 25 years for ceiling insulation.

Program Tracking Data & Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- The climate zone
- Base R-value of original insulation
- R-value of installed insulation
- Space cooling system type (evaporative cooling, refrigerated air conditioning)
- Space heating system type (gas, electric, heat pump)
- Square footage of ceiling insulation installed above a conditioned space

References and Efficiency Standards

Petitions and Rulings

- TBD

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-205: Ceiling Insulation Revision History

TRM Version	Date	Description of Change
v4.0	10/10/2016	TRM v4.0 origin.

[185] GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007). http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLife StudyLights&HVACGDS_1Jun2007.pdf

2.3.4 Wall Insulation Measure Overview

TRM Measure ID: R-BE-WI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling and Engineering Estimates

Measure Description

Wall insulation is added to the walls surrounding conditioned space in existing homes, either by removing wall enclosures and applying batt or spray insulation, or by otherwise filling (e.g. blowing loose insulation into) the cavity space between studs in the walls of existing homes. Walls may be either 2x4 or 2x6 construction. Savings are estimated for filling the wall cavities of 2x4 or 2x6 walls with either fiberglass batts or closed-cell spray foam, and are presented per square foot of treated wall area (gross wall area less window and door area).

Eligibility Criteria

To qualify for these deemed savings values, wall insulation may be added for customers with electric, central air conditioning or for customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Refer to the Baseline Condition section below for eligibility criteria regarding pre-retrofit level of wall insulation.

Baseline Condition

The baseline is considered to be a house with little or no wall insulation in the wall cavity. For those homes for which a minimal level of insulation is encountered, baseline is established at R-4. This baseline should be used to represent homes for which installed insulation covers a very limited amount of the wall area to be treated, is significantly degraded, and/or is less than an inch thick. Homes with more than this base level of insulation are not eligible for the measure.

Baseline homes may have either 2x4 or 2x6 construction.

High-Efficiency Condition

The standard throughout Texas for adding wall insulation to an existing wall cavity is R-13, as prescribed by United States Department of Energy (DOE) and Texas Department of Housing & Community Affairs (TDHCA) programs. The standard is achieved by filling a 2x4 wall cavity with fiberglass batt insulation, which typically provides an R-value per inch (thickness) of between 3 and 4 $hr \cdot ft^2 \cdot °F/BTU$. Other wall insulation materials may be used, such as closed-cell spray foam, which approximately provides an R-value of 6 per inch.

As such, deemed savings are provided for insulating 2x4 and 2x6 walls to the levels presented in Table 2-206:

Table 2-206: High-Efficiency Condition R-Values for 2x4 and 2x6 Walls

Insulation Material	2x4 Wall	2x6 Wall
Fiberglass Batt	R-13	R-17
Closed-cell Spray Foam	R-21	R-33

Wall insulation reduces the ventilation rate in the home and therefore a post-installation blower door test must be conducted. Results must comply with the Minimum Final Ventilation Rate discussed in the High-Efficiency Condition section found in the Air Infiltration section of this document. This requirement applies to retrofits implemented under the HTR and RSOP programs.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the default R-11 insulation was reduced to either R-0 or R-4.

The model runs calculated energy use for the prototypical home prior to the installation of the wall insulation measure. Next, change-case models were run to calculate energy use with the wall insulation measure in place.

Table 2-207: Residential Wall Insulation – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Base Wall Insulation	R-0 R-4	BEopt estimates wall assembly R-value for uninsulated walls to be 3.6 for 2x4 construction and 3.7 for 2x6 construction. Assembly R-values for R-4 walls are 6.7 and 7.1 for 2x4 and 2x6 construction, respectively. Listed base levels are for the insulation material only.
Change Wall Insulation 2x4 wall	R-13 R-21	For retrofit with fiberglass batt and closed-cell spray foam, respectively.
Change Wall Insulation 2x6 wall	R-17 R-33	EF or retrofit with fiberglass batt and closed-cell spray foam, respectively.

Deemed Energy Savings Tables

Savings are presented separately for insulating 2x4 wall construction and homes with 2x6 walls. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

2x4 Walls

Table 2-209 presents the deemed energy savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

Table 2-208: Deemed Annual Energy Savings, Insulation of 2x4 Walls to R- 13 (kWh/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	0.50	0.17	0.18	3.96	1.67
Climate Zone 2: North		0.85	N/A	0.09	2.44	0.99
Climate Zone 3: South		0.90	N/A	0.07	1.67	0.66
Climate Zone 4: Valley		0.53	N/A	0.04	1.19	0.45
Climate Zone 5: West		0.76	0.29	0.09	2.40	0.98
Climate Zone 1: Panhandle	R-4	0.18	0.06	0.07	1.52	0.64
Climate Zone 2: North		0.32	N/A	0.04	0.93	0.38
Climate Zone 3: South		0.33	N/A	0.03	0.64	0.25
Climate Zone 4: Valley		0.19	N/A	0.01	0.45	0.17
Climate Zone 5: West		0.28	0.11	0.03	0.92	0.37

Table 2-209 presents the deemed energy savings values for insulating 2x4 walls to R-21 for all five Texas climate zones.

Table 2-209: Deemed Annual Energy Savings, Insulation of 2x4 Walls to R-21 (kWh/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	0.56	0.18	0.20	4.44	1.87
Climate Zone 2: North		0.95	N/A	0.10	2.73	1.11
Climate Zone 3: South		1.01	N/A	0.08	1.88	0.74
Climate Zone 4: Valley		0.59	N/A	0.04	1.33	0.50
Climate Zone 5: West		0.85	0.33	0.10	2.69	1.09
Climate Zone 1: Panhandle	R-4	0.24	0.08	0.09	2.00	0.84
Climate Zone 2: North		0.42	N/A	0.05	1.23	0.50
Climate Zone 3: South		0.43	N/A	0.03	0.84	0.33
Climate Zone 4: Valley		0.26	N/A	0.02	0.59	0.22
Climate Zone 5: West		0.37	0.14	0.05	1.20	0.49

2x6 Walls

Table 2-210 presents the deemed energy savings values for insulating 2x6 walls to R-17 for all five Texas climate zones.

