



Priorities in building decarbonization: Accounting for total carbon and the time value of carbon in cost-benefit analyses of residential retrofits.

Citation

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Appendix A

Graphed results.

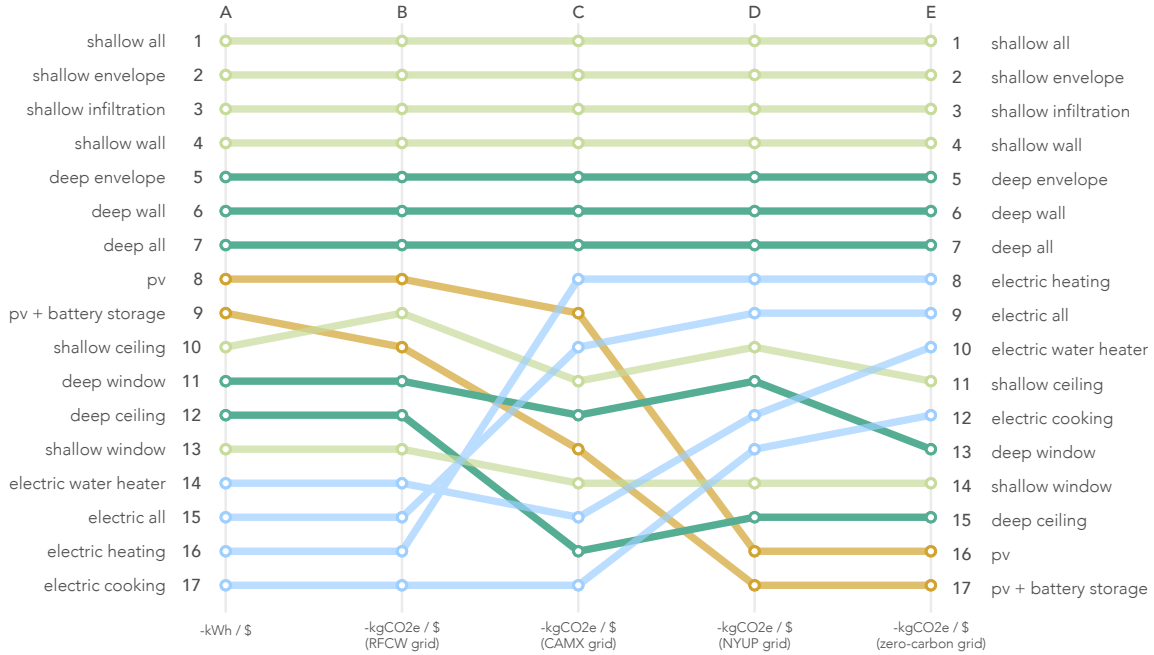


Figure A1. Ranking of retrofit interventions from best (1) to worst (17) as Chicago’s electric grid decarbonizes.

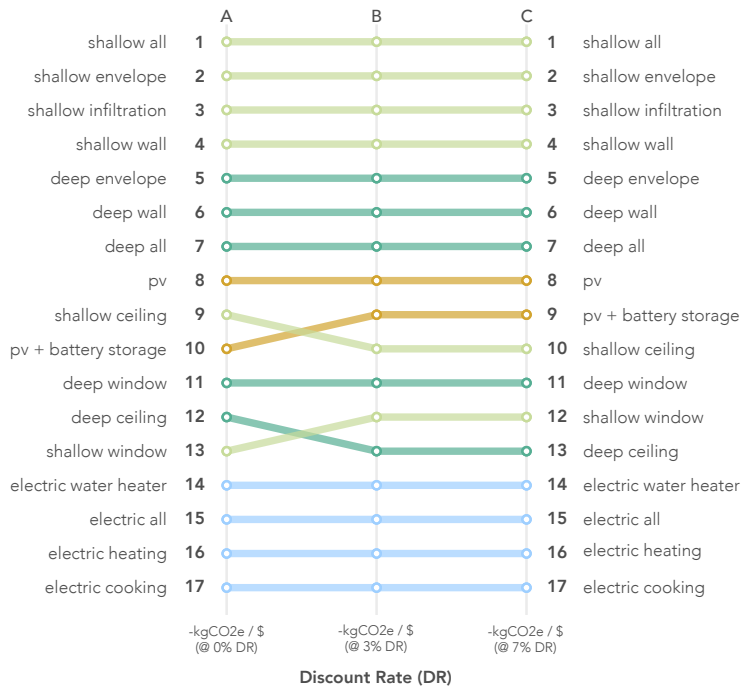


Figure A2. Ranking of Chicago retrofit interventions from best (1) to worst (17) considering the time value of carbon.

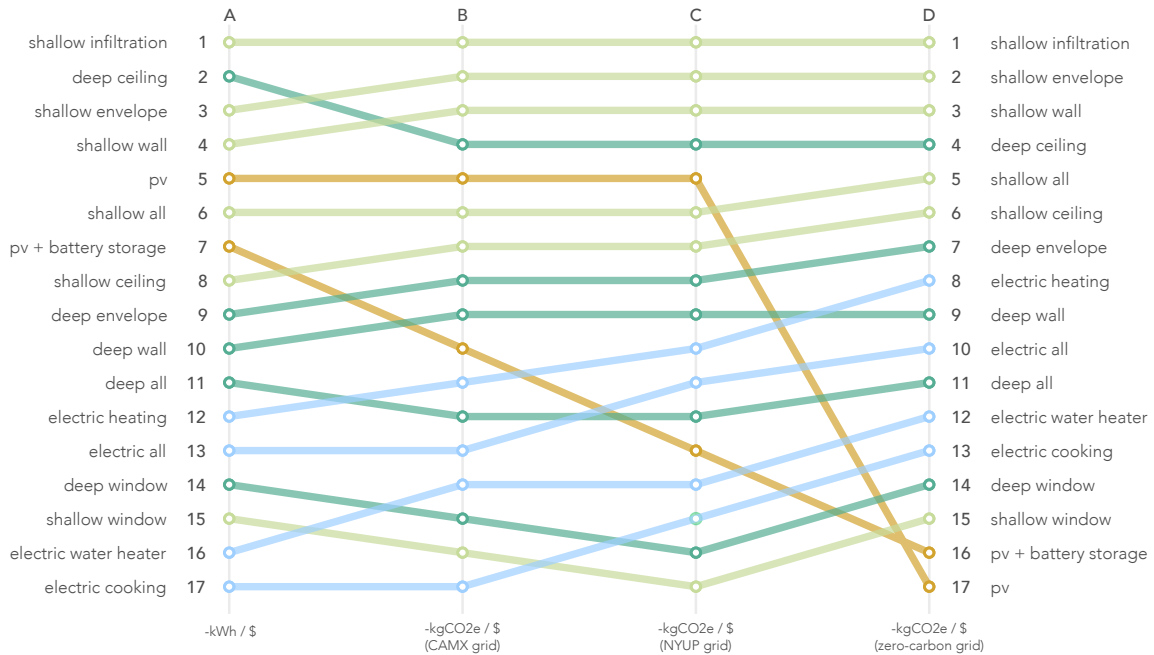


Figure A3. Ranking of retrofit interventions from best (1) to worst (17) as Los Angeles's electric grid decarbonizes.

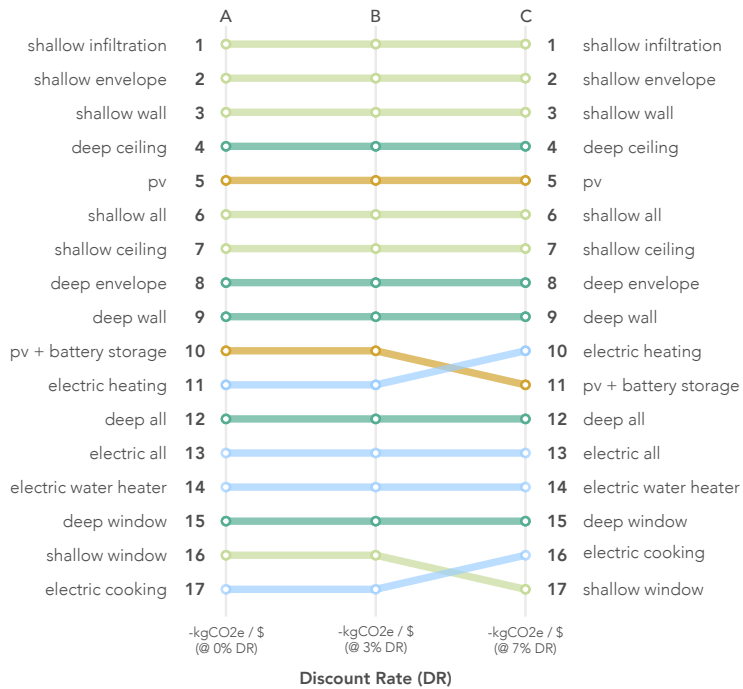


Figure A4. Ranking of Los Angeles retrofit interventions from best (1) to worst (17) considering the time value of carbon.

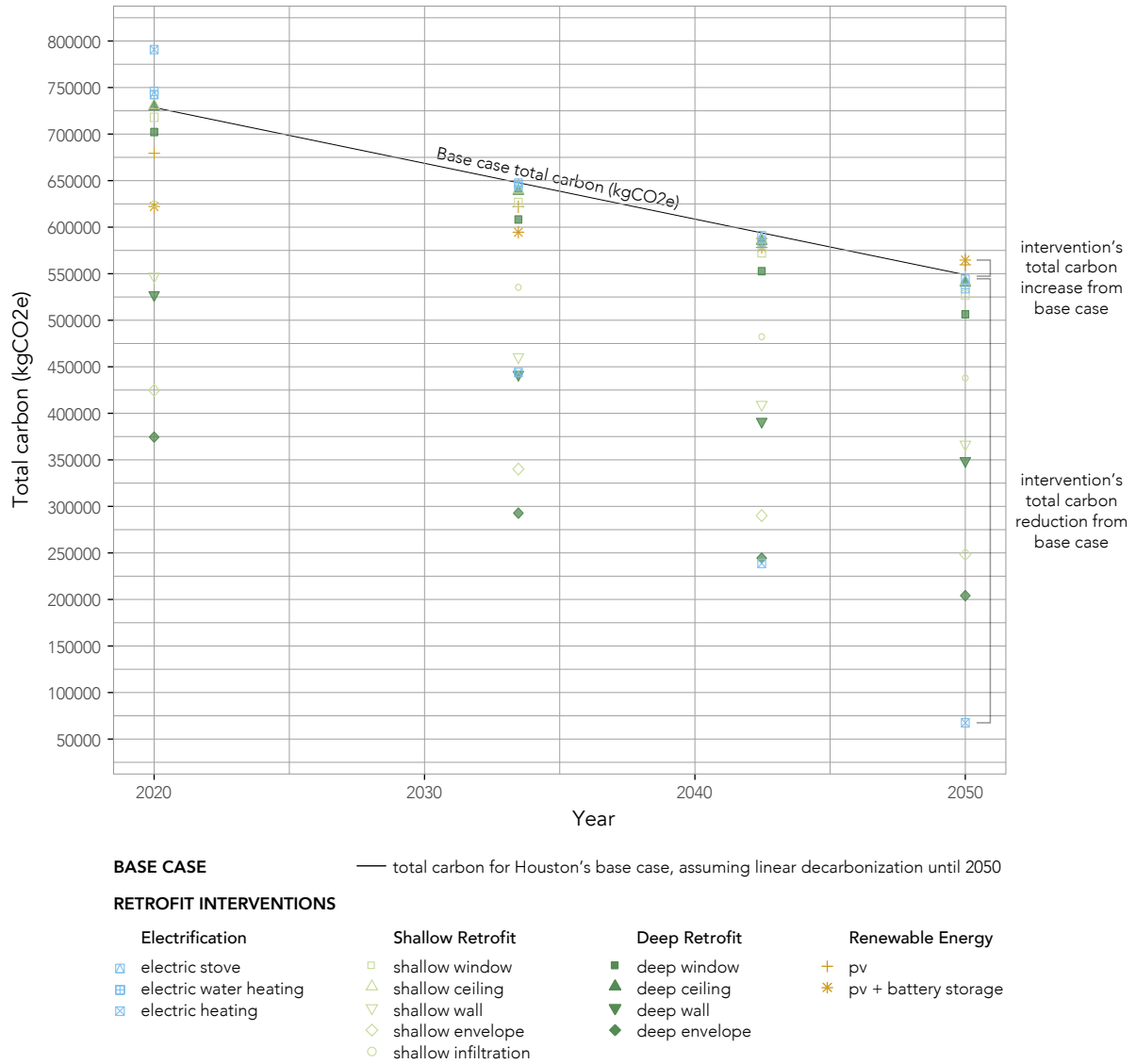


Figure A5. Total carbon associated with Chicago retrofit interventions, assuming linear decarbonization.

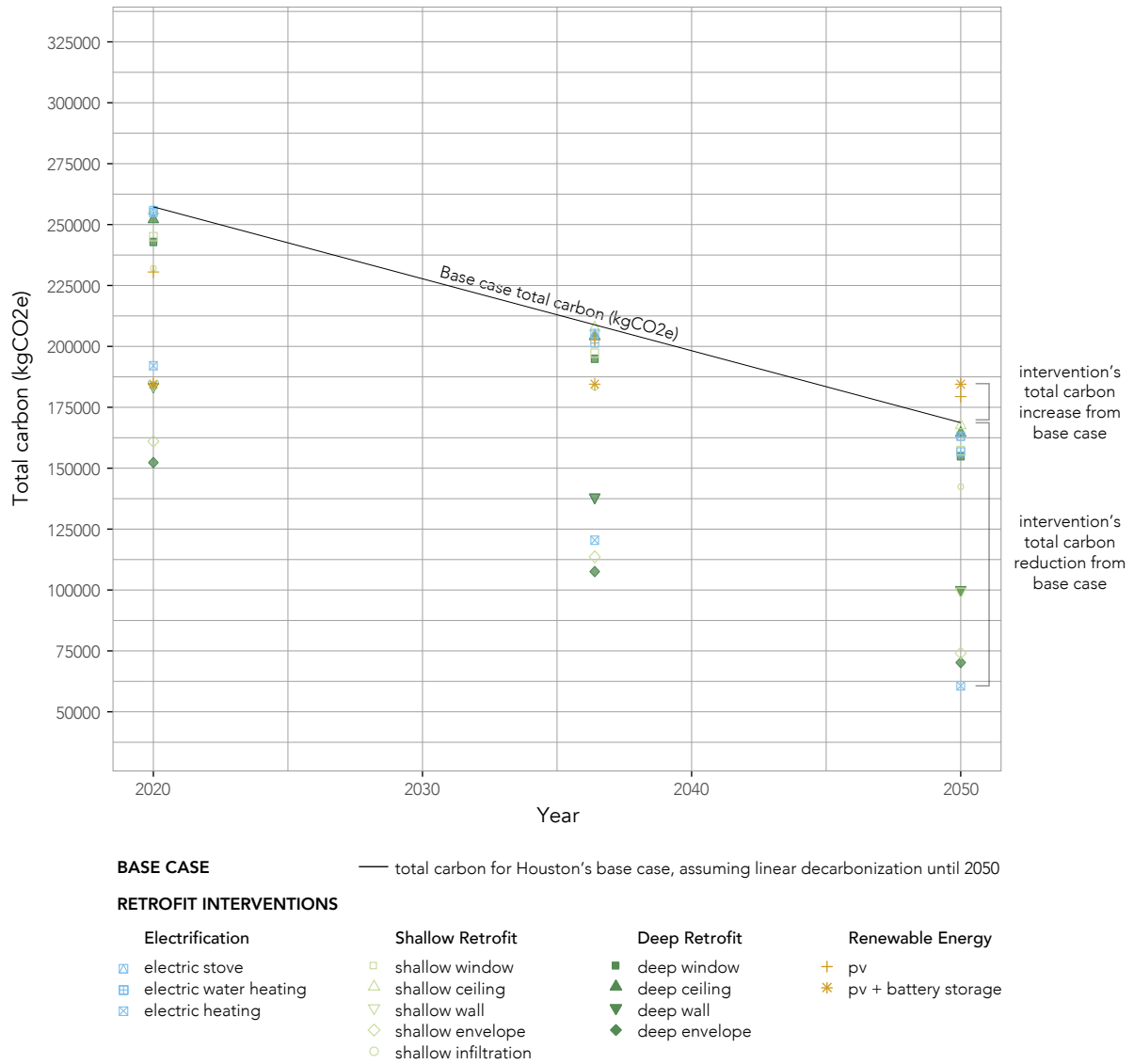


Figure A6. Total carbon associated with Los Angeles retrofit interventions, assuming linear decarbonization.