Table 2-210: Deemed Annual Energy Savings, Insulation of 2x6 Walls to R-17 (kWh/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	0.53	0.18	0.19	4.27	1.80
Climate Zone 2: North		0.91	N/A	0.10	2.63	1.07
Climate Zone 3: South		0.97	N/A	0.08	1.81	0.71
Climate Zone 4: Valley		0.56	N/A	0.04	1.27	0.48
Climate Zone 5: West		0.81	0.31	0.10	2.58	1.05
Climate Zone 1: Panhandle	R-4	0.22	0.07	0.08	1.81	0.76
Climate Zone 2: North		0.38	N/A	0.04	1.11	0.45
Climate Zone 3: South		0.39	N/A	0.03	0.76	0.30
Climate Zone 4: Valley		0.23	N/A	0.02	0.53	0.20
Climate Zone 5: West		0.33	0.13	0.04	1.08	0.44

Table 2-211 presents the deemed energy savings values for insulating 2x6 walls to R-33 for all five Texas climate zones.

Table 2-211: Deemed Annual Energy Savings, Insulation of 2x6 Walls to R-33 (kWh/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	0.59	0.20	0.22	4.79	2.01
Climate Zone 2: North		1.01	N/A	0.11	2.94	1.20
Climate Zone 3: South		1.07	N/A	0.09	2.02	0.80
Climate Zone 4: Valley		0.62	N/A	0.04	1.42	0.54
Climate Zone 5: West		0.90	0.35	0.11	2.88	1.17
Climate Zone 1: Panhandle	R-4	0.28	0.09	0.11	2.33	0.98
Climate Zone 2: North		0.48	N/A	0.05	1.42	0.58
Climate Zone 3: South		0.49	N/A	0.04	0.98	0.38
Climate Zone 4: Valley		0.29	N/A	0.02	0.67	0.25
Climate Zone 5: West		0.42	0.16	0.05	1.38	0.56

Deemed Summer Demand Savings Tables

2x4 Walls

Table 2-212 presents the deemed summer demand savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

Table 2-212: Deemed Summer Demand Savings, Insulation of 2x4 Walls to R-13 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Type	
		Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	Uninsulated	6.41E-04	2.40E-04
Climate Zone 2: North		7.32E-04	N/A
Climate Zone 3: South		8.50E-04	N/A
Climate Zone 4: Valley		4.17E-04	N/A
Climate Zone 5: West		6.52E-04	2.00E-04
Climate Zone 1: Panhandle	R-4	2.35E-04	9.16E-05
Climate Zone 2: North		2.70E-04	N/A
Climate Zone 3: South		3.02E-04	N/A
Climate Zone 4: Valley		1.55E-04	N/A
Climate Zone 5: West		2.43E-04	7.40E-05

Table 2-213 presents the deemed summer demand savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

Table 2-213: Deemed Summer Demand Savings, Insulation of 2x4 Walls to R-21 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Type	
		Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	Uninsulated	7.34E-04	2.66E-04
Climate Zone 2: North		8.16E-04	N/A
Climate Zone 3: South		9.55E-04	N/A
Climate Zone 4: Valley		4.69E-04	N/A
Climate Zone 5: West		7.32E-04	2.23E-04
Climate Zone 1: Panhandle	R-4	3.29E-04	1.18E-04
Climate Zone 2: North		3.55E-04	N/A
Climate Zone 3: South		4.08E-04	N/A
Climate Zone 4: Valley		2.07E-04	N/A
Climate Zone 5: West		3.24E-04	9.68E-05

2x6 Walls

Table 2-214 presents the deemed summer demand savings values for insulating 2x6 walls to R-17 for all five Texas climate zones.

Table 2-214: Deemed Summer Demand Savings, Insulation of 2x6 Walls to R-17 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Type	
		Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	Uninsulated	7.00E-04	2.59E-04
Climate Zone 2: North		7.87E-04	N/A
Climate Zone 3: South		9.20E-04	N/A
Climate Zone 4: Valley		4.56E-04	N/A
Climate Zone 5: West		7.06E-04	2.14E-04
Climate Zone 1: Panhandle	R-4	2.88E-04	1.06E-04
Climate Zone 2: North		3.19E-04	N/A
Climate Zone 3: South		3.67E-04	N/A
Climate Zone 4: Valley		1.88E-04	N/A
Climate Zone 5: West		2.91E-04	8.44E-05

Table 2-215 presents the deemed summer demand savings values for insulating 2x6 walls to R-33 for all five Texas climate zones.

Table 2-215: Deemed Summer Demand Savings, Insulation of 2x6 Walls to R-33 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Type	
		Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	Uninsulated	7.76E-04	2.83E-04
Climate Zone 2: North		8.77E-04	N/A
Climate Zone 3: South		1.02E-03	N/A
Climate Zone 4: Valley		5.08E-04	N/A
Climate Zone 5: West		7.80E-04	2.38E-04
Climate Zone 1: Panhandle	R-4	3.64E-04	1.30E-04
Climate Zone 2: North		4.09E-04	N/A
Climate Zone 3: South		4.64E-04	N/A
Climate Zone 4: Valley		2.40E-04	N/A
Climate Zone 5: West		3.65E-04	1.08E-04

Deemed Winter Demand Savings

2x4 Walls

Table 2-216 presents the deemed winter demand savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

Table 2-216: Deemed Winter Demand Savings, Insulation of 2x4 Walls to R-13 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	6.93E-05	1.71E-03	8.78E-04
Climate Zone 2: North		6.66E-05	1.96E-03	1.30E-03
Climate Zone 3: South		7.49E-05	1.48E-03	8.39E-04
Climate Zone 4: Valley		4.28E-05	1.22E-03	5.78E-04
Climate Zone 5: West		2.06E-05	6.78E-04	2.84E-04
Climate Zone 1: Panhandle	R-4	2.58E-05	6.20E-04	3.19E-04
Climate Zone 2: North		2.46E-05	7.32E-04	4.94E-04
Climate Zone 3: South		2.61E-05	5.50E-04	3.20E-04
Climate Zone 4: Valley		1.61E-05	4.51E-04	2.13E-04
Climate Zone 5: West		6.23E-06	2.23E-04	9.39E-05

Table 2-217 presents the deemed winter demand savings values for insulating 2x4 walls to R-21 for all five Texas climate zones.