Appendix B

Energy modeling assumptions.

eqpt	area_m2	fuel	W	W/m2	frac_latent	frac_rad	frac_lost
dishwasher1	220.8	elec	65.699	0.298	0.150	0.600	0.250
dishwasher1							
dishwasher1							
dishwasher power (W)							
refrigerator1	220.8	elec	91.058	0.412	0.000	1.000	0.000
refrigerator power (W)							
clotheswasher1	220.8	elec	28.478	0.129	0.000	0.800	0.200
clotheswasher1							
clotheswasher1							
clotheswasher power (W)							
gas_dryer1	220.8	elec	19.418	0.088	0.000	1.000	0.000
gas_dryer1							
gas_dryer1							
gas dryer power (W)							
gas_mels1	220.8	elec	507.150	2.297	0.060	0.690	0.250
gas_mels power (W)							
IECC_Adj1	220.8	elec	505.359	2.289	0.062	0.412	0.251
IECC power (W)							
total			1217.162	5.513	0.034	0.813	0.119
adjusted schedule							
gas_dryer1	220.8	gas	395.596	1.792	0.050	0.100	0.850
gas_dryer1							
gas_dryer1							
gas dryer power (W)							
gas_mels1	220.8	gas	61.125	0.277	0.060	0.690	0.250
gas_mels power (W)							
total			456.721	2.068	0.055	0.395	0.550
adjusted schedule							
gas_range1	220.8	gas	540.941	2.450	0.060	0.690	0.250
gas range power (W)			540.941	2.450	0.060	0.690	0.250

Figure B1. Gas equipment assumptions used to translate EP prototype model to Design Builder model.

Above are the equipment assumptions taken from the prototype building for the base case with predominantly gas-fueled equipment. The equipment in blue text represents electric equipment, the equipment in red text represents gas equipment, and the equipment in yellow was separated because electrification of the stove was a specific retrofit intervention and we wanted to be able to analyze the energy consumption from that individual piece of equipment. Power was summed among all equipment in each category. The fraction of radiant, latent, and lost heat were averaged among all equipment within the category.

eqpt	sched_name	sched_days	sched_1	sched_2	sched_3	sched_4	sched_5	sched_6	sched_7	sched_8	sched_9	sched_10	sched_11	sched_12	sched_13	sched_14	sched_15	sched_16	sched_17	sched_18	sched_19	sched_20	sched_21	sched_22	sched_23	sched_24		
dishwasher1	DishWasher	weekday	0.129	0.057	0.043	0.029	0.029	0.086	0.172	0.259	0.488	0.546	0.474	0.402	0.345	0.388	0.316	0.301	0.316	0.416	0.732	0.933	0.761	0.560	0.373	0.258		
dishwasher1	DishWasher	weekend	0.138	0.061	0.046	0.031	0.029	0.092	0.185	0.277	0.523	0.585	0.508	0.431	0.369	0.415	0.338	0.323	0.338	0.446	0.785	1.000	0.815	0.600	0.400	0.277		
dishwasher1	DishWasher	average	0.132	0.059	0.044	0.029	0.029	0.088	0.176	0.264	0.498	0.557	0.483	0.410	0.352	0.396	0.322	0.308	0.323	0.425	0.747	0.952	0.777	0.571	0.381	0.264		
dishwasher power (W)			8.659	3.847	2.883	1.924	1.924	5.771	11.547	17.324	32.729	36.572	31.765	26.953	23.100	25.988	21.176	20.212	21.176	27.912	49.094	62.570	51.017	37.641	25.024	17.324		
refrigerator	Refrigerator	all days	0.800	0.883	0.766	0.743	0.731	0.731	0.760	0.800	0.817	0.829	0.800	0.800	0.840	0.840	0.829	0.840	0.829	0.886	0.971	1.000	0.971	0.942	0.8571	0.926	0.866	
refrigerator power (W)			72.846	71.270	67.713	67.643	66.598	66.598	69.200	72.846	74.403	75.448	72.846	72.846	76.474	76.474	75.448	76.474	75.448	80.651	88.456	91.058	88.456	85.854	84.279	80.651	75.448	
dishwasher1	ClothesDyler	weekday	0.089	0.071	0.053	0.033	0.071	0.107	0.213	0.462	0.953	0.917	0.800	0.711	0.640	0.569	0.497	0.462	0.460	0.460	0.462	0.462	0.462	0.462	0.444	0.302	0.100	
dishwasher1	ClothesDyler	weekend	0.100	0.087	0.043	0.043	0.087	0.130	0.261	0.565	0.848	1.000	0.978	0.870	0.783	0.696	0.599	0.565	0.565	0.565	0.565	0.565	0.565	0.565	0.543	0.370	0.156	
dishwasher1	ClothesDyler	average	0.094	0.076	0.058	0.058	0.076	0.113	0.227	0.491	0.927	0.900	0.851	0.796	0.680	0.605	0.529	0.491	0.491	0.510	0.491	0.491	0.491	0.491	0.473	0.321	0.170	
dishwasher power (W)			2.690	2.152	1.074	1.074	2.152	3.229	6.457	13.995	20.994	24.764	24.225	21.552	19.378	17.226	15.072	13.995	13.995	14.833	13.995	13.995	13.995	13.995	13.456	9.150	4.844	
gas_dryer1	ClothesDyler	weekday	0.100	0.060	0.040	0.020	0.040	0.060	0.120	0.240	0.480	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660		
gas_dryer1	ClothesDyler	weekend	0.122	0.073	0.049	0.024	0.049	0.073	0.146	0.292	0.584	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856		
gas_dryer1	ClothesDyler	average	0.106	0.064	0.042	0.021	0.042	0.064	0.123	0.239	0.469	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658		
gas_dryer power (W)			2.059	1.236	0.824	0.412	0.824	1.236	3.295	6.899	10.448	14.167	16.226	16.885	15.402	14.003	12.603	11.943	11.943	11.284	10.708	10.543	10.543	10.543	10.872	11.284	9.060	4.942
gas_mels1	MiscPlugLoad	all days	0.607	0.559	0.553	0.545	0.524	0.545	0.585	0.676	0.719	0.607	0.517	0.529	0.520	0.538	0.569	0.600	0.600	0.710	0.863	0.937	0.967	1.000	0.977	0.845	0.734	
gas_mels power (W)			308.089	283.668	280.380	276.433	265.991	296.824	342.951	364.411	308.089	262.208	268.375	268.457	263.935	273.062	288.437	304.471	304.471	360.136	437.507	475.001	490.294	507.150	495.310	428.627	372.469	
IECC_Adjt	MiscPlugLoad	all days	0.607	0.559	0.553	0.545	0.524	0.585	0.676	0.719	0.607	0.517	0.529	0.529	0.520	0.538	0.569	0.600	0.600	0.710	0.863	0.937	0.967	1.000	0.977	0.845	0.734	
IECC power (W)			307.001	282.667	279.389	276.457	265.051	295.776	341.740	363.124	307.001	261.282	267.427	267.509	263.003	272.097	287.419	303.396	303.396	358.864	435.962	473.323	488.563	505.359	493.561	427.113	371.154	
total			701.343	644.840	634.262	622.942	602.539	669.433	775.190	838.289	753.264	674.441	680.864	674.183	661.292	678.850	700.155	730.900	730.900	846.892	1015.116	1113.178	1154.421	1174.247	1135.430	979.626	846.180	
adjusted schedule			0.58	0.53	0.52	0.51	0.50	0.55	0.64	0.69	0.62	0.55	0.56	0.55	0.54	0.56	0.58	0.60	0.70	0.83	0.91	0.95	0.96	0.93	0.80	0.70		
gas_dryer1	ClothesDyler	weekday	0.100	0.060	0.040	0.020	0.040	0.060	0.120	0.240	0.480	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660	0.660		
gas_dryer1	ClothesDyler	weekend	0.122	0.073	0.049	0.024	0.049	0.073	0.146	0.292	0.584	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856		
gas_dryer1	ClothesDyler	average	0.106	0.064	0.042	0.021	0.042	0.064	0.123	0.239	0.469	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658		
gas_dryer power (W)			2.059	1.236	0.824	0.412	0.824	1.236	3.295	6.899	10.448	14.167	16.226	16.885	15.402	14.003	12.603	11.943	11.943	11.284	10.708	10.543	10.543	10.543	10.872	11.284	9.060	
gas_mels1	MiscPlugLoad	all days	0.607	0.559	0.553	0.545	0.524	0.545	0.585	0.676	0.719	0.607	0.517	0.529	0.520	0.538	0.569	0.600	0.600	0.710	0.863	0.937	0.967	1.000	0.977	0.845		
gas_mels power (W)			308.089	283.668	280.380	276.433	265.991	296.824	342.951	364.411	308.089	262.208	268.375	268.457	263.935	273.062	288.437	304.471	304.471	360.136	437.507	475.001	490.294	507.150	495.310	428.627	372.469	
total			701.343	644.840	634.262	622.942	602.539	669.433	775.190	838.289	753.264	674.441	680.864	674.183	661.292	678.850	700.155	730.900	730.900	846.892	1015.116	1113.178	1154.421	1174.247	1135.430	979.626	846.180	
adjusted schedule			0.58	0.53	0.52	0.51	0.50	0.55	0.64	0.69	0.62	0.55	0.56	0.55	0.54	0.56	0.58	0.60	0.70	0.83	0.91	0.95	0.96	0.93	0.80	0.70		
gas_range power (W)			0.047	0.047	0.024	0.024	0.047	0.071	0.165	0.283	0.307	0.321	0.283	0.330	0.377	0.307	0.292	0.377	0.377	0.613	1.000	0.778	0.401	0.236	0.165	0.104		
gas_range power (W)			0.05	0.05	0.02	0.02	0.05	0.07	0.17	0.28	0.31	0.32	0.28	0.33	0.38	0.31	0.29	0.38	0.38	0.61	1.00	0.78	0.40	0.24	0.17	0.10		

Figure B2. Gas equipment schedule assumptions used to translate EP prototype model to Design Builder model.

Above are the schedule assumptions taken from the prototype building for the base case with predominantly gas-fueled equipment. The values for each hour were averaged among all equipment within each category.

eqpt	area_m2	fuel	W	W/m2	frac_latent	frac_rad	frac_lost
dishwasher1	220.8	elec	65.699	0.298	0.150	0.600	0.250
dishwasher1							
dishwasher1							
dishwasher power (W)							
refrigerator1	220.8	elec	91.058	0.412	0.000	1.000	0.000
refrigerator power (W)							
clotheswasher1	220.8	elec	28.478	0.129	0.000	0.800	0.200
clotheswasher1							
clotheswasher1							
clotheswasher power (W)							
gas_dryer1	220.8	elec	19.418	0.088	0.000	1.000	0.000
gas_dryer1							
gas_dryer1							
gas dryer power (W)							
gas_mels1	220.8	elec	507.150	2.297	0.060	0.690	0.250
gas_mels power (W)							
IECC_Adj1	220.8	elec	505.359	2.289	0.062	0.412	0.251
IECC power (W)							
total			1217.162	5.513	0.034	0.813	0.119
adjusted schedule							
gas_dryer1	220.8	gas	395.596	1.792	0.050	0.100	0.850
gas_dryer1							
gas_dryer1							
gas dryer power (W)							
gas_mels1	220.8	gas	61.125	0.277	0.060	0.690	0.250
gas_mels power (W)							
total			456.721	2.068	0.055	0.395	0.550
adjusted schedule							
gas_range1	220.8	electric	248.154	1.124	0.300	0.400	0.300
gas range power (W)			248.154	1.124	0.300	0.400	0.300

Figure B3. Electric equipment assumptions used to translate EP prototype model to Design Builder model. Below are the equipment assumptions taken from the prototype building for the base case with predominantly electric equipment. The equipment in blue text represents electric equipment, the equipment in red text represents gas equipment, and the cooking equipment, also in blue, was separated because electrification of the stove was a specific retrofit intervention and we wanted to be able to analyze the energy consumption from that individual piece of equipment. Power was summed among all equipment in each category. The fraction of radiant, latent, and lost heat were averaged among all equipment within the category.

eqpt	sched_name	sched_days	sched_1	sched_2	sched_3	sched_4	sched_5	sched_6	sched_7	sched_8	sched_9	sched_10	sched_11	sched_12	sched_13	sched_14	sched_15	sched_16	sched_17	sched_18	sched_19	sched_20	sched_21	sched_22	sched_23	sched_24	
dishwasher1	DishWasher	weekday	0.129	0.057	0.043	0.029	0.029	0.086	0.172	0.259	0.488	0.546	0.474	0.402	0.345	0.388	0.316	0.301	0.316	0.416	0.732	0.933	0.761	0.560	0.373	0.258	
dishwasher1	DishWasher	weekend	0.138	0.061	0.046	0.031	0.021	0.092	0.185	0.277	0.523	0.585	0.508	0.431	0.369	0.415	0.338	0.323	0.338	0.338	0.446	0.785	1.000	0.615	0.400	0.277	
dishwasher1	DishWasher	average	0.132	0.059	0.044	0.029	0.029	0.088	0.176	0.264	0.498	0.557	0.483	0.410	0.352	0.396	0.322	0.308	0.322	0.378	0.747	0.952	0.777	0.571	0.381	0.264	
refrigerator	Refrigerator	all days	8.659	3.847	2.883	1.924	1.924	5.771	11.547	17.324	32.729	36.572	31.765	26.953	23.100	25.988	21.176	20.212	21.176	27.912	49.094	62.570	51.017	37.641	25.024	17.324	
refrigerator power (W)		all days	0.800	0.383	0.286	0.243	0.231	0.731	1.231	1.760	3.400	3.829	3.299	2.760	2.360	2.640	2.176	2.040	2.176	2.912	4.904	6.257	5.017	3.641	2.502	1.732	
icec	IceC	all days	307.001	282.657	279.389	276.457	265.051	295.776	341.740	363.124	307.001	261.282	267.427	267.509	263.003	272.097	287.419	303.396	358.864	435.962	473.323	488.563	505.359	493.561	427.113	371.154	
icec power (W)		all days	0.607	0.559	0.553	0.545	0.524	0.585	0.676	0.719	0.607	0.517	0.529	0.529	0.520	0.538	0.569	0.600	0.710	0.863	0.937	0.967	1.000	0.977	0.845	0.734	
total			701.343	644.840	634.262	622.942	602.539	669.433	775.190	838.289	753.264	674.441	680.864	674.183	661.292	678.850	700.155	730.900	846.892	1015.116	1113.178	1154.421	1174.247	1135.430	979.626	846.180	
adjusted schedule			0.58	0.53	0.52	0.51	0.50	0.55	0.64	0.69	0.62	0.55	0.56	0.55	0.54	0.56	0.58	0.60	0.70	0.83	0.91	0.95	0.96	0.93	0.80	0.70	
gas_dryer1	ClothesDryer	weekday	0.100	0.060	0.040	0.020	0.040	0.060	0.100	0.159	0.319	0.466	0.585	0.785	0.817	0.746	0.678	0.610	0.578	0.558	0.546	0.518	0.510	0.526	0.546	0.539	0.239
gas_dryer1	ClothesDryer	weekend	0.122	0.073	0.049	0.024	0.049	0.073	0.122	0.195	0.390	0.595	0.839	0.961	1.000	0.912	0.825	0.746	0.707	0.683	0.668	0.634	0.624	0.644	0.668	0.637	0.293
gas_dryer1	ClothesDryer	average	0.106	0.064	0.042	0.021	0.042	0.064	0.106	0.170	0.339	0.517	0.730	0.836	0.870	0.793	0.721	0.649	0.615	0.594	0.581	0.551	0.543	0.560	0.581	0.467	0.255
gas_mels1	MiscPlugLoad	all days	308.089	283.668	280.380	276.433	265.991	296.824	342.951	364.411	308.089	262.208	268.375	268.457	263.935	273.062	288.437	304.471	360.136	437.507	475.001	490.294	507.150	495.310	428.627	372.469	
iecc	IECC	all days	307.001	282.657	279.389	276.457	265.051	295.776	341.740	363.124	307.001	261.282	267.427	267.509	263.003	272.097	287.419	303.396	358.864	435.962	473.323	488.563	505.359	493.561	427.113	371.154	
total			701.343	644.840	634.262	622.942	602.539	669.433	775.190	838.289	753.264	674.441	680.864	674.183	661.292	678.850	700.155	730.900	846.892	1015.116	1113.178	1154.421	1174.247	1135.430	979.626	846.180	
adjusted schedule			0.58	0.53	0.52	0.51	0.50	0.55	0.64	0.69	0.62	0.55	0.56	0.55	0.54	0.56	0.58	0.60	0.70	0.83	0.91	0.95	0.96	0.93	0.80	0.70	
gas_dryer1	ClothesDryer	weekday	0.100	0.060	0.040	0.020	0.040	0.060	0.100	0.159	0.319	0.466	0.585	0.785	0.817	0.746	0.678	0.610	0.578	0.558	0.546	0.518	0.510	0.526	0.546	0.539	0.239
gas_dryer1	ClothesDryer	weekend	0.122	0.073	0.049	0.024	0.049	0.073	0.122	0.195	0.390	0.595	0.839	0.961	1.000	0.912	0.825	0.746	0.707	0.683	0.668	0.634	0.624	0.644	0.668	0.637	0.293
gas_dryer1	ClothesDryer	average	0.106	0.064	0.042	0.021	0.042	0.064	0.106	0.170	0.339	0.517	0.730	0.836	0.870	0.793	0.721	0.649	0.615	0.594	0.581	0.551	0.543	0.560	0.581	0.467	0.255
gas_mels1	MiscPlugLoad	all days	308.089	283.668	280.380	276.433	265.991	296.824	342.951	364.411	308.089	262.208	268.375	268.457	263.935	273.062	288.437	304.471	360.136	437.507	475.001	490.294	507.150	495.310	428.627	372.469	
iecc	IECC	all days	307.001	282.657	279.389	276.457	265.051	295.776	341.740	363.124	307.001	261.282	267.427	267.509	263.003	272.097	287.419	303.396	358.864	435.962	473.323	488.563	505.359	493.561	427.113	371.154	
total			701.343	644.840	634.262	622.942	602.539	669.433	775.190	838.289	753.264	674.441	680.864	674.183	661.292	678.850	700.155	730.900	846.892	1015.116	1113.178	1154.421	1174.247	1135.430	979.626	846.180	
adjusted schedule			0.17	0.13	0.11	0.09	0.11	0.13	0.24	0.39	0.53	0.70	0.79	0.82	0.76	0.70	0.64	0.61	0.61	0.62	0.60	0.60	0.62	0.63	0.52	0.32	
gas_range1	CookingRange	all days	0.047	0.047	0.024	0.024	0.047	0.071	0.165	0.283	0.307	0.321	0.283	0.283	0.330	0.377	0.307	0.292	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	
gas_range power (W)		all days	0.05	0.05	0.02	0.02	0.05	0.07	0.17	0.28	0.31	0.32	0.28	0.28	0.33	0.38	0.31	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	

Figure B4. Electric equipment schedule assumptions used to translate EP prototype model to Design Builder model.