Table 2-217: Deemed Winter Demand Savings, Insulation of 2x4 Walls to R-13 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	7.69E-05	1.89E-03	9.75E-04
Climate Zone 2: North		7.41E-05	2.18E-03	1.46E-03
Climate Zone 3: South		8.19E-05	1.65E-03	9.40E-04
Climate Zone 4: Valley		4.78E-05	1.36E-03	6.41E-04
Climate Zone 5: West		2.24E-05	7.37E-04	3.10E-04
Climate Zone 1: Panhandle	R-4	3.34E-05	8.06E-04	4.16E-04
Climate Zone 2: North		3.20E-05	9.57E-04	6.50E-04
Climate Zone 3: South		3.31E-05	7.19E-04	4.21E-04
Climate Zone 4: Valley		2.11E-05	5.88E-04	2.77E-04
Climate Zone 5: West		8.01E-06	2.83E-04	1.20E-04

2x6 Walls

Table 2-218 presents the deemed winter demand savings values for insulating 2x6 walls to R-17 for all five Texas climate zones.

Table 2-218: Deemed Winter Demand Savings, Insulation of 2x6 Walls to R-17 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	6.99E-05	1.76E-03	9.09E-04
Climate Zone 2: North		7.01E-05	2.07E-03	1.40E-03
Climate Zone 3: South		7.86E-05	1.57E-03	9.10E-04
Climate Zone 4: Valley		4.58E-05	1.29E-03	6.08E-04
Climate Zone 5: West		1.84E-05	6.24E-04	2.64E-04
Climate Zone 1: Panhandle	R-4	2.68E-05	6.93E-04	3.58E-04
Climate Zone 2: North		2.84E-05	8.49E-04	5.84E-04
Climate Zone 3: South		2.96E-05	6.40E-04	3.82E-04
Climate Zone 4: Valley		1.90E-05	5.19E-04	2.41E-04
Climate Zone 5: West		5.59E-06	2.06E-04	8.81E-05

Table 2-219 presents the deemed winter demand savings values for insulating 2x6 walls to R-33 for all five Texas climate zones.

Table 2-219: Deemed Winter Demand Savings, Insulation of 2x6 Walls to R-33 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle		7.66E-05	1.95E-03	1.00E-03
Climate Zone 2: North		7.77E-05	2.31E-03	1.56E-03
Climate Zone 3: South	Uninsulated	8.62E-05	1.75E-03	1.02E-03
Climate Zone 4: Valley		5.11E-05	1.43E-03	6.73E-04
Climate Zone 5: West		1.96E-05	6.66E-04	2.82E-04
Climate Zone 1: Panhandle		3.35E-05	8.76E-04	4.53E-04
Climate Zone 2: North		3.60E-05	1.08E-03	7.44E-04
Climate Zone 3: South	R-4	3.72E-05	8.17E-04	4.92E-04
Climate Zone 4: Valley		2.43E-05	6.59E-04	3.06E-04
Climate Zone 5: West		6.87E-06	2.48E-04	1.06E-04

Examples

Example 1. A home with uninsulated 2x4 walls in Climate Zone 1 with evaporative cooling and an electric resistance furnace insulates 750 square feet to R-13 with fiberglass batt insulation.

$$kWh\ savings = (0.17 + 3.96) \times 750 = 3{,}091.5\ \text{kWh}$$

$$Summer\ kW\ savings = 2.40x10^{-4} \times 750 = 0.18\ \text{kW}$$

$$Winter\ kW\ savings = 1.71x10^{-3} \times 750 = 1.28\ \text{kW}$$

Example 2. A home in Climate Zone 4 with uninsulated 2x6 walls with a central air conditioning unit and a gas furnace insulates 500 square feet to R-17 with closed-cell spray foam.

$$kWh\ savings = (0.56 + 0.04) \times 500 = 300.0\ \text{kWh}$$

$$Summer\ kW\ savings = 4.56x10^{-4} \times 500 = 0.23\ \text{kW}$$

$$Winter\ kW\ savings = 4.58x10^{-5} \times 500 = 0.02\ \text{kW}$$

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for wall insulation.

Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- The climate zone
- Space heating system type (gas, electric, heat pump)
- Space cooling system type (evaporative cooling, refrigerated air conditioning)
- Square footage of retrofitted wall area (gross wall area excluding window and door area)

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 58. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-220: Wall Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations.
v4.0	August 31, 2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for 2x4 an 2x6 wall framing and for homes with central AC versus evaporative cooling. Added a two-tier baseline definition of R-0 and R-4.

2.3.5 Floor Insulation Measure Overview

TRM Measure ID: R-BE-FI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

Floor insulation is installed on the underside of floor areas sitting below conditioned space. Typically, it is installed in ventilated crawlspaces. Savings are presented per square foot of treated floor area.

Eligibility Criteria

To qualify for these deemed savings values, floor insulation may be added for customers with electric air conditioning or for customers in TRM climate zones 1 and 5 who have evaporative cooling systems in their homes. Homes with gas heating are disqualified for adding floor insulation since this may result in an energy penalty due to floors not getting cooled from the ground during summer.

Baseline Condition

The baseline is considered to be a house with pier and beam construction and no floor insulation against the floor of conditioned area.