Above are the schedule assumptions taken from the prototype building for the base case with predominantly electric equipment. The values for each hour were averaged among all equipment within each category.

Release date: May 2018

Table CE4.1 Annual household site end-use consumption by fuel in the U.S.—totals, 2015

Number of housing unit Total site energy consumption ¹																				
	Electricity (billion kWh)								Natural gas (billion cubic feet)				Propane (million gallons)				Fuel oil/kerosene (million gallons)			
	Total U.S.2	Total	Space heat	Water heat	Air condi-ti	Refrig-erati	Other4	Total	Space heat	Water heat	Other4	Total	Space heat	Water heat	Other4	Total	Space heat	Water heat	Other	
All homes	118.2	1,267	187	173	214		89	604	3,963	2,678	1,019	266	3,952	2,549	835	567	3,381	2,891	432	57
Census region and division																				
Northeast	21	172	20	21	18	14	99	895	628	206	61	869	572	175	122	2,874	2,451	390	Q	Q
New England	5.6	42	3	6	3	4	27	158	106	42	10	365	239	79	47	1,519	1,322	175	Q	Q
Middle Atlantic	15.4	130	17	15	15	11	72	737	522	164	51	504	333	96	75	1,356	1,129	215	Q	Q
Midwest	26.4	252	39	30	28	20	135	1,508	1,157	297	54	1,166	887	206	73	Q	Q	Q	N	Q
East North Central	18.1	165	25	20	18	14	89	1,115	857	212	45	695	509	Q	53	Q	Q	N	Q	Q
West North Central	8.3	87	14	10	10	6	46	394	300	85	9	471	378	74	20	Q	Q	N	N	N
South	44.4	618	98	95	140	34	250	772	486	209	77	1,321	828	235	258	371	330	Q	Q	N
South Atlantic	23.5	316	47	52	70	18	129	385	248	102	35	740	448	118	Q	355	314	Q	Q	Q
East South Central	7.2	105	21	19	18	5	41	117	76	27	14	223	166	37	19	Q	Q	N	N	N
West South Central	13.8	197	29	24	53	11	80	270	162	81	28	358	214	80	64	Q	Q	N	N	N
West	26.4	225	30	27	28	20	120	787	407	307	73	595	262	218	115	74	51	Q	Q	Q
Mountain	8.5	80	8	7	15	7	43	375	241	116	18	278	124	100	Q	N	N	N	N	N
Mountain North	4.2	36	4	3	3	3	22	253	170	75	8	123	Q	Q	Q	N	N	N	N	N
Mountain South	4.3	45	4	4	12	3	21	122	71	41	10	155	Q	79	29	N	N	N	N	N
Pacific	17.9	145	22	20	13	14	76	413	167	191	55	317	138	118	61	74	51	Q	Q	Q
Census urban/rural classification																				
Urban	94.7	935	117	116	172	69	461	3,578	2,396	939	242	983	566	222	196	2,296	1,965	300	Q	Q
Urbanized area	82.2	804	95	97	153	60	399	3,151	2,093	837	221	783	423	184	176	1,925	1,634	260	Q	Q
Urban cluster	12.5	131	21	20	19	9	62	427	304	102	22	200	143	38	19	371	331	Q	N	Q
Rural	23.5	332	70	57	42	20	143	385	282	80	23	2,968	1,984	613	372	1,085	926	132	Q	Q
Metropolitan or micropolitan statistical area																				
In metropolitan statistica	98.5	1,019	134	129	182	74	500	3,503	2,340	919	244	2,700	1,664	644	392	2,494	2,116	330	48	Q
In micropolitan statistica	12.3	155	35	27	18	9	65	319	235	67	17	552	383	86	82	380	345	Q	Q	Q
Not in metropolitan or n	7.4	93	18	17	14	5	39	141	103	33	5	700	502	105	93	Q	Q	Q	71	Q
Climate region⁶																				
Very cold/Cold	42.5	379	53	46	32	31	216	2,253	1,668	481	105	1,919	1,307	437	175	2,200	1,949	215	Q	Q
Mixed-humid	33.5	412	79	63	64	25	181	986	684	236	65	1,490	1,005	209	277	1,156	922	217	Q	Q
Mixed-dry/Hot-dry	12.7	97	6	7	22	10	53	319	117	154	48	162	49	84	29	Q	Q	N	N	N
Hot-humid	22.8	315	36	44	95	18	122	262	138	88	36	221	99	64	58	Q	Q	N	N	N
Marine	6.7	64	13	12	2	5	32	143	71	60	12	Q	Q	Q	29	Q	Q	Q	N	Q
Housing unit type																				
Single-family detached	73.9	931	133	107	172	65	455	3,117	2,197	727	193	3,439	2,303	645	491	2,841	2,513	276	52	Q
Single-family attached	7	60	8	8	10	5	29	270	186	64	20	48	Q	Q	Q	Q	Q	Q	Q	N
Apartments in buildings	9.4	63	10	11	7	5	30	252	137	90	26	83	Q	Q	Q	Q	172	129	Q	N
Apartments in buildings	21.1	128	18	27	15	10	58	249	105	122	22	63	Q	Q	Q	223	113	110	N	Q
Mobile homes	6.8	85	17	20	11	4	33	75	53	17	5	319	165	95	59	84	76	Q	Q	Q
Year of construction																				
Before 1950	20.8	183	27	22	27	13	94	995	726	219	50	670	506	111	53	1,071	927	138	Q	Q
1950 to 1959	12.6	117	16	13	22	9	57	545	387	126	33	264	171	65	28	675	594	74	Q	Q
1960 to 1969	12.8	122	17	14	24	9	58	444	302	115	27	368	247	83	Q	461	396	43	Q	Q
1970 to 1979	18.3	197	37	29	32	13	86	516	341	142	34	441	322	76	44	451	397	45	Q	Q
1980 to 1989	16	176	25	26	30	12	83	364	222	112	30	422	230	90	103	376	303	59	Q	Q
1990 to 1999	16.8	209	29	30	35	14	100	524	347	144	33	695	437	178	80	171	148	Q	N	Q
2000 to 2009	17	218	30	31	37	15	105	487	296	139	52	905	516	186	202	164	123	40	Q	Q
2010 to 2015	3.8	45	6	8	7	3	21	88	57	23	7	186	119	47	20	Q	Q	Q	Q	N
Total square footage⁸																				
Fewer than 1,000	26.6	176	29	35	21	13	78	404	201	169	34	279	109	120	50	284	175	98	Q	Q
1,000 to 1,499	26.1	262	42	47	41	17	114	573	340	183	49	422	261	105	56	258	187	68	Q	Q
1,500 to 1,999	17.5	205	33	29	40	14	90	556	370	144	42	496	368	82	45	417	382	27	Q	Q
2,000 to 2,499	14.1	164	22	20	30	12	80	584	410	136	38	764	545	137	82	400	343	47	Q	Q
2,500 to 2,999	10.8	133	19	13	24	10	68	538	397	116	25	403	270	82	51	620	544	67	Q	Q
3,000 or greater	23.1	328	42	30	59	23	174	1,308	959	271	78	1,588	997	308	283	1,402	1,260	126	Q	Q
Number of household members																				
1 member	28.7	211	39	21	37	18	96	747	578	126	43	537	388	94	54	548	501	40	Q	Q
2 members	42.7	457	72	55	81	33	215	1,341	962	294	86	1,758	1,153	322	283	1,242	1,076	156	Q	Q
3 members	19.4	221	29	33	37	15	107	728	471	206	51	695	448	145	102	699	578	103	Q	Q
4 members	15.5	207	25	32	34	13	104	634	372	214	48	558	316	157	86	558	461	96	Q	Q
5 members	7.2	105	14	20	16	6	48	296	178	96	21	273	169	80	24	146	118	Q	Q	Q
6 or more members	4.6	67	7	13	9	4	34	217	116	83	18	131	75	Q	20	188	157	Q	N	N
Main heating fuel																				
Natural gas	57.7	514	21	29	103	46	314	3,758	2,663	892	203	29	Q	Q	Q	23	13	Q	Q	Q
Electricity	40.9	557	155	109	81	29	184	132	9	74	48	620	181	157	282	Q	10	Q	Q	Q
Fuel oil/kerosene	5.8	51	3	9	6	4	30	16	Q	9	6	127	42	Q	56	3,223	2,807	381	Q	Q
Propane	5	60	4	9	8	4	35	Q	N	Q	Q	2,833	2,249	468	116	Q	N	Q	N	N

1Consumption and expenditures for biomass (wood), coal, district steam, and solar thermal are excluded. Electricity consumption from on-site solar photovoltaic generation (i.e., solar panels) is included.
2Total U.S. includes all primary occupied housing units in the 50 states and District of Columbia. Vacant housing units, seasonal units, second homes, military houses, and group quarters are excluded.
3Includes main (primary) and secondary space heating.
4Includes end uses not in this table. A more detailed breakout of end uses is shown in the Series 5 tables.
5Housing units are classified using criteria created by the U.S. Census Bureau based on 2010 Census data. Urbanized areas are densely settled groupings of blocks or tracts with 50,000 or more people. Urban clusters have at least 2,500 but less than 50,000 people. All other areas
6These climate regions were created by the Building America program, sponsored by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE).
7Rented includes households that occupy their primary housing units without paying rent.
8Total square footage includes all basements, finished or conditioned (heated or cooled) areas of attics, and conditioned garage space that is attached to the home. Unconditioned and unfinished areas in attics and attached garages are excluded. The square footage for some households was withheld because either the Relative Standard Error (RSE) was greater than 50% or fewer than 10 cases responded.
9 = No cases responded.
(*) Number rounds to zero.
Notes: Because of rounding, data may not sum to totals. See RECS Terminology for definition of terms used in these tables.
Source: U.S. Energy Information Administration, Office of Energy Consumption and Efficiency Statistics, Forms EIA-457A, C, D, E, F, G of the 2015 Residential Energy Consumption Survey.

Figure B5. Benchmarking based on 2015 RECS data
Highlighted cells indicate building characteristics in our study scope.

CHICAGO_5A_2006														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_6	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406		4.000		0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consol_layer	2006	Rough	0.340	13.401	0.062	0.181	0.032	5.515	31.316			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.353	13.901		0.179	0.031	5.595	31.766				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consol_layer	2006	Rough	0.140	5.500	0.058	0.415	0.073	2.410	13.686			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.179	7.058		0.363	0.064	2.756	15.646				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	2006			0.000		1.988	0.350	0.503	2.857	0.334	0.880		
Exterior Door	door_const	2006	Smooth	0.036	1.426	0.072	1.988	0.350	0.503	2.857			512.640	767.580

Figure B6. Chicago 2006 calibration model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

CHICAGO_5A_1980														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_6	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406		4.000		0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consol_layer	1980	Rough	0.212	8.366	0.062	0.290	0.051	3.443	19.550			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.225	8.866		0.284	0.050	3.522	20.000				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consol_layer	1980	Rough	0.065	2.548	0.058	0.896	0.158	1.117	6.340			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.104	4.105		0.684	0.120	1.462	8.300				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	1980					3.688	0.650			0.334	0.880		
Exterior Door	door_const	2006	Smooth	0.036	1.426	0.072	1.988	0.350	0.503	2.857			512.640	767.580

Figure B7. Chicago 1980 base case model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

CHICAGO_5A_RENO_LOW														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRou	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406		4.000		0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consol_layer	2022L	Rough	0.407	16.026	0.062	0.152	0.027	6.596	37.450			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.420	16.526		0.150	0.026	6.675	37.900				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consol_layer	2022L	Rough	0.145	5.723	0.058	0.399	0.070	2.508	14.240			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.185	7.280		0.350	0.062	2.853	16.200				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	2022L					1.702	0.300			0.550			
Exterior Door	door_const	2006	Smooth	0.036	1.426	0.072	1.988	0.350	0.503	2.857			512.640	767.580

Figure B8. Chicago shallow envelope model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

CHICAGO_5A_RENO_HI														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRou	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406		4.000		0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consol_layer	2022H	Rough	0.767	30.191	0.062	0.080	0.014	12.425	70.550			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.780	30.691		0.080	0.014	12.504	71.000				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consol_layer	2022H	Rough	0.388	15.287	0.058	0.149	0.026	6.700	38.040			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.428	16.844		0.142	0.025	7.045	40.000				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	2022H					0.851	0.150			0.550			
Exterior Door	door_const	2006	Smooth	0.036	1.426	0.072	1.988	0.350	0.503	2.857			512.640	767.580

Figure B9. Chicago deep envelope model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

HOUSTON_2A_2006														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406				0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consol_layer	2006	Rough	0.285	11.213	0.062	0.217	0.038	4.615	26.203			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.298	11.713		0.213	0.038	4.694	26.654				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consol_layer	2006	Rough	0.089	3.500	0.058	0.652	0.115	1.534	8.709			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.128	5.058		0.532	0.094	1.879	10.669				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	2006			0.000		4.259	0.751	0.235	1.333	0.334	0.880		
Exterior Door	door_const	2006	Smooth	0.017	0.666	0.072	4.259	0.751	0.235	1.333			512.640	767.580

Figure B10. Houston 2006 calibration model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

HOUSTON_2A_1980														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406				0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consol_layer	1980	Rough	0.212	8.366	0.062	0.290	0.051	3.443	19.550			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.225	8.866		0.284	0.050	3.522	20.000				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consol_layer	1980	Rough	0.002	0.096	0.058	23.662	4.167	0.042	0.240			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.042	1.654		2.581	0.751	0.387	2.200				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	1980					6.412	1.130	0.156	0.886	0.334	0.880		
Exterior Door	door_const	2006	Smooth	0.017	0.666	0.072	4.259	0.751	0.235	1.333			512.640	767.580

Figure B11. Houston 1980 base case model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

HOUSTON_2A_RENO_LOW														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406		4.000		0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consolo_layer	2022L	Rough		0.242	9.521	0.062	0.255	0.045	3.919	22.250		41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.255	10.021		0.250	0.044	3.998	22.700				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consolo_layer	2022L	Rough		0.109	4.276	0.058	0.534	0.094	1.874	10.640		120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.148	5.833		0.451	0.079	2.219	12.600				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	2022L					2.270	0.400	0.441	2.502	0.250			
Exterior Door	door_const	2006	Smooth	0.017	0.666	0.072	4.259	0.751	0.235	1.333			512.640	767.580

Figure B12. Houston shallow envelope model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

HOUSTON_2A_RENO_HIGH														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406		4.000		0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consolo_layer	2022H	Rough		0.582	22.916	0.062	0.106	0.019	9.431	53.550		41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.595	23.416		0.105	0.019	9.510	54.000				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consolo_layer	2022H	Rough		0.235	9.259	0.058	0.246	0.043	4.058	23.040		120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.275	10.816		0.227	0.040	4.403	25.000				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	2022H					1.050	0.185	0.953	5.409	0.250			
Exterior Door	door_const	2006	Smooth	0.017	0.666	0.072	4.259	0.751	0.235	1.333			512.640	767.580

Figure B13. Houston deep envelope model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

LA_3B_2006														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406				0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consol_layer	2006	Rough	0.285	11.213	0.062	0.217	0.038	4.615	26.203			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.298	11.713		0.213	0.038	4.694	26.654				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consol_layer	2006	Rough	0.089	3.500	0.058	0.652	0.115	1.534	8.709			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.128	5.058		0.532	0.094	1.879	10.669				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	2006			0.000		3.691	0.650	0.271	1.538	0.334	0.880		
Exterior Door	door_const	2006	Smooth	0.020	0.768	0.072	3.691	0.650	0.271	1.538			512.640	767.580

Figure B14. Los Angeles 2006 calibration model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

LA_3B_1980														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406				0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consol_layer	1980	Rough	0.212	8.366	0.062	0.290	0.051	3.443	19.550			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.225	8.866		0.284	0.050	3.522	20.000				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consol_layer	1980	Rough	0.002	0.096	0.058	23.662	4.167	0.042	0.240			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.042	1.654		2.581	0.455	0.387	2.200				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	1980			0.000		6.412	1.130	0.156	0.886	0.334	0.880		
Exterior Door	door_const	2006	Smooth	0.020	0.768	0.072	3.691	0.650	0.271	1.538			512.640	767.580

Figure B15. Los Angeles 1980 base case model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

LA_3B_RENO_LOW														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406		4.000		0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consolo_layer	2022L	Rough		8.366	0.062	0.290	0.051	3.443	19.550			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.225	8.866		0.284	0.050	3.522	20.000				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consolo_layer	2022L	Rough	0.058	2.267	0.058	1.007	0.177	0.993	5.640			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.097	3.824		0.747	0.132	1.338	7.600				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	2022L					1.702	0.300	0.587	3.335	0.250			
Exterior Door	door_const	2006	Smooth	0.020	0.768	0.072	3.691	0.650	0.271	1.538			512.640	767.580

Figure B16. Los Angeles shallow envelope model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

LA_3B_RENO_HIGH														
const	mtl	yr_doe	roughness	thick_m	thick_in	kSLW_p_mK	USLW_p_m2	J_Btu_p_hft	RSLm2K_p_1	R_hft2F_p_5	SHGC	VT	dens_kg_p_n	sphT_J_p_kg
Exterior Roof	Asphalt_shingle	2006	MediumRoug	0.006	0.250	0.082	12.912	2.275	0.077	0.440			1,121.292	1,255.200
Exterior Roof	OSB_1/2in	2006	MediumSmo	0.013	0.500	0.116	9.157	1.614	0.109	0.620			544.627	1,213.360
Exterior Roof total				0.019	0.750		5.358	0.944	0.187	1.060				
Gable_end	cement_stucco	2006	MediumSmo	0.019	0.750	0.721	37.848	6.670	0.026	0.150			1,865.580	878.640
Gable_end	Bldg_paper_felt	2006	Smooth		0.000				0.011	0.060				
Gable_end	OSB_5/8in	2006	MediumSmo	0.016	0.625	0.116	7.326	1.291	0.137	0.775			544.627	1,213.360
Gable_end	Air_4_in_vert	2006			0.406		4.000		0.158	0.900				
Gable_end	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Gable_end total				0.454	5.875		2.431	0.428	0.411	2.335				
Interior Ceiling	ceil_consolo_layer	2022H	Rough		23.772	0.062	0.102	0.018	9.783	55.550			41.929	776.251
Interior Ceiling	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Interior Ceiling total				0.617	24.272		0.101	0.018	9.863	56.000				
Exterior Wall	syn_stucco	2006	MediumSmo	0.003	0.120	0.087	28.379	5.001	0.035	0.200			400.000	878.640
Exterior Wall	sheathing_conso	2006	Rough	0.013	0.500	0.094	7.403	1.305	0.135	0.767			685.008	1,172.332
Exterior Wall	OSB_7/16in	2006	MediumSmo	0.011	0.438	0.116	10.466	1.844	0.096	0.543			544.627	1,213.360
Exterior Wall	wall_consolo_layer	2022H	Rough	0.245	9.661	0.058	0.236	0.042	4.234	24.040			120.801	1,036.258
Exterior Wall	Drywall_1/2in	2006	MediumSmo	0.013	0.500	0.160	12.605	2.221	0.079	0.450			800.923	1,087.840
Exterior Wall total				0.285	11.218		0.218	0.038	4.579	26.000				
Interior Floor	Plywood_3/4in	2006	Rough	0.019	0.750	0.115	6.061	1.068	0.165	0.937			544.680	674.540
Interior Floor	Carpet_n_pad	2006	MediumSmo	0.025	1.000	0.060	2.367	0.417	0.422	2.398			32.037	836.800
Interior Floor total				0.044	1.750		1.702	0.300	0.587	3.335				
Exterior Window	Glass	2022H					1.250	0.220	0.800	4.542	0.250			
Exterior Door	door_const	2006	Smooth	0.020	0.768	0.072	3.691	0.650	0.271	1.538			512.640	767.580

Figure B17. Los Angeles deep envelope model assembly assumptions. Energy simulation parameters were based on the EP prototype models and modified per Table 2; fields with red text were modified from case to case.

	Site to Source Conversion Factor per EP9.5		
Electricity	3.167		
Natural Gas	1.084		
District Cooling	1.056		
District Heating	3.613		
Steam	1.2		
Gasoline	1.05		
Diesel	1.05		
Coal	1.05		
Fuel Oil No 1	1.05		
Fuel Oil No 2	1.05		
Propane	1.05		
Other Fuel 1	1		
Other Fuel 2	1		

Figure B18. Site to source conversion factors per EnergyPlus v9.5.

	area (m2)	exp_ann_kWh_p_m2	max_ann_kWh	pv_ann_prod	pv_ann_prod_75%cov	pv_eff
source	DOE Prototype m	Climate Studio	Climate Studio		0.75	0.197
houston						
E facing	58.757	1544.342	90740.90289	17875.95787	13406.9684	
N facing	58.757	1364.442	80170.51859	15793.59216	11845.19412	
S facing	58.757	1719.168	101013.1542	19899.59137	14924.69353	
W facing	58.757	1562.186	91789.3628	18082.50447	13561.87835	
NS roofs	117.514	3281.354	192802.517	37982.09584	28486.57188	
EW roofs	117.514	2908.784	170911.4215	33669.55003	25252.16252	
average	117.514	3095.069	181856.9692	35825.82294	26869.3672	
la						
E facing	58.757	1697.91	99764.09787	19653.52728	14740.14546	
N facing	58.757	1463.128	85969.0119	16935.89534	12701.92151	
S facing	58.757	1983.037	116517.305	22953.90909	17215.43182	
W facing	58.757	1772.626	104154.1859	20518.37462	15388.78096	
NS roofs	117.514	3446.165	202486.3169	39889.80443	29917.35332	
EW roofs	117.514	3470.536	203918.2838	40171.9019	30128.92642	
average	117.514	3458.3505	203202.3003	40030.85316	30023.13987	
chicago						
E facing	58.757	1377.711	80950.16523	15947.18255	11960.38691	
N facing	58.757	1162.511	68305.65883	13456.21479	10092.16109	
S facing	58.757	1571.61	92343.08877	18191.58849	13643.69137	
W facing	58.757	1372.317	80633.22997	15884.7463	11913.55973	
NS roofs	117.514	2734.121	160648.7476	31647.80328	23735.85246	
EW roofs	117.514	2750.028	161583.3952	31831.92885	23873.94664	
average	117.514	2742.0745	161116.0714	31739.86607	23804.89955	

Figure B19. Estimated solar radiation and PV-generated electricity from PV array. The PV array in this analysis is assumed to cover 75% of the prototype models' roof area. These estimates were used to determine whether the proposed area of PV on the south-side of the roof could be reasonably achieved with PV arrays in other configurations with different roof aspects.

Appendix C

Energy modeling results.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	
1/1/2002	585.309	267.9252	143.2104	148.4652	18191.26	0	486.871	29.26059		
2/1/2002	546.2884	250.0636	129.3513	134.0976	14747.69	0	439.7546	26.42892		
3/1/2002	604.8193	276.8561	143.2104	148.4652	11631.56	0.036148	486.871	29.26059		
4/1/2002	547.0019	250.1693	138.5907	143.676	7166.753	86.51702	471.1656	28.3167		
5/1/2002	604.8193	276.8561	143.2104	148.4652	3541.659	186.798	486.871	29.26059		
6/1/2002	585.309	267.9252	138.5907	143.676	1093.873	480.799	471.1656	28.3167		
7/1/2002	604.8193	276.8561	143.2104	148.4652	312.4106	893.189	486.871	29.26059		
8/1/2002	604.8193	276.8561	143.2104	148.4652	630.7775	599.1968	486.871	29.26059		
9/1/2002	585.309	267.9252	138.5907	143.676	1743.03	292.7847	471.1656	28.3167		
10/1/2002	604.8193	276.8561	143.2104	148.4652	5572.098	25.0749	486.871	29.26059		
11/1/2002	585.309	267.9252	138.5907	143.676	10485.02	0.942797	471.1656	28.3167		
12/1/2002	565.7987	258.9944	143.2104	148.4652	16877.95	0	486.871	29.26059		
	7024.4215		1686.1869	1748.058		2565.338365		344.51985	13368.52462	Tot Site Elec
		3215.2086			91994.0811		5732.514		100941.8037	Tot Site Gas
									114310.3283	Tot Site Engy
									151759.0327	Tot Source Engy

Figure C1. Chicago energy simulation results for pre-1980's base case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Electric) kWh	Cooling (Electric) kWh	DHW (Electricity) kWh	Exterior lighting kWh	Totals kWh		Total Reductions kWh
1/1/2002	635.571	158.369	143.210	148.465	7422.212	0.000	129.832	29.261			
2/1/2002	593.199	147.811	129.351	134.098	6019.405	0.000	117.268	26.429			
3/1/2002	656.756	163.648	143.210	148.465	4752.383	0.015	129.832	29.261			
4/1/2002	593.925	147.890	138.591	143.676	2929.395	85.284	125.644	28.317			
5/1/2002	656.756	163.648	143.210	148.465	1450.123	183.579	129.832	29.261			
6/1/2002	635.571	158.369	138.591	143.676	448.356	475.062	125.644	28.317			
7/1/2002	656.756	163.648	143.210	148.465	128.244	886.706	129.832	29.261			
8/1/2002	656.756	163.648	143.210	148.465	258.726	592.544	129.832	29.261			
9/1/2002	635.571	158.369	138.591	143.676	715.001	288.253	125.644	28.317			
10/1/2002	656.756	163.648	143.210	148.465	2282.665	24.127	129.832	29.261			
11/1/2002	635.571	158.369	138.591	143.676	4285.009	0.902	125.644	28.317			
12/1/2002	614.385	153.090	143.210	148.465	6887.132	0.000	129.832	29.261			
	7627.573		1686.187	1748.058	37578.651	2536.471	1528.670	344.520	53050.131	Tot Site Elec	-39681.606 Reduction (increas
		1900.508							1900.508	Tot Site Gas	99041.296 Reduction fr 1981
									54950.639	Tot Site Engy	59359.690 Reduction fr 1981
									170069.915	Tot Source Engy	-18310.882 Reduction (increas

Figure C2. Chicago energy simulation results for electrification: "all electric" case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Electric) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh		Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	7402.344	0.000	486.871	29.261			
2/1/2002	546.288	250.064	129.351	134.098	6001.094	0.000	439.755	26.429			
3/1/2002	604.819	276.856	143.210	148.465	4733.084	0.036	486.871	29.261			
4/1/2002	547.002	250.169	138.591	143.676	2916.278	86.517	471.166	28.317			
5/1/2002	604.819	276.856	143.210	148.465	1441.164	186.798	486.871	29.261			
6/1/2002	585.309	267.925	138.591	143.676	445.116	480.799	471.166	28.317			
7/1/2002	604.819	276.856	143.210	148.465	127.125	893.189	486.871	29.261			
8/1/2002	604.819	276.856	143.210	148.465	256.675	599.197	486.871	29.261			
9/1/2002	585.309	267.925	138.591	143.676	709.269	292.785	471.166	28.317			
10/1/2002	604.819	276.856	143.210	148.465	2267.384	25.075	486.871	29.261			
11/1/2002	585.309	267.925	138.591	143.676	4266.538	0.943	471.166	28.317			
12/1/2002	565.799	258.994	143.210	148.465	6867.933	0.000	486.871	29.261			
	7024.422		1686.187	1748.058	37434.004	2565.338		344.520	50802.529	Tot Site Elec	-37434.004 Reduction (increas
		3215.209					5732.514		8947.723	Tot Site Gas	91994.081 Reduction fr 1981
									59750.251	Tot Site Engy	54560.077 Reduction fr 1981
									170590.940	Tot Source Engy	-18831.907 Reduction (increas

Figure C3. Chicago energy simulation results for electrification: "electric heating" case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	635.571	158.369	143.210	148.465	18240.090	0.000	486.871	29.261		
2/1/2002	593.199	147.811	129.351	134.098	14792.690	0.000	439.755	26.429		
3/1/2002	656.756	163.648	143.210	148.465	11678.980	0.015	486.871	29.261		
4/1/2002	593.925	147.890	138.591	143.676	7198.989	85.284	471.166	28.317		
5/1/2002	656.756	163.648	143.210	148.465	3563.677	183.579	486.871	29.261		
6/1/2002	635.571	158.369	138.591	143.676	1101.836	475.062	471.166	28.317		
7/1/2002	656.756	163.648	143.210	148.465	315.160	886.706	486.871	29.261		
8/1/2002	656.756	163.648	143.210	148.465	635.819	592.544	486.871	29.261		
9/1/2002	635.571	158.369	138.591	143.676	1757.114	288.253	471.166	28.317		
10/1/2002	656.756	163.648	143.210	148.465	5609.649	24.127	486.871	29.261		
11/1/2002	635.571	158.369	138.591	143.676	10530.410	0.902	471.166	28.317		
12/1/2002	614.385	153.090	143.210	148.465	16925.130	0.000	486.871	29.261		
	7627.573		1686.187	1748.058		2536.471		344.520	13942.809 Tot Site Elec	-574.285 Reduction (increas
		1900.508			92349.544		5732.514		99982.566 Tot Site Gas	959.238 Reduction fr 1981
									113925.375 Tot Site Engy	384.953 Reduction fr 1981
									152537.978 Tot Source Engy	-778.946 Reduction (increas

Figure C4. Chicago energy simulation results for electrification: “electric cooking” case.

Date	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Electricity) kWh	Exterior lighting kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	148.465	18191.260	0.000	129.832	29.261		
2/1/2002	546.288	250.064	129.351	134.098	14747.690	0.000	117.268	26.429		
3/1/2002	604.819	276.856	143.210	148.465	11631.560	0.036	129.832	29.261		
4/1/2002	547.002	250.169	138.591	143.676	7166.753	86.517	125.644	28.317		
5/1/2002	604.819	276.856	143.210	148.465	3541.659	186.798	129.832	29.261		
6/1/2002	585.309	267.925	138.591	143.676	1093.873	480.799	125.644	28.317		
7/1/2002	604.819	276.856	143.210	148.465	312.411	893.189	129.832	29.261		
8/1/2002	604.819	276.856	143.210	148.465	630.778	599.197	129.832	29.261		
9/1/2002	585.309	267.925	138.591	143.676	1743.030	292.785	125.644	28.317		
10/1/2002	604.819	276.856	143.210	148.465	5572.098	25.075	129.832	29.261		
11/1/2002	585.309	267.925	138.591	143.676	10485.020	0.943	125.644	28.317		
12/1/2002	565.799	258.994	143.210	148.465	16877.950	0.000	129.832	29.261		
	7024.422		1686.187	1748.058		2565.338	1528.670	344.520	14897.195 Tot Site Elec	-1528.670 Reduction (increas
		3215.209			91994.081				95209.290 Tot Site Gas	5732.514 Reduction fr 1981
									110106.485 Tot Site Engy	4203.844 Reduction fr 1981
									150386.287 Tot Source Engy	1372.746 Reduction fr 1981

Figure C5. Chicago energy simulation results for electrification: “electric water heater” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Outside Dry-Bulb Temperature °C	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	6907.300	0.000	486.871	29.261	-4.645	
2/1/2002	546.288	250.064	129.351	134.098	5597.131	0.000	439.755	26.429	-2.522	
3/1/2002	604.819	276.856	143.210	148.465	4459.521	0.156	486.871	29.261	3.824	
4/1/2002	547.002	250.169	138.591	143.676	2626.002	37.820	471.166	28.317	9.948	
5/1/2002	604.819	276.856	143.210	148.465	950.479	90.799	486.871	29.261	15.307	
6/1/2002	585.309	267.925	138.591	143.676	133.560	283.300	471.166	28.317	21.109	
7/1/2002	604.819	276.856	143.210	148.465	6.241	573.277	486.871	29.261	24.134	
8/1/2002	604.819	276.856	143.210	148.465	19.144	421.505	486.871	29.261	21.775	
9/1/2002	585.309	267.925	138.591	143.676	172.919	219.662	471.166	28.317	18.136	
10/1/2002	604.819	276.856	143.210	148.465	1286.741	17.868	486.871	29.261	10.981	
11/1/2002	585.309	267.925	138.591	143.676	3596.630	0.593	471.166	28.317	4.734	
12/1/2002	565.799	258.994	143.210	148.465	6106.136	0.000	486.871	29.261	-3.683	
	7024.422		1686.187	1748.058		1644.979		344.520	12448.165 Tot Site Elec	920.360 Reduction fr 1981
		3215.209			31861.805		5732.514		40809.528 Tot Site Gas	60132.276 Reduction fr 1981
									53257.693 Tot Site Engy	61052.636 Reduction fr 1981
									83660.867 Tot Source Engy	68098.166 Reduction fr 1981