High-Efficiency Condition

A floor insulation level of R-19 is recommended for site-built homes throughout Texas as prescribed by DOE and Texas Department of Housing & Community Affairs (TDHCA) programs. Batt insulation is recommended in most cases, and must have the vapor barrier installed facing up and against the floor or conditioned area. Insulation should be attached or secured so that it can reasonably be expected to remain in place for at least 10 years.

Typical floor construction depth of manufactured homes usually does not allow R-19 batt to be installed within the floor joists so R-15 loose-fill insulation is recommended by TDHCA.

A minimum of 24-inch clearance from bottom of the insulation to the ground is required by Occupational Safety and Health Association (OSHA).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values.

Savings values for the deemed savings estimates for this measure were developed using demand and energy savings calculated using BEopt 2.6, running Energy Plus 8.1 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: slab foundation was replaced with a crawlspace. A 5/8" thick wood floor is also specified.

The model runs calculated energy use for the prototypical home prior to the installation of the floor insulation measure. Next, change-case models were run to calculate energy use with the floor insulation measure in place.

Table 2-221: Residential Floor Insulation – Modifications to the Prototype Home Characteristics

Shell Characteristic	Value	Source
Foundation	Crawlspace	Skirting around perimeter is assumed uninsulated and vented. Ground under home is assumed to be bare, without any type of moisture barrier.
Base Floor Insulation	R-3.1	BEopt default for floor assembly, assuming 5/8" thick hardwood floor without carpet or other type of covering.
Change Floor Insulation	R-19 (except for manufactured housing, R-15)	Efficiency measure - retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs in Texas. Due to the typical floor joists depths found in manufactured housing, TDHCA recommends an R-15 loose-fill insulation for manufactured housing and other non-site-built homes.

Deemed Energy Savings Tables

Table 2-222 through Table 2-226 present energy savings on a kWh per square foot of insulation installed basis for all five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Table 2-222: Climate Zone 1: Panhandle Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.13	-0.07	1.72	0.68
Manufactured Home	-0.11	-0.06	1.52	0.60

Table 2-223: Climate Zone 2: North Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.12	-	0.96	0.38
Manufactured Home	-0.10	-	0.85	0.33

Table 2-224: Climate Zone 3: South Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.12	-	0.63	0.24
Manufactured Home	-0.10	-	0.56	0.21

Table 2-225: Climate Zone 4: Valley Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.07	-	0.40	0.15
Manufactured Home	-0.06	-	0.35	0.13

Table 2-226: Climate Zone 5: West Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.16	-0.07	1.10	0.43
Manufactured Home	-0.13	-0.06	0.97	0.38

Deemed Summer Demand Savings Tables

Table 2-227 through Table 2-231 present the deemed summer demand savings (kW) for all five Texas climate zones.

Table 2-227: Climate Zone 1: Panhandle Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	6.17E-06	-1.52E-05
Manufactured Home	5.48E-06	-1.30E-05

Table 2-228: Climate Zone 2: North Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	3.10E-05	-
Manufactured Home	2.75E-05	-

Table 2-229: Climate Zone 3: South Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	3.36E-05	-
Manufactured Home	2.77E-05	-

Table 2-230: Climate Zone 4: Valley Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	3.58E-05	-
Manufactured Home	3.07E-05	-

Table 2-231: Climate Zone 5: West Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	6.29E-06	-1.34E-06
Manufactured Home	8.30E-07	1.85E-07

Deemed Winter Demand Savings Tables

Table 2-232 presents the deemed winter demand savings for climate zone 5. Deemed winter demand savings for this measure are not currently available for the other climate zones. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-232: Climate Zone 1: Panhandle Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	5.23E-04	2.55E-04
Manufactured Home	4.62E-04	2.25E-04

Table 2-233: Climate Zone 2: North Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	5.19E-04	2.88E-04
Manufactured Home	4.56E-04	2.50E-04

Table 2-234: Climate Zone 3: South Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	4.22E-04	2.03E-04
Manufactured Home	3.64E-04	1.74E-04

Table 2-235: Climate Zone 4: Valley Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	3.51E-04	1.53E-04
Manufactured Home	3.02E-04	1.31E-04

Table 2-236: Climate Zone 5: West Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	3.54E-04	1.44E-04
Manufactured Home	3.19E-04	1.30E-04

Examples

Example 1. A manufactured home in Climate Zone 5 with evaporative cooling and an electric resistance furnace insulates 500 square feet.

$$kWh\ savings = (-0.06 + 0.97) \times 500 = 457.0\ \text{kWh}$$

$$Summer\ kW\ savings = 1.85x10^{-7} \times 500 = 0.00\ \text{kW}$$

$$Winter\ kW\ savings = 3.19x10^{-4} \times 500 = 0.16\ \text{kW}$$

Example 2. A site-built home in Climate Zone 2 with an air-source heat pump insulates 825 square feet.

$$kWh\ savings = (-0.12 + 0.38) \times 825 = 212.0\ \text{kWh}$$

$$Summer\ kW\ savings = 3.10x10^{-5} \times 825 = 0.03\ \text{kW}$$

$$Winter\ kW\ savings = 2.88x10^{-4} \times 825 = 0.24\ \text{kW}$$

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for floor insulation.

Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are: The climate zone

- Space heating system type (gas, electric, heat pump)
- Space cooling system type (evaporative cooling or electric air conditioning)
- Home type (site built or manufactured)
- Square footage of installed insulation

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-237: Floor Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling. Disqualified homes with gas heating for adding floor insulation.

2.3.6 ENERGY STAR® Windows Measure Overview

TRM Measure ID: R-BE-EW

Market Sector: Residential

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Measure Category: Building Envelope

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

ENERGY STAR® windows savings are calculated on per square foot of window basis, inclusive of frame and sash. To qualify for these deemed savings values, ENERGY STAR® windows may be installed only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline

Two base cases are contemplated: single-pane and double-pane windows. In both cases a metal frame is specified. Estimated U-Values and SHGCs for baseline windows are presented in **Table 2-238**.

Table 2-238: Baseline Windows

Number of Panes	U-Factor Btu/(h·ft²·°F)	Solar Heat Gain Coefficient (SHGC)
1	1.16	0.76
2	0.76	0.67

High-Efficiency Condition

For a window to qualify for these deemed savings, it must meet the relevant ENERGY STAR® criteria for the location in the state where the window is to be installed. Table 2-239 lists the ENERGY STAR® specifications for windows as of January 1, 2015. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® code.

Table 2-239: ENERGY STAR® Windows Specifications effective January 2015

U.S. Region, ENERGY STAR®	U-Factor Btu/(h·ft²·°F)	Solar Heat Gain Coefficient (SHGC)
North-Central	≤ 0.30	≤ 0.40
South-Central	≤ 0.30	≤ 0.25
Southern	≤ 0.40	≤ 0.25

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values have been estimated using calibrated simulation models. Base case homes were fitted with single-pane and double-pane windows: change case homes were equipped with windows meeting the appropriate ENERGY STAR window specification for the location in which the window was to be installed. The Climate Zones in the Energy Star Windows specification were mapped to the Texas TRM Climate Zones as shown in Table 2-240:

Table 2-240. TRM Climate Zones and ENERGY STAR® Windows Climate Zones

Texas TRM Climate Zones	U.S. Region, ENERGY STAR® Windows
Climate Zone 1: Panhandle	North-Central
Climate Zone 2: North	South-Central
Climate Zone 3: South	Southern
Climate Zone 4: Valley	Southern
Climate Zone 5: West	South-Central

Deemed Energy Savings Tables

Table 2-241 presents the energy savings (kWh) for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Table 2-241: ENERGY STAR® Windows Replacing Single-Pane Windows, Deemed Annual Energy Savings (kWh/sq. ft.)

Climate Zone	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	2.83	0.98	0.29	6.70	3.16
Climate Zone 2: North	5.42	-	0.10	3.09	1.45
Climate Zone 3: South	5.32		0.02	0.77	0.41
Climate Zone 4: Valley	5.97	-	0.02	0.82	0.34
Climate Zone 5: West	5.67	1.90	0.00	0.99	0.69

Table 2-242: ENERGY STAR® Windows Replacing Double-Pane Windows Deemed Annual Energy Savings (kWh/sq. ft.)

Climate Zone	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	2.03	0.72	0.18	4.15	2.00
Climate Zone 2: North	4.11	-	0.04	1.47	0.76
Climate Zone 3: South	3.96		-0.01	-0.21	0.01
Climate Zone 4: Valley	4.45	-	0.00	-0.01	0.02
Climate Zone 5: West	4.24	1.46	-0.03	-0.18	0.16

Deemed Summer Demand Savings Tables

Table 2-242 presents the summer demand savings tables for the five Texas climate zones.

Table 2-243: ENERGY STAR® Windows Replacing Single-Pane Windows, Deemed Summer Demand Savings (kW/sq. ft.)

Climate Zone	Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	3.09E-03	1.16E-03
Climate Zone 2: North	3.89E-03	-
Climate Zone 3: South	3.51E-03	-
Climate Zone 4: Valley	2.99E-03	-
Climate Zone 5: West	3.86E-03	1.05E-03

Table 2-244: ENERGY STAR® Windows Replacing Double-Pane Windows, Deemed Summer Demand Savings (kW/sq. ft.)

Climate Zone	Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	2.08E-03	8.36E-04
Climate Zone 2: North	2.80E-03	-
Climate Zone 3: South	2.40E-03	-
Climate Zone 4: Valley	2.15E-03	-
Climate Zone 5: West	2.76E-03	8.09E-04

Deemed Winter Demand Savings Tables

Table 2-244 presents the winter demand savings tables for the five Texas climate zones.

Table 2-245: ENERGY STAR® Windows Replacing Single-Pane Windows, Deemed Winter Demand Savings by Heat Type (kW/sq. ft.)

Climate Zone	Gas Heat	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	2.01E-04	4.98E-03	2.43E-03
Climate Zone 2: North	1.77E-04	4.73E-03	2.74E-03
Climate Zone 3: South	6.89E-05	1.78E-03	3.11E-04
Climate Zone 4: Valley	4.78E-05	1.65E-03	6.68E-04
Climate Zone 5: West	2.83E-05	1.10E-03	5.00E-04

Table 2-246: ENERGY STAR® Windows Replacing Double-Pane Windows, Deemed Winter Demand Savings by Heat Type (kW/sq. ft.)

Climate Zone	Gas Heat	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	1.32E-04	3.30E-03	1.64E-03
Climate Zone 2: North	1.12E-04	3.16E-03	1.89E-03
Climate Zone 3: South	2.33E-05	6.68E-04	3.58E-06
Climate Zone 4: Valley	1.53E-05	5.62E-04	2.34E-04
Climate Zone 5: West	1.31E-05	5.84E-04	2.76E-04

Examples

Example 1. A home in Climate Zone 1 with evaporative cooling and an electric resistance furnace replaces 125 square feet of single-pane windows with ENERGY STAR® windows.

$$kWh\ savings = (0.98 + 6.70) \times 125 = 960\ \text{kWh}$$

$$Summer\ kW\ savings = 1.16x10^{-3} \times 125 = 0.15\ \text{kW}$$

$$Winter\ kW\ savings = 4.98x10^{-3} \times 125 = 0.62\ \text{kW}$$

Example 2. A home in Climate Zone 5 with a central air conditioning unit and a gas furnace replaces 250 square feet of double-pane windows with ENERGY STAR® windows.

$$kWh\ savings = \big(4.24 + (-0.03)\big) \times 250 = 1{,}052.5\ \text{kWh}$$

$$Summer\ kW\ savings = 2.76x10^{-3} \times 250 = 0.69\ \text{kW}$$

$$Winter\ kW\ savings = 1.31x10^{-5} \times 250 = 0.00\ kW$$

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for ENERGY STAR® windows.