Figure C6. Chicago energy simulation results for shallow envelope retrofit: “shallow all” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	17939.720	0.000	486.871	29.261		
2/1/2002	546.288	250.064	129.351	134.098	14547.090	0.000	439.755	26.429		
3/1/2002	604.819	276.856	143.210	148.465	11480.840	0.000	486.871	29.261		
4/1/2002	547.002	250.169	138.591	143.676	7065.116	83.116	471.166	28.317		
5/1/2002	604.819	276.856	143.210	148.465	3450.612	173.995	486.871	29.261		
6/1/2002	585.309	267.925	138.591	143.676	1046.093	467.891	471.166	28.317		
7/1/2002	604.819	276.856	143.210	148.465	283.411	883.375	486.871	29.261		
8/1/2002	604.819	276.856	143.210	148.465	586.568	586.556	486.871	29.261		
9/1/2002	585.309	267.925	138.591	143.676	1672.359	282.452	471.166	28.317		
10/1/2002	604.819	276.856	143.210	148.465	5464.461	22.592	486.871	29.261		
11/1/2002	585.309	267.925	138.591	143.676	10331.800	0.803	471.166	28.317		
12/1/2002	565.799	258.994	143.210	148.465	16632.230	0.000	486.871	29.261		
	7024.422		1686.187	1748.058		2500.779		344.520	13303.966 Tot Site Elec	64.559 Reduction fr 1981
		3215.209			90500.299		5732.514		99448.022 Tot Site Gas	1493.782 Reduction fr 1981
									112751.987 Tot Site Engy	1558.341 Reduction fr 1981
									149935.315 Tot Source Engy	1823.718 Reduction fr 1981

Figure C7. Chicago energy simulation results for shallow envelope retrofit: “shallow ceiling” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	7825.910	0.000	486.871	29.261		
2/1/2002	546.288	250.064	129.351	134.098	6355.812	0.000	439.755	26.429		
3/1/2002	604.819	276.856	143.210	148.465	5082.724	0.000	486.871	29.261		
4/1/2002	547.002	250.169	138.591	143.676	3013.958	37.114	471.166	28.317		
5/1/2002	604.819	276.856	143.210	148.465	1158.089	85.239	486.871	29.261		
6/1/2002	585.309	267.925	138.591	143.676	193.512	276.062	471.166	28.317		
7/1/2002	604.819	276.856	143.210	148.465	13.652	567.781	486.871	29.261		
8/1/2002	604.819	276.856	143.210	148.465	39.718	405.566	486.871	29.261		
9/1/2002	585.309	267.925	138.591	143.676	266.287	203.035	471.166	28.317		
10/1/2002	604.819	276.856	143.210	148.465	1650.499	13.649	486.871	29.261		
11/1/2002	585.309	267.925	138.591	143.676	4177.242	0.339	471.166	28.317		
12/1/2002	565.799	258.994	143.210	148.465	6977.137	0.000	486.871	29.261		
	7024.422		1686.187	1748.058		1588.785		344.520	12391.971 Tot Site Elec	976.553 Reduction fr 1981
		3215.209			36754.539		5732.514		45702.261 Tot Site Gas	55239.542 Reduction fr 1981
									58094.233 Tot Site Engy	56216.096 Reduction fr 1981
									88786.624 Tot Source Engy	62972.408 Reduction fr 1981

Figure C8. Chicago energy simulation results for shallow envelope retrofit: “shallow envelope” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	14410.850	0.000	486.871	29.261		
2/1/2002	546.288	250.064	129.351	134.098	11636.280	0.000	439.755	26.429		
3/1/2002	604.819	276.856	143.210	148.465	9139.915	0.884	486.871	29.261		
4/1/2002	547.002	250.169	138.591	143.676	5540.314	80.830	471.166	28.317		
5/1/2002	604.819	276.856	143.210	148.465	2644.497	192.847	486.871	29.261		
6/1/2002	585.309	267.925	138.591	143.676	781.257	439.640	471.166	28.317		
7/1/2002	604.819	276.856	143.210	148.465	206.682	754.571	486.871	29.261		
8/1/2002	604.819	276.856	143.210	148.465	432.640	538.918	486.871	29.261		
9/1/2002	585.309	267.925	138.591	143.676	1234.486	300.642	471.166	28.317		
10/1/2002	604.819	276.856	143.210	148.465	4133.520	34.625	486.871	29.261		
11/1/2002	585.309	267.925	138.591	143.676	8176.238	1.602	471.166	28.317		
12/1/2002	565.799	258.994	143.210	148.465	13265.240	0.000	486.871	29.261		
	7024.422		1686.187	1748.058		2344.559		344.520	13147.745 Tot Site Elec	220.780 Reduction fr 1981
		3215.209			71601.919		5732.514		80549.642 Tot Site Gas	20392.162 Reduction fr 1981
									93697.387 Tot Site Engy	20612.941 Reduction fr 1981
									128954.721 Tot Source Engy	22804.312 Reduction fr 1981

Figure C9. Chicago energy simulation results for shallow envelope retrofit: “shallow infiltration” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	148.465	11904.670	0.000	486.871	29.261			
2/1/2002	546.288	250.064	129.351	134.098	9706.171	0.000	439.755	26.429			
3/1/2002	604.819	276.856	143.210	148.465	7759.095	0.000	486.871	29.261			
4/1/2002	547.002	250.169	138.591	143.676	4767.667	48.539	471.166	28.317			
5/1/2002	604.819	276.856	143.210	148.465	2160.077	98.203	486.871	29.261			
6/1/2002	585.309	267.925	138.591	143.676	513.834	331.722	471.166	28.317			
7/1/2002	604.819	276.856	143.210	148.465	83.535	725.808	486.871	29.261			
8/1/2002	604.819	276.856	143.210	148.465	205.448	465.218	486.871	29.261			
9/1/2002	585.309	267.925	138.591	143.676	775.581	197.437	471.166	28.317			
10/1/2002	604.819	276.856	143.210	148.465	3226.832	9.962	486.871	29.261			
11/1/2002	585.309	267.925	138.591	143.676	6671.335	0.169	471.166	28.317			
12/1/2002	565.799	258.994	143.210	148.465	10881.360	0.000	486.871	29.261			
	7024.422		1686.187	1748.058		1877.058		344.520	12680.244	Tot Site Elec	
		3215.209			58655.605		5732.514		67603.327	Tot Site Gas	
									80283.571	Tot Site Engy	
									113440.339	Tot Source Engy	
										688.281	Reduction fr 1981
										33338.476	Reduction fr 1981
										34026.757	Reduction fr 1981
										38318.693	Reduction fr 1981

Figure C10. Chicago energy simulation results for shallow envelope retrofit: “shallow wall” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	148.465	17400.710	0.000	486.871	29.261			
2/1/2002	546.288	250.064	129.351	134.098	14097.360	0.000	439.755	26.429			
3/1/2002	604.819	276.856	143.210	148.465	11104.460	0.151	486.871	29.261			
4/1/2002	547.002	250.169	138.591	143.676	6835.765	86.772	471.166	28.317			
5/1/2002	604.819	276.856	143.210	148.465	3356.606	190.337	486.871	29.261			
6/1/2002	585.309	267.925	138.591	143.676	1021.156	484.810	471.166	28.317			
7/1/2002	604.819	276.856	143.210	148.465	284.771	897.280	486.871	29.261			
8/1/2002	604.819	276.856	143.210	148.465	580.630	605.652	486.871	29.261			
9/1/2002	585.309	267.925	138.591	143.676	1627.814	299.282	471.166	28.317			
10/1/2002	604.819	276.856	143.210	148.465	5255.308	27.269	486.871	29.261			
11/1/2002	585.309	267.925	138.591	143.676	9993.507	1.073	471.166	28.317			
12/1/2002	565.799	258.994	143.210	148.465	16129.740	0.000	486.871	29.261			
	7024.422		1686.187	1748.058		2592.627		344.520	13395.813	Tot Site Elec	
		3215.209			87687.827		5732.514		96635.549	Tot Site Gas	
									110031.362	Tot Site Engy	
									147177.475	Tot Source Engy	
										-27.288	Reduction fr 1981
										4306.254	Reduction fr 1981
										4278.966	Reduction fr 1981
										4581.558	Reduction fr 1981

Figure C11. Chicago energy simulation results for shallow envelope retrofit: “shallow window” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	148.465	3908.011	0.001	486.871	29.261			
2/1/2002	546.288	250.064	129.351	134.098	3098.506	0.002	439.755	26.429			
3/1/2002	604.819	276.856	143.210	148.465	2446.678	1.486	486.871	29.261			
4/1/2002	547.002	250.169	138.591	143.676	1344.597	40.266	471.166	28.317			
5/1/2002	604.819	276.856	143.210	148.465	334.115	96.886	486.871	29.261			
6/1/2002	585.309	267.925	138.591	143.676	13.541	283.827	471.166	28.317			
7/1/2002	604.819	276.856	143.210	148.465	0.000	537.123	486.871	29.261			
8/1/2002	604.819	276.856	143.210	148.465	0.000	425.606	486.871	29.261			
9/1/2002	585.309	267.925	138.591	143.676	2.469	217.353	471.166	28.317			
10/1/2002	604.819	276.856	143.210	148.465	338.090	25.107	486.871	29.261			
11/1/2002	585.309	267.925	138.591	143.676	1743.807	2.118	471.166	28.317			
12/1/2002	565.799	258.994	143.210	148.465	3246.886	0.001	486.871	29.261			
	7024.422		1686.187	1748.058		1629.774		344.520	12432.960	Tot Site Elec	
		3215.209			16476.700		5732.514		25424.422	Tot Site Gas	
									37857.383	Tot Site Engy	
									66935.259	Tot Source Engy	
										935.565	Reduction fr 1981
										75517.381	Reduction fr 1981
										76452.946	Reduction fr 1981
										84823.774	Reduction fr 1981

Figure C12. Chicago energy simulation results for deep envelope retrofit: “deep all” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	17826.550	0.000	486.871	29.261		
2/1/2002	546.288	250.064	129.351	134.098	14457.940	0.000	439.755	26.429		
3/1/2002	604.819	276.856	143.210	148.465	11415.670	0.000	486.871	29.261		
4/1/2002	547.002	250.169	138.591	143.676	7024.520	82.118	471.166	28.317		
5/1/2002	604.819	276.856	143.210	148.465	3429.590	171.321	486.871	29.261		
6/1/2002	585.309	267.925	138.591	143.676	1034.148	463.419	471.166	28.317		
7/1/2002	604.819	276.856	143.210	148.465	276.290	879.339	486.871	29.261		
8/1/2002	604.819	276.856	143.210	148.465	575.855	583.172	486.871	29.261		
9/1/2002	585.309	267.925	138.591	143.676	1653.709	280.748	471.166	28.317		
10/1/2002	604.819	276.856	143.210	148.465	5423.837	22.545	486.871	29.261		
11/1/2002	585.309	267.925	138.591	143.676	10262.510	0.801	471.166	28.317		
12/1/2002	565.799	258.994	143.210	148.465	16521.840	0.000	486.871	29.261		
	7024.422		1686.187	1748.058		2483.463		344.520	13286.649	Tot Site Elec 81.876 Reduction fr 1981
		3215.209			89902.459		5732.514		98850.182	Tot Site Gas 2091.622 Reduction fr 1981
									112136.831	Tot Site Engy 2173.498 Reduction fr 1981
									149232.414	Tot Source Engy 2526.618 Reduction fr 1981

Figure C13. Chicago energy simulation results for deep envelope retrofit: “deep ceiling” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.9252	143.2104	148.4652	5604.011	0	486.871	29.26059		
2/1/2002	546.2884	250.0636	129.3513	134.0976	4558.179	0	439.7546	26.42892		
3/1/2002	604.8193	276.8561	143.2104	148.4652	3687.646	0	486.871	29.26059		
4/1/2002	547.0019	250.1693	138.5907	143.676	2125.302	22.79477	471.1656	28.3167		
5/1/2002	604.8193	276.8561	143.2104	148.4652	684.9428	49.05453	486.871	29.26059		
6/1/2002	585.309	267.9252	138.5907	143.676	63.47871	198.4737	471.1656	28.3167		
7/1/2002	604.8193	276.8561	143.2104	148.4652	0.558382	427.1179	486.871	29.26059		
8/1/2002	604.8193	276.8561	143.2104	148.4652	1.765361	315.975	486.871	29.26059		
9/1/2002	585.309	267.9252	138.5907	143.676	68.97723	142.8293	471.1656	28.3167		
10/1/2002	604.8193	276.8561	143.2104	148.4652	856.5658	6.428143	486.871	29.26059		
11/1/2002	585.309	267.9252	138.5907	143.676	2822.009	0.050992	471.1656	28.3167		
12/1/2002	565.7987	258.9944	143.2104	148.4652	4842.964	0	486.871	29.26059		
	7024.4215		1686.1869	1748.058		1162.724335		344.51985	11965.91059	Tot Site Elec 1402.614 Reduction fr 1981
		3215.2086			25316.39928		5732.514		34264.12188	Tot Site Gas 66677.682 Reduction fr 1981
									46230.03247	Tot Site Engy 68080.296 Reduction fr 1981
									75038.34694	Tot Source Engy 76720.686 Reduction fr 1981

Figure C14. Chicago energy simulation results for deep envelope retrofit: “deep envelope” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	10806.610	0.000	486.871	29.261		
2/1/2002	546.288	250.064	129.351	134.098	8823.799	0.000	439.755	26.429		
3/1/2002	604.819	276.856	143.210	148.465	7075.766	0.000	486.871	29.261		
4/1/2002	547.002	250.169	138.591	143.676	4325.508	39.591	471.166	28.317		
5/1/2002	604.819	276.856	143.210	148.465	1880.509	77.209	486.871	29.261		
6/1/2002	585.309	267.925	138.591	143.676	386.571	295.161	471.166	28.317		
7/1/2002	604.819	276.856	143.210	148.465	43.371	687.804	486.871	29.261		
8/1/2002	604.819	276.856	143.210	148.465	117.481	436.977	486.871	29.261		
9/1/2002	585.309	267.925	138.591	143.676	576.358	173.549	471.166	28.317		
10/1/2002	604.819	276.856	143.210	148.465	2793.796	6.756	486.871	29.261		
11/1/2002	585.309	267.925	138.591	143.676	5990.600	0.023	471.166	28.317		
12/1/2002	565.799	258.994	143.210	148.465	9820.468	0.000	486.871	29.261		
	7024.422		1686.187	1748.058		1717.070		344.520	12520.256	Tot Site Elec 848.268 Reduction fr 1981
		3215.209			52640.836		5732.514		61588.559	Tot Site Gas 39353.245 Reduction fr 1981
									74108.815	Tot Site Engy 40201.513 Reduction fr 1981
									106413.649	Tot Source Engy 45345.383 Reduction fr 1981

Figure C15. Chicago energy simulation results for deep envelope retrofit: “deep wall” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh			Total Reductions kWh		
1/1/2002	585.309	267.925	143.210	148.465	16768.770	0.000	486.871	29.261					
2/1/2002	546.288	250.064	129.351	134.098	13513.930	0.000	439.755	26.429					
3/1/2002	604.819	276.856	143.210	148.465	10548.600	2.014	486.871	29.261					
4/1/2002	547.002	250.169	138.591	143.676	6469.565	105.963	471.166	28.317					
5/1/2002	604.819	276.856	143.210	148.465	3143.807	238.460	486.871	29.261					
6/1/2002	585.309	267.925	138.591	143.676	946.870	552.770	471.166	28.317					
7/1/2002	604.819	276.856	143.210	148.465	263.424	968.292	486.871	29.261					
8/1/2002	604.819	276.856	143.210	148.465	541.630	675.475	486.871	29.261					
9/1/2002	585.309	267.925	138.591	143.676	1529.276	359.275	471.166	28.317					
10/1/2002	604.819	276.856	143.210	148.465	4925.817	46.752	486.871	29.261					
11/1/2002	585.309	267.925	138.591	143.676	9563.311	2.684	471.166	28.317					
12/1/2002	565.799	258.994	143.210	148.465	15538.770	0.000	486.871	29.261					
	7024.422		1686.187	1748.058		2951.686		344.520		13754.872	Tot Site Elec	-386.347	Reduction fr 1981
		3215.209			83753.770		5732.514			92701.493	Tot Site Gas	8240.311	Reduction fr 1981
										106456.364	Tot Site Engy	7853.964	Reduction fr 1981
										144050.097	Tot Source Engy	7708.936	Reduction fr 1981