Program Tracking Data & Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- The climate zone
- Space heating system type (non-electric, electric resistance, heat pump)
- Space cooling system type (evaporative cooling or electric air conditioning)
- Area of ENERGY STAR® windows installed

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 48. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003 Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-247: ENERGY STAR® Windows Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations. Consolidated table formats.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling.

2.3.7 Solar Screens Measure Overview

TRM Measure ID: R-BE-SC

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

Savings are presented for the installation of solar screens on west and/or south-facing windows or glass doors. Deemed savings are calculated per square foot of treated window or door opening.

Eligibility Criteria

To qualify for these deemed savings values, solar screens may be installed for customers with electric refrigerated air conditioning or evaporative cooling systems in their homes.

Solar screens must be installed on windows or glass doors that face west or south and receive significant direct sun exposure. Solar screens must block at least 65 percent of the solar heat gain to qualify for deemed savings.

Baseline Condition

The baseline is a single pane, clear glass, unshaded, west-, or south-facing window with a solar heat gain coefficient of 0.68. Baseline window area is assumed to be 7.5 percent of the total wall area.

High-Efficiency Condition

Solar screen material installed on south or west-facing windows must reduce solar heat gain by at least 65 percent. Solar screens are not recommended for homes with electric resistance heat.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values have been estimated using calibrated simulation models. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. A single modification was made to the prototype models for the various climate zone-HVAC type combinations to create the base case models for estimating savings for the solar screens measure. Windows facing all directions are assumed to be single-pane windows with U-Values of 1.16 BTU/h-ft^2-R and Solar Heat Gain Coefficients (SHGC) of 0.76.

For the change case models, an 80 percent reduction was applied to the solar heat gain coefficient for the south and west-facing windows.

Summer and winter peak demand savings are estimated by taking the difference in demand for the 20 hours identified from the TMY3 datasets in which the summer and winter peaks are most likely to occur as described in section 4 - Peak Demand Definitions, of TRM Volume 1.

The model assumes the average solar screen installed blocks 80% of the solar heat gain attributed to the south and west facing windows based on performance data from solar screens analyzed at sun angles of 30, 45 and 75 degrees to the window. [186]

While it is recommended that solar screens be removed during winter to allow the advantage of free heat from the sun, often they are not removed seasonally. This may be due to solar screens serving as an insect screen in addition to blocking the sun or simply that they're installed in difficult-to-reach areas such as second floor windows. The savings estimates presented herein assume that the installed solar screens remain in place year-round.

Thermal Performance Improvement

Manual J and other studies researched indicate a thermal improvement to a window with a solar screen due to reduced air infiltration. The National Certified Testing Laboratories provided a report stating a 15% reduction in the thermal transmittance of a single pane, ¼" clear glass window with a solar screen added to the exterior.

Another study that was conducted for NFRC indicated between a 22% and 4% improvement to the U-value of a window with a solar screen. A single pane, clear window has a 22% improvement with the addition of a solar screen, whereas a double pane, spectrally selective low-E window may only have a 4% improvement. The deemed savings models assume an average 10% improvement in thermal performance with the addition of a solar screen.

[186] Performance data from Matrix, Inc., Mesa, Arizona testing facility for Phifer Wire Products' SunTex screen, blocks 80% of solar heat gain.

Window Frame

The window frame accounts for 10-30 percent[187] of the window area and since it is opaque and blocks sunlight from entering the home, it is factored into the model. An average of 15% frame area was incorporated into the performance of the window.

Example Calculation

Example 1. A home in Climate Zone 4 with a central air conditioning unit and an electric resistance furnace installs 75 square feet of solar screens.

$$kWh\ savings = (6.09 + (-3.21)) \times 75 = 216\ \text{kWh}$$

$$Summer\ kW\ savings = 3.17x10^{-3} \times 75 = 0.24\ \text{kW}$$

$$Winter\ kW\ savings = -2.32x10^{-3} \times 75 = -0.17\ \text{kW}$$

Deemed Energy Savings Tables

Table 2-247 presents the deemed energy savings value per square foot of solar screen installed. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Table 2-248: Deemed Energy (kWh) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning

Climate Zone	Cooling Savings (kWh/sq. ft.)		Heating Savings (kWh/sq. ft.)		
	Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	3.67	1.34	-0.62	-12.81	-4.54
Climate Zone 2: North	5.38	-	-0.29	-7.14	-2.56
Climate Zone 3: South	5.33	-	-0.16	-4.69	-1.69
Climate Zone 4: Valley	6.09	-	-0.09	-3.21	-1.16
Climate Zone 5: West	5.62	1.99	-0.44	-10.48	-3.81

Deemed Summer Demand Savings Tables

Table 2-248 presents the deemed summer peak demand savings value per square foot of solar screen installed.

Table 2-249: Deemed Summer Peak Demand (kW) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning

Climate Zone	Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	2.89E-03	1.35E-03
Climate Zone 2: North	3.42E-03	-

[187] Residential Windows – A Guide to New Technologies and Energy Performance, 2000.

Climate Zone 3: South	3.29E-03	-
Climate Zone 4: Valley	3.17E-03	-
Climate Zone 5: West	3.12E-03	1.07E-03

Deemed Winter Demand Savings Tables

Table 2-249 presents the deemed winter peak demand savings value per square foot of solar screen installed. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-250: Deemed Winter Peak Demand (kW) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning

Climate Zone	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	-1.16E-04	-1.73E-03	-9.45E-04
Climate Zone 2: North	-5.20E-05	-1.32E-03	-7.96E-04
Climate Zone 3: South	-1.07E-04	-2.65E-03	-1.71E-03
Climate Zone 4: Valley	-7.68E-05	-2.32E-03	-1.08E-03
Climate Zone 5: West	-1.45E-04	-3.34E-03	-1.30E-03

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of solar screens is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[188]

Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- The climate zone
- Space cooling system type (evaporative cooling, refrigerated air conditioning)

[188] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

- Space heating system type (gas, electric, heat pump)
- Square footage of windows or door openings treated

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-251: Solar Screens Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics. Savings awarded for south-facing windows, in addition to east- and west-facing windows.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling.