Figure C16. Chicago energy simulation results for deep envelope retrofit: “deep window” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Generation (Elect) kWh	Totals kWh	Total Reduction kWh		
1/1/2002	585.309	267.925	143.210	148.465	18191.260	0.000	486.871	29.261	-411.944				
2/1/2002	546.288	250.064	129.351	134.098	14747.690	0.000	439.755	26.429	-485.514				
3/1/2002	604.819	276.856	143.210	148.465	11631.550	0.035	486.871	29.261	-685.813				
4/1/2002	547.002	250.169	138.591	143.676	7166.669	86.458	471.166	28.317	-794.354				
5/1/2002	604.819	276.856	143.210	148.465	3541.515	186.832	486.871	29.261	-1071.067				
6/1/2002	585.309	267.925	138.591	143.676	1093.884	480.624	471.166	28.317	-1065.463				
7/1/2002	604.819	276.856	143.210	148.465	312.323	893.341	486.871	29.261	-1094.970				
8/1/2002	604.819	276.856	143.210	148.465	630.889	599.262	486.871	29.261	-945.604				
9/1/2002	585.309	267.925	138.591	143.676	1743.042	292.874	471.166	28.317	-791.766				
10/1/2002	604.819	276.856	143.210	148.465	5572.029	25.002	486.871	29.261	-624.102				
11/1/2002	585.309	267.925	138.591	143.676	10485.020	0.943	471.166	28.317	-387.913				
12/1/2002	565.799	258.994	143.210	148.465	16877.950	0.000	486.871	29.261	-360.529				
	7024.422		1686.187	1748.058		2565.372		344.520	-5121.514274	8247.044	Tot Site Elec	5121.481	Reduction (increas)
		3215.209			91993.821		5732.514			100941.544	Tot Site Gas	0.260	Reduction fr 1981
										109188.587	Tot Site Engy	5121.741	Reduction fr 1981
										135539.020	Tot Source Engy	16220.012	Reduction fr 1981

Figure C17. Chicago energy simulation results for renewable energy: “pv” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Generation (Elect) kWh	Totals kWh	Total Reduction kWh		
1/1/2002	585.309	267.925	143.210	148.465	18191.260	0.000	486.871	29.261	-411.944				
2/1/2002	546.288	250.064	129.351	134.098	14747.690	0.000	439.755	26.429	-485.514				
3/1/2002	604.819	276.856	143.210	148.465	11631.550	0.035	486.871	29.261	-685.813				
4/1/2002	547.002	250.169	138.591	143.676	7166.669	86.458	471.166	28.317	-794.354				
5/1/2002	604.819	276.856	143.210	148.465	3541.515	186.832	486.871	29.261	-1071.067				
6/1/2002	585.309	267.925	138.591	143.676	1093.884	480.624	471.166	28.317	-1065.463				
7/1/2002	604.819	276.856	143.210	148.465	312.323	893.341	486.871	29.261	-1094.970				
8/1/2002	604.819	276.856	143.210	148.465	630.889	599.262	486.871	29.261	-945.604				
9/1/2002	585.309	267.925	138.591	143.676	1743.042	292.874	471.166	28.317	-791.766				
10/1/2002	604.819	276.856	143.210	148.465	5572.029	25.002	486.871	29.261	-624.102				
11/1/2002	585.309	267.925	138.591	143.676	10485.020	0.943	471.166	28.317	-387.913				
12/1/2002	565.799	258.994	143.210	148.465	16877.950	0.000	486.871	29.261	-360.529				
	7024.422		1686.187	1748.058		2565.372		344.520	-9324.388482	4044.169	Tot Site Elec	9324.355	Reduction (increas)
		3215.209			91993.821		5732.514			100941.544	Tot Site Gas	0.260	Reduction fr 1981
										104985.713	Tot Site Engy	9324.615	Reduction fr 1981
										122228.518	Tot Source Engy	29530.515	Reduction fr 1981

Figure C18. Chicago energy simulation results for renewable energy: “pv + battery” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Outside Dry-Bulb Temperature °C	
1/1/2002	585.309	267.925	143.210	165.680	4473.155	35.176	357.085	29.261	10.503	
2/1/2002	546.288	250.064	129.351	150.618	3300.677	78.464	322.528	26.429	12.766	
3/1/2002	604.819	276.856	143.210	158.149	2182.560	143.362	357.085	29.261	16.204	
4/1/2002	547.002	250.169	138.591	158.149	853.364	255.769	345.566	28.317	20.489	
5/1/2002	604.819	276.856	143.210	173.211	232.175	433.476	357.085	29.261	24.028	
6/1/2002	585.309	267.925	138.591	150.618	32.472	615.857	345.566	28.317	27.019	
7/1/2002	604.819	276.856	143.210	173.211	0.000	698.268	357.085	29.261	28.271	
8/1/2002	604.819	276.856	143.210	165.680	0.000	685.345	357.085	29.261	28.206	
9/1/2002	585.309	267.925	138.591	158.149	155.095	532.915	345.566	28.317	26.436	
10/1/2002	604.819	276.856	143.210	173.211	1224.735	293.566	357.085	29.261	20.327	
11/1/2002	585.309	267.925	138.591	158.149	1943.846	178.791	345.566	28.317	17.097	
12/1/2002	565.799	258.994	143.210	150.618	3780.863	79.560	357.085	29.261	12.537	
	7024.422		1686.187	1935.440		4030.550		344.520	15021.119	Tot Site Elec
		3215.209			18178.941		4204.387		25598.537	Tot Site Gas
									40619.656	Tot Site Engy
									75320.697	Tot Source Engy

Figure C19. Houston energy simulation results for pre-1980's base case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Electric) kWh	Cooling (Electric) kWh	DHW (Electricity) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	635.571	158.369	143.210	165.680	1244.520	34.335	95.223	29.261			
2/1/2002	593.199	147.811	129.351	150.618	918.039	76.961	86.008	26.429			
3/1/2002	656.756	163.648	143.210	158.149	607.853	141.356	95.223	29.261			
4/1/2002	593.925	147.890	138.591	158.149	237.527	253.464	92.151	28.317			
5/1/2002	656.756	163.648	143.210	173.211	64.759	431.163	95.223	29.261			
6/1/2002	635.571	158.369	138.591	150.618	9.064	613.876	92.151	28.317			
7/1/2002	656.756	163.648	143.210	173.211	0.000	696.603	95.223	29.261			
8/1/2002	656.756	163.648	143.210	165.680	0.000	683.368	95.223	29.261			
9/1/2002	635.571	158.369	138.591	158.149	43.278	531.296	92.151	28.317			
10/1/2002	656.756	163.648	143.210	173.211	340.624	291.483	95.223	29.261			
11/1/2002	635.571	158.369	138.591	158.149	541.335	176.523	92.151	28.317			
12/1/2002	614.385	153.090	143.210	150.618	1051.206	78.152	95.223	29.261			
	7627.573		1686.187	1935.440	5058.204	4008.580	1121.170	344.520	21781.674	Tot Site Elec	-6760.555 Reduction (increas
		1900.508							1900.508	Tot Site Gas	23698.030 Reduction fr 1981
									23682.182	Tot Site Engy	16937.474 Reduction fr 1981
									71042.712	Tot Source Engy	4277.985 Reduction fr 1981

Figure C20. Houston energy simulation results for electrification: "all electric" case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Electric) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	694.865	158.369	143.210	165.680	1235.251	35.176	357.085	29.261			
2/1/2002	648.541	147.811	129.351	150.618	911.474	78.464	322.528	26.429			
3/1/2002	718.027	163.648	143.210	158.149	602.709	143.362	357.085	29.261			
4/1/2002	649.282	147.890	138.591	158.149	235.655	255.769	345.566	28.317			
5/1/2002	718.027	163.648	143.210	173.211	64.114	433.476	357.085	29.261			
6/1/2002	694.865	158.369	138.591	150.618	8.967	615.857	345.566	28.317			
7/1/2002	718.027	163.648	143.210	173.211	0.000	698.268	357.085	29.261			
8/1/2002	718.027	163.648	143.210	165.680	0.000	685.345	357.085	29.261			
9/1/2002	694.865	158.369	138.591	158.149	42.829	532.915	345.566	28.317			
10/1/2002	718.027	163.648	143.210	173.211	338.208	293.566	357.085	29.261			
11/1/2002	694.865	158.369	138.591	158.149	536.789	178.791	345.566	28.317			
12/1/2002	671.703	153.090	143.210	150.618	1044.077	79.560	357.085	29.261			
	8339.122		1686.187	1935.440	5020.073	4030.550		344.520	21355.892	Tot Site Elec	-6334.773 Reduction (increas
		1900.508					4204.387		6104.895	Tot Site Gas	19493.642 Reduction fr 1981
									27460.787	Tot Site Engy	13158.869 Reduction fr 1981
									74251.815	Tot Source Engy	1068.882 Reduction (increas

Figure C21. Houston energy simulation results for electrification: "electric heating" case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	635.571	158.369	143.210	148.465	18240.090	0.000	486.871	29.261		
2/1/2002	593.199	147.811	129.351	134.098	14792.690	0.000	439.755	26.429		
3/1/2002	656.756	163.648	143.210	148.465	11678.980	0.015	486.871	29.261		
4/1/2002	593.925	147.890	138.591	143.676	7198.989	85.284	471.166	28.317		
5/1/2002	656.756	163.648	143.210	148.465	3563.677	183.579	486.871	29.261		
6/1/2002	635.571	158.369	138.591	143.676	1101.836	475.062	471.166	28.317		
7/1/2002	656.756	163.648	143.210	148.465	315.160	886.706	486.871	29.261		
8/1/2002	656.756	163.648	143.210	148.465	635.819	592.544	486.871	29.261		
9/1/2002	635.571	158.369	138.591	143.676	1757.114	288.253	471.166	28.317		
10/1/2002	656.756	163.648	143.210	148.465	5609.649	24.127	486.871	29.261		
11/1/2002	635.571	158.369	138.591	143.676	10530.410	0.902	471.166	28.317		
12/1/2002	614.385	153.090	143.210	148.465	16925.130	0.000	486.871	29.261		
	7627.573		1686.187	1748.058		2536.471		344.520	13942.809 Tot Site Elec	-574.285 Reduction (increas
		1900.508			92349.544		5732.514		99982.566 Tot Site Gas	959.238 Reduction fr 1981
									113925.375 Tot Site Engy	384.953 Reduction fr 1981
									152537.978 Tot Source Engy	-778.946 Reduction (increas

Figure C22. Houston energy simulation results for electrification: “electric cooking” case.

Date	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Electricity) kWh	Exterior lighting kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	148.465	18191.260	0.000	129.832	29.261		
2/1/2002	546.288	250.064	129.351	134.098	14747.690	0.000	117.268	26.429		
3/1/2002	604.819	276.856	143.210	148.465	11631.560	0.036	129.832	29.261		
4/1/2002	547.002	250.169	138.591	143.676	7166.753	86.517	125.644	28.317		
5/1/2002	604.819	276.856	143.210	148.465	3541.659	186.798	129.832	29.261		
6/1/2002	585.309	267.925	138.591	143.676	1093.873	480.799	125.644	28.317		
7/1/2002	604.819	276.856	143.210	148.465	312.411	893.189	129.832	29.261		
8/1/2002	604.819	276.856	143.210	148.465	630.778	599.197	129.832	29.261		
9/1/2002	585.309	267.925	138.591	143.676	1743.030	292.785	125.644	28.317		
10/1/2002	604.819	276.856	143.210	148.465	5572.098	25.075	129.832	29.261		
11/1/2002	585.309	267.925	138.591	143.676	10485.020	0.943	125.644	28.317		
12/1/2002	565.799	258.994	143.210	148.465	16877.950	0.000	129.832	29.261		
	7024.422		1686.187	1748.058		2565.338	1528.670	344.520	14897.195 Tot Site Elec	-1528.670 Reduction (increas
		3215.209			91994.081				95209.290 Tot Site Gas	5732.514 Reduction fr 1981
									110106.485 Tot Site Engy	4203.844 Reduction fr 1981
									150386.287 Tot Source Engy	1372.746 Reduction fr 1981

Figure C23. Houston energy simulation results for electrification: “electric water heater” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Outside Dry-Bulb Temperature °C	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	6907.300	0.000	486.871	29.261	-4.645	
2/1/2002	546.288	250.064	129.351	134.098	5597.131	0.000	439.755	26.429	-2.522	
3/1/2002	604.819	276.856	143.210	148.465	4459.521	0.156	486.871	29.261	3.824	
4/1/2002	547.002	250.169	138.591	143.676	2626.002	37.820	471.166	28.317	9.948	
5/1/2002	604.819	276.856	143.210	148.465	950.479	90.799	486.871	29.261	15.307	
6/1/2002	585.309	267.925	138.591	143.676	133.560	283.300	471.166	28.317	21.109	
7/1/2002	604.819	276.856	143.210	148.465	6.241	573.277	486.871	29.261	24.134	
8/1/2002	604.819	276.856	143.210	148.465	19.144	421.505	486.871	29.261	21.775	
9/1/2002	585.309	267.925	138.591	143.676	172.919	219.662	471.166	28.317	18.136	
10/1/2002	604.819	276.856	143.210	148.465	1286.741	17.868	486.871	29.261	10.981	
11/1/2002	585.309	267.925	138.591	143.676	3596.630	0.593	471.166	28.317	4.734	
12/1/2002	565.799	258.994	143.210	148.465	6106.136	0.000	486.871	29.261	-3.683	
	7024.422		1686.187	1748.058		1644.979		344.520	12448.165 Tot Site Elec	920.360 Reduction fr 1981
		3215.209			31861.805		5732.514		40809.528 Tot Site Gas	60132.276 Reduction fr 1981
									53257.693 Tot Site Engy	61052.636 Reduction fr 1981
									83660.867 Tot Source Engy	68098.166 Reduction fr 1981

Figure C24. Houston energy simulation results for shallow envelope retrofit: “shallow all” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	17939.720	0.000	486.871	29.261		
2/1/2002	546.288	250.064	129.351	134.098	14547.090	0.000	439.755	26.429		
3/1/2002	604.819	276.856	143.210	148.465	11480.840	0.000	486.871	29.261		
4/1/2002	547.002	250.169	138.591	143.676	7065.116	83.116	471.166	28.317		
5/1/2002	604.819	276.856	143.210	148.465	3450.612	173.995	486.871	29.261		
6/1/2002	585.309	267.925	138.591	143.676	1046.093	467.891	471.166	28.317		
7/1/2002	604.819	276.856	143.210	148.465	283.411	883.375	486.871	29.261		
8/1/2002	604.819	276.856	143.210	148.465	586.568	586.556	486.871	29.261		
9/1/2002	585.309	267.925	138.591	143.676	1672.359	282.452	471.166	28.317		
10/1/2002	604.819	276.856	143.210	148.465	5464.461	22.592	486.871	29.261		
11/1/2002	585.309	267.925	138.591	143.676	10331.800	0.803	471.166	28.317		
12/1/2002	565.799	258.994	143.210	148.465	16632.230	0.000	486.871	29.261		
	7024.422		1686.187	1748.058		2500.779		344.520	13303.966 Tot Site Elec	64.559 Reduction fr 1981
		3215.209			90500.299		5732.514		99448.022 Tot Site Gas	1493.782 Reduction fr 1981
									112751.987 Tot Site Engy	1558.341 Reduction fr 1981
									149935.315 Tot Source Engy	1823.718 Reduction fr 1981

Figure C25. Houston energy simulation results for shallow envelope retrofit: “shallow ceiling” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	7825.910	0.000	486.871	29.261		
2/1/2002	546.288	250.064	129.351	134.098	6355.812	0.000	439.755	26.429		
3/1/2002	604.819	276.856	143.210	148.465	5082.724	0.000	486.871	29.261		
4/1/2002	547.002	250.169	138.591	143.676	3013.958	37.114	471.166	28.317		
5/1/2002	604.819	276.856	143.210	148.465	1158.089	85.239	486.871	29.261		
6/1/2002	585.309	267.925	138.591	143.676	193.512	276.062	471.166	28.317		
7/1/2002	604.819	276.856	143.210	148.465	13.652	567.781	486.871	29.261		
8/1/2002	604.819	276.856	143.210	148.465	39.718	405.566	486.871	29.261		
9/1/2002	585.309	267.925	138.591	143.676	266.287	203.035	471.166	28.317		
10/1/2002	604.819	276.856	143.210	148.465	1650.499	13.649	486.871	29.261		
11/1/2002	585.309	267.925	138.591	143.676	4177.242	0.339	471.166	28.317		
12/1/2002	565.799	258.994	143.210	148.465	6977.137	0.000	486.871	29.261		
	7024.422		1686.187	1748.058		1588.785		344.520	12391.971 Tot Site Elec	976.553 Reduction fr 1981
		3215.209			36754.539		5732.514		45702.261 Tot Site Gas	55239.542 Reduction fr 1981
									58094.233 Tot Site Engy	56216.096 Reduction fr 1981
									88786.624 Tot Source Engy	62972.408 Reduction fr 1981