2.4 RESIDENTIAL: WATER HEATING

2.4.1 Faucet Aerators Measure Overview

TRM Measure ID: R-WH-FA

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure involves installing aerators on kitchen and bathroom water faucets as a retrofit measure.

Eligibility Criteria

The savings values are per faucet aerator installed. It is not a requirement that all faucets in a home be treated for the deemed savings to be applicable.

These deemed savings are for residential, retrofit-only installation of kitchen and bathroom faucet aerators. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-252: Faucet Aerators – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

The 2.2 gallon per minute (GPM) baseline faucet flow rate is based on the Energy Policy Act of 1992 (EPAct 92). The deemed savings assume that the existing faucet aerators have a minimum flow rate of 2.2 GPM. The US EPA WaterSense specification for faucet aerators is 1.5 GPM.[189]

Table 2-253: Faucet Aerators – Baseline and Efficiency Standard

Baseline	Efficiency Standard
2.2 GPM minimum	1.5 GPM maximum

High-Efficiency Condition

Aerators that have been defaced so as to make the flow rating illegible are not eligible for replacement. For direct install programs, all aerators removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

The deemed savings, for any faucet aerator change case using aerators with flow rates of 1.5 GPM or lower, are calculated as follows:

$$Energy\ Savings\ (per\ aerator) = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times (T_{FaucetAvg} - T_{SupplyAvg})}{FPH \times RE \times Conversion\ Factor}$$

Equation 74

Where:

ρ	=	*Water density, 8.33 lbs/gallon*
C_P	=	*Specific heat of water, 1 Btu/lb°F*
GPM_{Base}	=	*Average baseline flow rate of aerator = 2.2 gallons per minute*
GPM_{Low}	=	*Post-installation flow rate of aerator, typically 1.5, 1.0, or 0.5 gallons per minute; if unknown, assume 1.5 gallons per minute*
N	=	*Average number of persons per household = 2.82 persons*[190]

[189] http://www.epa.gov/watersense/partners/faucets_final.html.

[190] Occupants per home for Texas from US Census Bureau, "Persons per household, 2009-2013". Accessed December 2015. http://quickfacts.census.gov/qfd/states/48000.html.

t	=	*Average time in minutes of hot water usage per person per day; default = 2.34 min/person/day*[191]
$T_{SetPoint}$	=	*Average faucet temperature = 88°F*[192]
$T_{SupplyAverage}$	=	*Average supply water temperature (seeTable 2-253)*
FPH	=	*Average number of faucets per household = 3.93 faucets*[193]
RE	=	*Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[194]
ConversionFactor	=	*3,412 Btu/kWh*

Demand Savings Algorithms

Demand savings will be calculated using the following formula:

$$\boldsymbol{Demand\ Savings\ (per\ aerator)} = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times (T_{FaucetAvg} - T_{SupplySeasonal})}{FPH \times RE \times Conversion\ Factor} \times Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$$

Equation 75

Where:

$T_{SupplySeasonal}$	=	*Seasonal supply water temperature (Table2-253)*
$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$	=	*Ratio of peak seasonal kW to annual kWh savings (Table 2-254)*

[191] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group. Derived by taking weighted average of average minutes per person per day specified for kitchens (4.5) and bathrooms (1.6) assuming 1 kitchen aerator and 2.93 bathrooms.

[192] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group. Derived by taking weighted average of average temperature for kitchens (93 °F) and bathrooms (86 °F) assuming 1 kitchen aerator and 2.93 bathrooms.

Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

[193] Faucets per home assumed to be equal to one (kitchen) plus number of half bathrooms and full bathrooms per home as specified in the 2009 Residential Energy Consumption Survey (RECS), Table HC2.10.

[194] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://www.ahrinet.org

Table 2-254: Water Mains Temperature

Climate Zone	Water Mains Temperature °F*		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Panhandle	62.9	73.8	53.7
Climate Zone 2: North	71.8	84.0	60.6
Climate Zone 3: South	74.7	84.5	65.5
Climate Zone 4: Valley	77.2	86.1	68.5
Climate Zone 5: West	70.4	81.5	60.4

* Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

Table 2-255: Water Fixture Peak Demand Ratios

Peak Demand Ratios*	
Summer	**Winter**
0.000110	0.000274

* US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

The fixture peak demand ratios were derived by taking the fraction hot water use during the peak hour (summer: 4-5PM, winter: 7-8AM) to the total daily usage from the Building America Performance Analysis Procedures for Existing Homes, and dividing it by the number of days per year (365). The fraction of hot water use during the winter peak hour to total daily water usage is 0.1: $0.1/365 = 0.000274$. The summer peak hour to total daily water usage is 0.04: $0.04/365 = 0.000110$.