Figure C26. Houston energy simulation results for shallow envelope retrofit: “shallow envelope” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	148.465	14410.850	0.000	486.871	29.261		
2/1/2002	546.288	250.064	129.351	134.098	11636.280	0.000	439.755	26.429		
3/1/2002	604.819	276.856	143.210	148.465	9139.915	0.884	486.871	29.261		
4/1/2002	547.002	250.169	138.591	143.676	5540.314	80.830	471.166	28.317		
5/1/2002	604.819	276.856	143.210	148.465	2644.497	192.847	486.871	29.261		
6/1/2002	585.309	267.925	138.591	143.676	781.257	439.640	471.166	28.317		
7/1/2002	604.819	276.856	143.210	148.465	206.682	754.571	486.871	29.261		
8/1/2002	604.819	276.856	143.210	148.465	432.640	538.918	486.871	29.261		
9/1/2002	585.309	267.925	138.591	143.676	1234.486	300.642	471.166	28.317		
10/1/2002	604.819	276.856	143.210	148.465	4133.520	34.625	486.871	29.261		
11/1/2002	585.309	267.925	138.591	143.676	8176.238	1.602	471.166	28.317		
12/1/2002	565.799	258.994	143.210	148.465	13265.240	0.000	486.871	29.261		
	7024.422		1686.187	1748.058		2344.559		344.520	13147.745 Tot Site Elec	220.780 Reduction fr 1981
		3215.209			71601.919		5732.514		80549.642 Tot Site Gas	20392.162 Reduction fr 1981
									93697.387 Tot Site Engy	20612.941 Reduction fr 1981
									128954.721 Tot Source Engy	22804.312 Reduction fr 1981

Figure C27. Houston energy simulation results for shallow envelope retrofit: “shallow infiltration” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	165.680	2105.389	23.578	357.085	29.261			
2/1/2002	546.288	250.064	129.351	150.618	1515.109	63.045	322.528	26.429			
3/1/2002	604.819	276.856	143.210	158.149	912.139	125.687	357.085	29.261			
4/1/2002	547.002	250.169	138.591	158.149	308.230	244.170	345.566	28.317			
5/1/2002	604.819	276.856	143.210	173.211	54.736	421.021	357.085	29.261			
6/1/2002	585.309	267.925	138.591	150.618	3.309	600.440	345.566	28.317			
7/1/2002	604.819	276.856	143.210	173.211	0.000	679.220	357.085	29.261			
8/1/2002	604.819	276.856	143.210	165.680	0.000	669.178	357.085	29.261			
9/1/2002	585.309	267.925	138.591	158.149	26.180	513.405	345.566	28.317			
10/1/2002	604.819	276.856	143.210	173.211	441.314	268.798	357.085	29.261			
11/1/2002	585.309	267.925	138.591	158.149	795.087	155.119	345.566	28.317			
12/1/2002	565.799	258.994	143.210	150.618	1752.762	56.674	357.085	29.261			
	7024.422		1686.187	1935.440		3820.333		344.520	14810.901	Tot Site Elec	
		3215.209			7914.255		4204.387		15333.851	Tot Site Gas	
									30144.753	Tot Site Engy	
									63528.019	Tot Source Engy	
										210.217	Reduction fr 1981
										10264.686	Reduction fr 1981
										10474.903	Reduction fr 1981
										0.000	
										11792.678	Reduction fr 1981

Figure C28. Houston energy simulation results for shallow envelope retrofit: “shallow wall” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	165.680	4076.732	32.709	357.085	29.261			
2/1/2002	546.288	250.064	129.351	150.618	3000.730	75.209	322.528	26.429			
3/1/2002	604.819	276.856	143.210	158.149	1970.334	138.872	357.085	29.261			
4/1/2002	547.002	250.169	138.591	158.149	766.622	250.789	345.566	28.317			
5/1/2002	604.819	276.856	143.210	173.211	203.717	426.898	357.085	29.261			
6/1/2002	585.309	267.925	138.591	150.618	27.014	607.885	345.566	28.317			
7/1/2002	604.819	276.856	143.210	173.211	0.000	688.945	357.085	29.261			
8/1/2002	604.819	276.856	143.210	165.680	0.000	676.187	357.085	29.261			
9/1/2002	585.309	267.925	138.591	158.149	135.327	524.820	345.566	28.317			
10/1/2002	604.819	276.856	143.210	173.211	1107.643	286.870	357.085	29.261			
11/1/2002	585.309	267.925	138.591	158.149	1758.680	173.850	345.566	28.317			
12/1/2002	565.799	258.994	143.210	150.618	3446.790	75.510	357.085	29.261			
	7024.422		1686.187	1935.440		3958.545		344.520	14949.113	Tot Site Elec	
		3215.209			16493.589		4204.387		23913.185	Tot Site Gas	
									38862.298	Tot Site Engy	
									73265.734	Tot Source Engy	
										72.005	Reduction fr 1981
										1685.353	Reduction fr 1981
										1757.358	Reduction fr 1981
										2054.963	Reduction fr 1981

Figure C29. Houston energy simulation results for shallow envelope retrofit: “shallow window” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.3090	267.9252	143.2104	165.6797	416.5135	10.76637	357.085	29.26059			
2/1/2002	546.2884	250.0636	129.3513	150.6179	295.0944	37.80737	322.5284	26.42892			
3/1/2002	604.8193	276.8561	143.2104	158.1488	121.0467	83.34398	357.085	29.26059			
4/1/2002	547.0019	250.1693	138.5907	158.1488	33.2927	189.3767	345.566	28.3167			
5/1/2002	604.8193	276.8561	143.2104	173.2106	0.2623	334.9658	357.085	29.26059			
6/1/2002	585.3090	267.9252	138.5907	150.6179	0.0000	464.0331	345.566	28.3167			
7/1/2002	604.8193	276.8561	143.2104	173.2106	0.0000	522.0495	357.085	29.26059			
8/1/2002	604.8193	276.8561	143.2104	165.6797	0.0000	519.3593	357.085	29.26059			
9/1/2002	585.3090	267.9252	138.5907	158.1488	0.0000	411.4937	345.566	28.3167			
10/1/2002	604.8193	276.8561	143.2104	173.2106	39.3537	198.2132	357.085	29.26059			
11/1/2002	585.3090	267.9252	138.5907	158.1488	104.6713	107.4866	345.566	28.3167			
12/1/2002	565.7987	258.9944	143.2104	150.6179	353.4169	31.54798	357.085	29.26059			
	7024.422		1686.187	1935.440		2910.444		344.520	13901.012	Tot Site Elec	
		3215.209			1363.652		4204.387		8783.248	Tot Site Gas	
									22684.259	Tot Site Engy	
									53545.545	Tot Source Engy	
										1120.107	Reduction fr 1981
										16815.290	Reduction fr 1981
										17935.397	Reduction fr 1981
										21775.152	Reduction fr 1981

Figure C30. Houston energy simulation results for deep envelope retrofit: “deep all” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	165.680	4329.774	32.940	357.085	29.261			
2/1/2002	546.288	250.064	129.351	150.618	3186.881	75.486	322.528	26.429			
3/1/2002	604.819	276.856	143.210	158.149	2084.793	138.845	357.085	29.261			
4/1/2002	547.002	250.169	138.591	158.149	794.523	250.796	345.566	28.317			
5/1/2002	604.819	276.856	143.210	173.211	203.183	432.291	357.085	29.261			
6/1/2002	585.309	267.925	138.591	150.618	24.419	619.713	345.566	28.317			
7/1/2002	604.819	276.856	143.210	173.211	0.000	703.708	357.085	29.261			
8/1/2002	604.819	276.856	143.210	165.680	0.000	691.541	357.085	29.261			
9/1/2002	585.309	267.925	138.591	158.149	127.848	534.729	345.566	28.317			
10/1/2002	604.819	276.856	143.210	173.211	1128.957	289.219	357.085	29.261			
11/1/2002	585.309	267.925	138.591	158.149	1844.063	176.087	345.566	28.317			
12/1/2002	565.799	258.994	143.210	150.618	3645.171	76.915	357.085	29.261			
	7024.422		1686.187	1935.440		4022.268		344.520	15012.836	Tot Site Elec	
		3215.209			17369.611		4204.387		24789.207	Tot Site Gas	
									39802.044	Tot Site Engy	
									74417.153	Tot Source Engy	
										8.282	Reduction fr 1981
										809.330	Reduction fr 1981
										817.612	Reduction fr 1981
										903.544	Reduction fr 1981

Figure C31. Houston energy simulation results for deep envelope retrofit: “deep ceiling” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	165.680	1081.523	12.1655	357.085	29.26059			
2/1/2002	546.288	250.064	129.351	150.618	767.427	41.08074	322.5284	26.42892			
3/1/2002	604.819	276.856	143.210	158.149	403.483	88.11653	357.085	29.26059			
4/1/2002	547.002	250.169	138.591	158.149	113.473	202.2602	345.566	28.3167			
5/1/2002	604.819	276.856	143.210	173.211	9.650	362.1757	357.085	29.26059			
6/1/2002	585.309	267.9252	138.5907	150.6179	0.06934	506.6678	345.566	28.3167			
7/1/2002	604.819	276.8561	143.2104	173.2106	0	571.7333	357.085	29.26059			
8/1/2002	604.819	276.8561	143.2104	165.6797	0	570.6202	357.085	29.26059			
9/1/2002	585.309	267.9252	138.5907	158.1488	0.846086	447.4962	345.566	28.3167			
10/1/2002	604.819	276.8561	143.2104	173.2106	147.0827	220.073	357.085	29.26059			
11/1/2002	585.309	267.9252	138.5907	158.1488	337.369	116.1192	345.566	28.3167			
12/1/2002	565.799	258.9944	143.2104	150.6179	887.0087	33.30715	357.085	29.26059			
	7024.422		1686.187	1935.440		3171.816		344.520	14162.384	Tot Site Elec	
		3215.209			3747.932		4204.387		11167.528	Tot Site Gas	
									25329.912	Tot Site Engy	
									56957.871	Tot Source Engy	
										858.735	Reduction fr 1981
										14431.009	Reduction fr 1981
										15289.744	Reduction fr 1981
										18362.826	Reduction fr 1981

Figure C32. Houston energy simulation results for deep envelope retrofit: “deep envelope” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	165.680	1761.826	18.295	357.085	29.261			
2/1/2002	546.288	250.064	129.351	150.618	1251.956	55.392	322.528	26.429			
3/1/2002	604.819	276.856	143.210	158.149	711.981	116.605	357.085	29.261			
4/1/2002	547.002	250.169	138.591	158.149	216.919	238.315	345.566	28.317			
5/1/2002	604.819	276.856	143.210	173.211	29.183	422.548	357.085	29.261			
6/1/2002	585.309	267.925	138.591	150.618	0.744	604.413	345.566	28.317			
7/1/2002	604.819	276.856	143.210	173.211	0.000	684.936	357.085	29.261			
8/1/2002	604.819	276.856	143.210	165.680	0.000	675.669	357.085	29.261			
9/1/2002	585.309	267.925	138.591	158.149	6.486	517.102	345.566	28.317			
10/1/2002	604.819	276.856	143.210	173.211	297.186	258.663	357.085	29.261			
11/1/2002	585.309	267.925	138.591	158.149	603.831	143.485	345.566	28.317			
12/1/2002	565.799	258.994	143.210	150.618	1445.271	47.182	357.085	29.261			
	7024.422		1686.187	1935.440		3782.604		344.520	14773.172	Tot Site Elec	
		3215.209			6325.381		4204.387		13744.977	Tot Site Gas	
									28518.150	Tot Site Engy	
									61686.192	Tot Source Engy	
										247.946	Reduction fr 1981
										11853.560	Reduction fr 1981
										12101.506	Reduction fr 1981
										13634.505	Reduction fr 1981

Figure C33. Houston energy simulation results for deep envelope retrofit: “deep wall” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	165.680	3850.554	35.132	357.085	29.261		
2/1/2002	546.288	250.064	129.351	150.618	2833.872	77.894	322.528	26.429		
3/1/2002	604.819	276.856	143.210	158.149	1852.063	142.949	357.085	29.261		
4/1/2002	547.002	250.169	138.591	158.149	716.391	255.093	345.566	28.317		
5/1/2002	604.819	276.856	143.210	173.211	187.099	431.421	357.085	29.261		
6/1/2002	585.309	267.925	138.591	150.618	23.902	611.640	345.566	28.317		
7/1/2002	604.819	276.856	143.210	173.211	0.000	692.420	357.085	29.261		
8/1/2002	604.819	276.856	143.210	165.680	0.000	679.847	357.085	29.261		
9/1/2002	585.309	267.925	138.591	158.149	123.699	528.073	345.566	28.317		
10/1/2002	604.819	276.856	143.210	173.211	1039.921	291.189	357.085	29.261		
11/1/2002	585.309	267.925	138.591	158.149	1655.749	178.102	345.566	28.317		
12/1/2002	565.799	258.994	143.210	150.618	3261.196	78.663	357.085	29.261		
	7024.422		1686.187	1935.440		4002.423		344.520	14992.992	Tot Site Elec
		3215.209			15544.446		4204.387		22964.042	Tot Site Gas
									37957.034	Tot Site Engy
									72375.826	Tot Source Engy
									28.127	Reduction fr 1981
									2634.496	Reduction fr 1981
									2662.622	Reduction fr 1981
									2944.871	Reduction fr 1981

Figure C34. Houston energy simulation results for deep envelope retrofit: “deep window” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Generation (Elect) kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	165.680	4473.146	35.144	357.085	29.261	-608.982		
2/1/2002	546.288	250.064	129.351	150.618	3300.504	78.447	322.528	26.429	-599.997		
3/1/2002	604.819	276.856	143.210	158.149	2182.505	143.355	357.085	29.261	-813.224		
4/1/2002	547.002	250.169	138.591	158.149	853.355	255.708	345.566	28.317	-853.518		
5/1/2002	604.819	276.856	143.210	173.211	231.892	433.543	357.085	29.261	-934.894		
6/1/2002	585.309	267.925	138.591	150.618	32.507	615.772	345.566	28.317	-969.989		
7/1/2002	604.819	276.856	143.210	173.211	0.000	698.269	357.085	29.261	-1053.985		
8/1/2002	604.819	276.856	143.210	165.680	0.000	685.228	357.085	29.261	-969.396		
9/1/2002	585.309	267.925	138.591	158.149	154.982	532.892	345.566	28.317	-918.357		
10/1/2002	604.819	276.856	143.210	173.211	1224.790	293.549	357.085	29.261	-857.102		
11/1/2002	585.309	267.925	138.591	158.149	1943.888	178.802	345.566	28.317	-660.373		
12/1/2002	565.799	258.994	143.210	150.618	3780.842	79.559	357.085	29.261	-569.551		
	7024.422		1686.187	1935.440		4030.268		344.520	-6834.268707	8186.568	Tot Site Elec
		3215.209			18178.410		4204.387			25598.006	Tot Site Gas
										33784.574	Tot Site Engy
										53675.099	Tot Source Engy
										6834.551	Reduction (increas)
										0.531	Reduction fr 1981
										6835.082	Reduction fr 1981
										21645.598	Reduction fr 1981

Figure C35. Houston energy simulation results for renewable energy: “pv” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Generation (Elect) kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	165.680	4473.146	35.144	357.085	29.261	-608.982		
2/1/2002	546.288	250.064	129.351	150.618	3300.504	78.447	322.528	26.429	-599.997		
3/1/2002	604.819	276.856	143.210	158.149	2182.505	143.355	357.085	29.261	-813.224		
4/1/2002	547.002	250.169	138.591	158.149	853.355	255.708	345.566	28.317	-853.518		
5/1/2002	604.819	276.856	143.210	173.211	231.892	433.543	357.085	29.261	-934.894		
6/1/2002	585.309	267.925	138.591	150.618	32.507	615.772	345.566	28.317	-969.989		
7/1/2002	604.819	276.856	143.210	173.211	0.000	698.269	357.085	29.261	-1053.985		
8/1/2002	604.819	276.856	143.210	165.680	0.000	685.228	357.085	29.261	-969.396		
9/1/2002	585.309	267.925	138.591	158.149	154.982	532.892	345.566	28.317	-918.357		
10/1/2002	604.819	276.856	143.210	173.211	1224.790	293.549	357.085	29.261	-857.102		
11/1/2002	585.309	267.925	138.591	158.149	1943.888	178.802	345.566	28.317	-660.373		
12/1/2002	565.799	258.994	143.210	150.618	3780.842	79.559	357.085	29.261	-569.551		
	7024.422		1686.187	1935.440		4030.268		344.520	-10490.41733	4530.419	Tot Site Elec
		3215.209			18178.410		4204.387			25598.006	Tot Site Gas
										30128.425	Tot Site Engy
										42096.076	Tot Source Engy
										10490.699	Reduction (increas)
										0.531	Reduction fr 1981
										10491.231	Reduction fr 1981
										33224.621	Reduction fr 1981