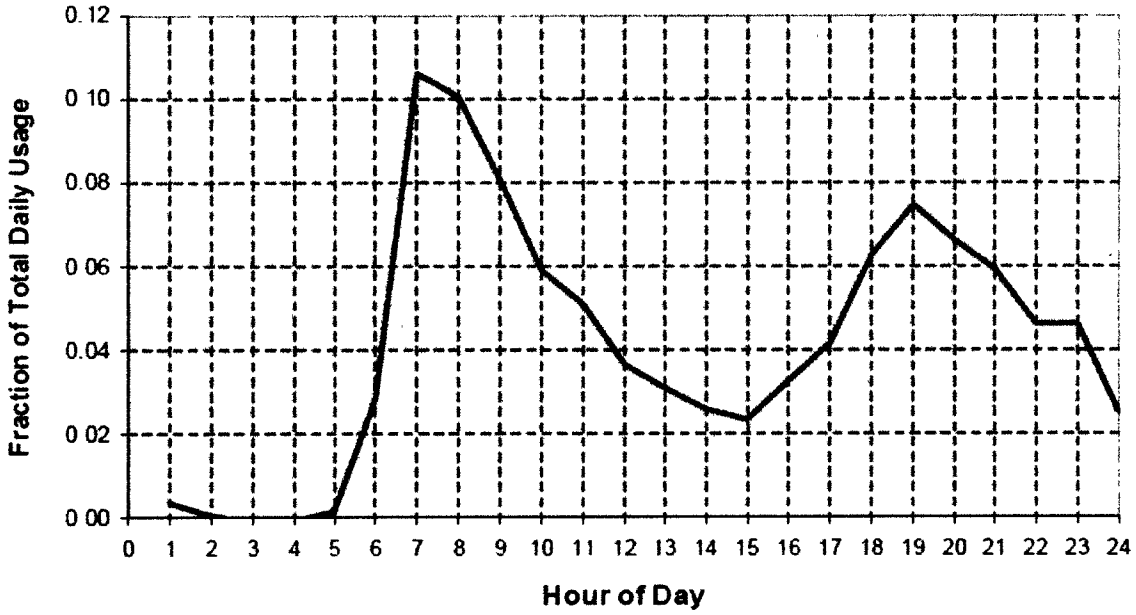

Figure 2-6: Shower, Bath, and Sink Hot Water Use Profile

Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Winter Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a faucet aerator is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[195]

Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- The climate zone
- Recovery Efficiency (RE) or COP, if available
- Flow rate in gallons per minute (GPM) of faucet installed
- Water heater type (e.g., heat pump, electric resistance)

References and Efficiency Standards

Petitions and Rulings

- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-256: Faucet Aerators Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	10/30/2015	TRM v3.1 update. Supplemented reference for water heater set point temperature.
v4.0	10/10/2016	Updated methodology to calculate energy and demand savings.

[195] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

2.4.2 Low-Flow Showerheads Measure Overview

TRM Measure ID: R-WH-SH

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure consists of removing existing showerheads and installing low-flow showerheads in residences.

Eligibility Criteria

The incentive is for replacement of an existing showerhead with a new showerhead rated at 2.0, 1.7, or 1.5 gallons per minute (GPM). The only showerheads eligible for installation are those that are not easily modified to increase the flow rate.

These deemed savings are for showerheads installed as a retrofit measure in existing homes. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-257: Low-Flow Showerheads – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

Federal standards set a maximum flow rate of 2.5 GPM,[196] while the US Environmental Protection Agency (EPA) WaterSense Program has implemented efficiency standards for showerheads requiring a maximum flow rate of 2.0 GPM.[197]

[196] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/37
[197] http://www.epa.gov/watersense/products/showerheads.html

Table 2-258: Low-Flow Showerhead – Baseline and Efficiency Standards

Existing Showerhead Baseline Flow Rate	New Showerhead Flow Rate*
2.5 GPM maximum	1.5 GPM, 1.75 GPM or 2.0 GPM maximum

* All flow rate requirements listed here are the rated flow of the showerhead measured at 80 pounds per square inch of pressure (psi).

High-Efficiency Condition

In addition to the meeting the baseline requirements above, existing showerheads that have been defaced so as to make the flow rating illegible are not eligible for replacement. All showerheads removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ (per\ showerhead) = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times (T_{ShowerAvg} - T_{SupplyAverage})}{SPH \times RE \times Conversion\ Factor}$$

Equation 76

Where:

ρ = *Water density, 8.33 lbs/gallon*

C_P = *Specific heat of water, 1 Btu/lb°F*

GPM_{Base} = *Average baseline flow rate of aerator = 2.5 gallons per minute*

GPM_{Low} = *Post-installation flow rate of aerator, typically 2.0, 1.75, or 1.5 gallons per minute; if unknown, assume 2.0 gallons per minute*

N = *Average number of persons per household = 2.82 persons*[198]

t = *Average time in minutes of hot water usage per person per day; default = 7.8 min/person/day*[199]

[198] Occupants per home for Texas from US Census Bureau, "Persons per household, 2009-2013". Accessed December 2015: http://quickfacts.census.gov/qfd/states/48000.html.

[199] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group.

$T_{SetPoint}$ = *Average shower temperature = 101°F*[200]

T_{Supply} = *Average supply water temperature (see Table 2-253*

SPH = *Average number of showerheads per household = 1.68 showerheads*[201]

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water* heaters.[202]

ConversionFactor = *3,412 Btu/kWh*

Demand Savings Algorithms

Demand savings will be calculated using the following formula:

$$\boldsymbol{Demand\ Savings\ (per\ showerhead)} = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times (T_{ShowerAvg} - T_{SupplySeasonal})}{SPH \times RE \times Conversion\ Factor} \times Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$$

Equation 77

Where:

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 2-259)*

$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$ = *Ratio of peak seasonal kW to annual kWh savings (see Table 2-260)*

[200] Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

[201] Showerheads per home assumed to be equal to the number of full bathrooms per home as specified in the 2009 Residential Energy Consumption Survey (RECS), Table HC2.10.

[202] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Table 2-259: Water Mains Temperature

Climate Zone	Water Mains Temperature (°F) *		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Panhandle	62.9	73.8	53.7
Climate Zone 2: North	71.8	84.0	60.6
Climate Zone 3: South	74.7	84.5	65.5
Climate Zone 4: Valley	77.2	86.1	68.5
Climate Zone 5: West	70.4	81.5	60.4

* Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

Table 2-260: Water Fixture Peak Demand Ratios

Peak Demand Ratios*	
Summer	Winter
0.000110	0.000274

* US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

The fixture peak demand ratios were derived by taking the fraction hot water use during the peak hour (summer: 4-5pm, winter: 7-8am) to the total daily usage from the Building America Performance Analysis Procedures for Existing Homes, and dividing it by the number of days per year (365). The fraction of hot water use during the winter peak hour to total daily water usage is 0.1: $0.1/365 = 0.000274$. The summer peak hour to total daily water usage is 0.04: $0.04/365 = 0.000110$.