Figure C36. Houston energy simulation results for renewable energy: “pv + battery” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	
1/1/2002	585.309	267.9252	143.2104	91.3632	3511.204	71.09305	394.1666	29.26059		
2/1/2002	546.2884	250.0636	129.3513	82.5216	2799.124	61.74611	356.0216	26.42892		
3/1/2002	604.8193	276.8561	143.2104	91.3632	2891.357	67.97474	394.1666	29.26059		
4/1/2002	547.0019	250.1693	138.5907	88.416	2179.042	97.6507	381.4516	28.3167		
5/1/2002	604.8193	276.8561	143.2104	91.3632	1567.828	127.1083	394.1666	29.26059		
6/1/2002	585.309	267.9252	138.5907	88.416	1085.211	190.7685	381.4516	28.3167		
7/1/2002	604.8193	276.8561	143.2104	91.3632	795.8548	274.9639	394.1666	29.26059		
8/1/2002	604.8193	276.8561	143.2104	91.3632	632.4669	274.0673	394.1666	29.26059		
9/1/2002	585.309	267.9252	138.5907	88.416	801.4513	259.2759	381.4516	28.3167		
10/1/2002	604.8193	276.8561	143.2104	91.3632	1401.483	164.2334	394.1666	29.26059		
11/1/2002	585.309	267.9252	138.5907	88.416	2267.332	120.6576	381.4516	28.3167		
12/1/2002	565.7987	258.9944	143.2104	91.3632	3238.53	78.23531	394.1666	29.26059		
	7024.4215		1686.1869	1075.728		1787.77481		344.51985	11918.63106	Tot Site Elec
		3215.2086			23170.884		4640.9942		31027.0868	Tot Site Gas
									42945.71786	Tot Site Engy
									71379.66666	Tot Source Engy

Figure C37. Los Angeles energy simulation results for pre-1980's base case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Electric) kWh	Cooling (Electric) kWh	DHW (Electricity) kWh	Exterior lighting kWh	Totals kWh		Total Reductions kWh
1/1/2002	635.571	158.369	143.210	91.363	888.641	69.705	105.111	29.261			
2/1/2002	593.199	147.811	129.351	82.522	709.501	60.643	94.939	26.429			
3/1/2002	656.756	163.648	143.210	91.363	732.703	66.450	105.111	29.261			
4/1/2002	593.925	147.890	138.591	88.416	551.740	95.688	101.720	28.317			
5/1/2002	656.756	163.648	143.210	91.363	397.383	123.699	105.111	29.261			
6/1/2002	635.571	158.369	138.591	88.416	275.031	187.114	101.720	28.317			
7/1/2002	656.756	163.648	143.210	91.363	201.933	272.543	105.111	29.261			
8/1/2002	656.756	163.648	143.210	91.363	160.668	271.467	105.111	29.261			
9/1/2002	635.571	158.369	138.591	88.416	203.708	256.909	101.720	28.317			
10/1/2002	656.756	163.648	143.210	91.363	356.316	162.201	105.111	29.261			
11/1/2002	635.571	158.369	138.591	88.416	575.280	119.310	101.720	28.317			
12/1/2002	614.385	153.090	143.210	91.363	819.877	77.003	105.111	29.261			
	7627.573		1686.187	1075.728	5872.781	1762.731	1237.598	344.520	19607.118	Tot Site Elec	-7688.487 Reduction (increas
		1900.508							1900.508	Tot Site Gas	29126.579 Reduction fr 1981
									21507.626	Tot Site Engy	21438.092 Reduction fr 1981
									64155.893	Tot Source Engy	7223.774 Reduction fr 1981

Figure C38. Los Angeles energy simulation results for electrification: "all electric" case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Electric) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh		Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	881.382	71.093	394.167	29.261			
2/1/2002	546.288	250.064	129.351	82.522	702.635	61.746	356.022	26.429			
3/1/2002	604.819	276.856	143.210	91.363	725.788	67.975	394.167	29.261			
4/1/2002	547.002	250.169	138.591	88.416	546.983	97.651	381.452	28.317			
5/1/2002	604.819	276.856	143.210	91.363	393.556	127.108	394.167	29.261			
6/1/2002	585.309	267.925	138.591	88.416	272.409	190.769	381.452	28.317			
7/1/2002	604.819	276.856	143.210	91.363	199.775	274.964	394.167	29.261			
8/1/2002	604.819	276.856	143.210	91.363	158.762	274.067	394.167	29.261			
9/1/2002	585.309	267.925	138.591	88.416	201.180	259.276	381.452	28.317			
10/1/2002	604.819	276.856	143.210	91.363	351.800	164.233	394.167	29.261			
11/1/2002	585.309	267.925	138.591	88.416	569.145	120.658	381.452	28.317			
12/1/2002	565.799	258.994	143.210	91.363	812.935	78.235	394.167	29.261			
	7024.422		1686.187	1075.728	5816.349	1787.775		344.520	17734.980	Tot Site Elec	-5816.349 Reduction (increas
		3215.209					4640.994		7856.203	Tot Site Gas	23170.884 Reduction fr 1981
									25591.183	Tot Site Engy	17354.535 Reduction fr 1981
									64682.807	Tot Source Engy	6696.860 Reduction fr 1981

Figure C39. Los Angeles energy simulation results for electrification: "electric heating" case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	635.571	158.369	143.210	91.363	3540.123	69.705	394.167	29.261		
2/1/2002	593.199	147.811	129.351	82.522	2826.474	60.643	356.022	26.429		
3/1/2002	656.756	163.648	143.210	91.363	2918.905	66.450	394.167	29.261		
4/1/2002	593.925	147.890	138.591	88.416	2197.992	95.688	381.452	28.317		
5/1/2002	656.756	163.648	143.210	91.363	1583.076	123.699	394.167	29.261		
6/1/2002	635.571	158.369	138.591	88.416	1095.653	187.114	381.452	28.317		
7/1/2002	656.756	163.648	143.210	91.363	804.449	272.543	394.167	29.261		
8/1/2002	656.756	163.648	143.210	91.363	640.060	271.467	394.167	29.261		
9/1/2002	635.571	158.369	138.591	88.416	811.522	256.909	381.452	28.317		
10/1/2002	656.756	163.648	143.210	91.363	1419.475	162.201	394.167	29.261		
11/1/2002	635.571	158.369	138.591	88.416	2291.774	119.310	381.452	28.317		
12/1/2002	614.385	153.090	143.210	91.363	3266.186	77.003	394.167	29.261		
	7627.573		1686.187	1075.728		1762.731		344.520	12496.739 Tot Site Elec	-578.108 Reduction (increas
		1900.508			23395.689		4640.994		29937.192 Tot Site Gas	1089.895 Reduction fr 1981
									42433.930 Tot Site Engy	511.788 Reduction fr 1981
									72029.088 Tot Source Engy	-649.421 Reduction (increas

Figure C40. Los Angeles energy simulation results for electrification: “electric cooking” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Electricity) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	3511.204	75.676	105.111	29.261		
2/1/2002	546.288	250.064	129.351	82.522	2799.124	65.726	94.939	26.429		
3/1/2002	604.819	276.856	143.210	91.363	2891.357	72.356	105.111	29.261		
4/1/2002	547.002	250.169	138.591	88.416	2179.042	103.945	101.720	28.317		
5/1/2002	604.819	276.856	143.210	91.363	1567.828	135.302	105.111	29.261		
6/1/2002	585.309	267.925	138.591	88.416	1085.211	203.065	101.720	28.317		
7/1/2002	604.819	276.856	143.210	91.363	795.855	292.688	105.111	29.261		
8/1/2002	604.819	276.856	143.210	91.363	632.467	291.733	105.111	29.261		
9/1/2002	585.309	267.925	138.591	88.416	801.451	275.989	101.720	28.317		
10/1/2002	604.819	276.856	143.210	91.363	1401.483	174.820	105.111	29.261		
11/1/2002	585.309	267.925	138.591	88.416	2267.332	128.435	101.720	28.317		
12/1/2002	565.799	258.994	143.210	91.363	3238.530	83.278	105.111	29.261		
	7024.422		1686.187	1075.728		1903.013	1237.598	344.520	13271.467 Tot Site Elec	-1352.836 Reduction (increas
		3215.209			23170.884				26386.093 Tot Site Gas	4640.994 Reduction fr 1981
									39657.560 Tot Site Engy	3288.158 Reduction fr 1981
									70633.262 Tot Source Engy	746.405 Reduction fr 1981

Figure C41. Los Angeles energy simulation results for electrification: “electric water heater” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	742.247	44.395	394.167	29.261		
2/1/2002	546.288	250.064	129.351	82.522	520.061	44.742	356.022	26.429		
3/1/2002	604.819	276.856	143.210	91.363	504.048	62.507	394.167	29.261		
4/1/2002	547.002	250.169	138.591	88.416	360.310	93.518	381.452	28.317		
5/1/2002	604.819	276.856	143.210	91.363	185.146	124.463	394.167	29.261		
6/1/2002	585.309	267.925	138.591	88.416	87.080	175.181	381.452	28.317		
7/1/2002	604.819	276.856	143.210	91.363	33.082	240.752	394.167	29.261		
8/1/2002	604.819	276.856	143.210	91.363	14.288	247.342	394.167	29.261		
9/1/2002	585.309	267.925	138.591	88.416	43.358	231.065	381.452	28.317		
10/1/2002	604.819	276.856	143.210	91.363	146.107	144.431	394.167	29.261		
11/1/2002	585.309	267.925	138.591	88.416	358.707	87.816	381.452	28.317		
12/1/2002	565.799	258.994	143.210	91.363	633.833	42.133	394.167	29.261		
	7024.422		1686.187	1075.728		1538.345		344.520	11669.201 Tot Site Elec	249.430 Reduction fr 1981
		3215.209			3628.267		4640.994		11484.470 Tot Site Gas	19542.617 Reduction fr 1981
									23153.671 Tot Site Engy	19792.047 Reduction fr 1981
									49405.525 Tot Source Engy	21974.142 Reduction fr 1981

Figure C42. Los Angeles energy simulation results for shallow envelope retrofit: “shallow all” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	91.363	3488.909	70.479	394.167	29.261			
2/1/2002	546.288	250.064	129.351	82.522	2781.794	61.138	356.022	26.429			
3/1/2002	604.819	276.856	143.210	91.363	2873.080	67.019	394.167	29.261			
4/1/2002	547.002	250.169	138.591	88.416	2163.402	96.239	381.452	28.317			
5/1/2002	604.819	276.856	143.210	91.363	1554.117	125.323	394.167	29.261			
6/1/2002	585.309	267.925	138.591	88.416	1074.014	188.979	381.452	28.317			
7/1/2002	604.819	276.856	143.210	91.363	785.026	273.932	394.167	29.261			
8/1/2002	604.819	276.856	143.210	91.363	622.338	272.922	394.167	29.261			
9/1/2002	585.309	267.925	138.591	88.416	790.786	258.624	381.452	28.317			
10/1/2002	604.819	276.856	143.210	91.363	1387.986	163.433	394.167	29.261			
11/1/2002	585.309	267.925	138.591	88.416	2249.802	120.136	381.452	28.317			
12/1/2002	565.799	258.994	143.210	91.363	3216.667	77.650	394.167	29.261			
	7024.422		1686.187	1075.728		1775.876		344.520	11906.732	Tot Site Elec	
		3215.209			22987.921		4640.994		30844.124	Tot Site Gas	
									42750.856	Tot Site Engy	
									71143.650	Tot Source Engy	
										11.899	Reduction fr 1981
										182.963	Reduction fr 1981
										194.862	Reduction fr 1981
										236.016	Reduction fr 1981

Figure C43. Los Angeles energy simulation results for shallow envelope retrofit: "shallow ceiling" case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	91.363	1101.382	50.099	394.167	29.261			
2/1/2002	546.288	250.064	129.351	82.522	818.048	49.076	356.022	26.429			
3/1/2002	604.819	276.856	143.210	91.363	816.633	63.774	394.167	29.261			
4/1/2002	547.002	250.169	138.591	88.416	583.443	95.127	381.452	28.317			
5/1/2002	604.819	276.856	143.210	91.363	343.553	125.758	394.167	29.261			
6/1/2002	585.309	267.925	138.591	88.416	194.425	178.952	381.452	28.317			
7/1/2002	604.819	276.856	143.210	91.363	104.617	249.274	394.167	29.261			
8/1/2002	604.819	276.856	143.210	91.363	62.118	256.658	394.167	29.261			
9/1/2002	585.309	267.925	138.591	88.416	112.061	238.756	381.452	28.317			
10/1/2002	604.819	276.856	143.210	91.363	284.781	149.095	394.167	29.261			
11/1/2002	585.309	267.925	138.591	88.416	597.170	96.367	381.452	28.317			
12/1/2002	565.799	258.994	143.210	91.363	967.680	50.238	394.167	29.261			
	7024.422		1686.187	1075.728		1603.174		344.520	11734.031	Tot Site Elec	
		3215.209			5985.911		4640.994		13842.114	Tot Site Gas	
									25576.145	Tot Site Engy	
									52166.527	Tot Source Engy	
										184.600	Reduction fr 1981
										17184.973	Reduction fr 1981
										17369.573	Reduction fr 1981
										19213.140	Reduction fr 1981

Figure C44. Los Angeles energy simulation results for shallow envelope retrofit: "shallow envelope" case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh	
1/1/2002	585.309	267.925	143.210	91.363	2818.110	89.196	394.167	29.261			
2/1/2002	546.288	250.064	129.351	82.522	2217.914	76.722	356.022	26.429			
3/1/2002	604.819	276.856	143.210	91.363	2294.517	89.954	394.167	29.261			
4/1/2002	547.002	250.169	138.591	88.416	1717.162	121.478	381.452	28.317			
5/1/2002	604.819	276.856	143.210	91.363	1220.112	157.419	394.167	29.261			
6/1/2002	585.309	267.925	138.591	88.416	834.691	213.471	381.452	28.317			
7/1/2002	604.819	276.856	143.210	91.363	617.574	277.774	394.167	29.261			
8/1/2002	604.819	276.856	143.210	91.363	487.568	280.251	394.167	29.261			
9/1/2002	585.309	267.925	138.591	88.416	616.924	259.059	381.452	28.317			
10/1/2002	604.819	276.856	143.210	91.363	1093.321	179.531	394.167	29.261			
11/1/2002	585.309	267.925	138.591	88.416	1809.352	135.985	381.452	28.317			
12/1/2002	565.799	258.994	143.210	91.363	2604.561	95.561	394.167	29.261			
	7024.422		1686.187	1075.728		1976.402		344.520	12107.258	Tot Site Elec	
		3215.209			18331.807		4640.994		26188.010	Tot Site Gas	
									38295.268	Tot Site Engy	
									66731.490	Tot Source Engy	
										-188.627	Reduction fr 1981
										4839.077	Reduction fr 1981
										4650.450	Reduction fr 1981
										4648.177	Reduction fr 1981

Figure C45. Los Angeles energy simulation results for shallow envelope retrofit: "shallow infiltration" case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	1807.297	32.228	394.167	29.261		
2/1/2002	546.288	250.064	129.351	82.522	1404.461	32.758	356.022	26.429		
3/1/2002	604.819	276.856	143.210	91.363	1408.249	41.472	394.167	29.261		
4/1/2002	547.002	250.169	138.591	88.416	1034.213	67.782	381.452	28.317		
5/1/2002	604.819	276.856	143.210	91.363	664.355	87.718	394.167	29.261		
6/1/2002	585.309	267.925	138.591	88.416	414.189	144.726	381.452	28.317		
7/1/2002	604.819	276.856	143.210	91.363	251.365	231.817	394.167	29.261		
8/1/2002	604.819	276.856	143.210	91.363	171.272	235.229	394.167	29.261		
9/1/2002	585.309	267.925	138.591	88.416	263.195	226.036	381.452	28.317		
10/1/2002	604.819	276.856	143.210	91.363	552.263	120.677	394.167	29.261		
11/1/2002	585.309	267.925	138.591	88.416	1038.586	73.574	381.452	28.317		
12/1/2002	565.799	258.994	143.210	91.363	1606.660	31.938	394.167	29.261		
	7024.422		1686.187	1075.728		1325.955		344.520	11456.811 Tot Site Elec	461.820 Reduction fr 1981
		3215.209			10616.104		4640.994		18472.307 Tot Site Gas	12554.780 Reduction fr 1981
									29929.118 Tot Site Engy	13016.600 Reduction fr 1981
									56307.701 Tot Source Engy	15071.965 Reduction fr 1981

Figure C46. Los Angeles energy simulation results for shallow envelope retrofit: “shallow wall” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	3174.983	65.904	394.167	29.261		
2/1/2002	546.288	250.064	129.351	82.522	2520.033	57.839	356.022	26.429		
3/1/2002	604.819	276.856	143.210	91.363	2590.571	64.164	394.167	29.261		
4/1/2002	547.002	250.169	138.591	88.416	1956.036	92.888	381.452	28.317		
5/1/2002	604.819	276.856	143.210	91.363	1395.652	120.985	394.167	29.261		
6/1/2002	585.309	267.925	138.591	88.416	958.964	183.832	381.452	28.317		
7/1/2002	604.819	276.856	143.210	91.363	692.095	269.088	394.167	29.261		
8/1/2002	604.819	276.856	143.210	91.363	545.343	267.945	394.167	29.261		
9/1/2002	585.309	267.925	138.591	88.416	700.530	254.000	381.452	28.317		
10/1/2002	604.819	276.856	143.210	91.363	1236.933	158.798	394.167	29.261		
11/1/2002	585.309	267.925	138.591	88.416	2026.719	114.820	381.452	28.317		
12/1/2002	565.799	258.994	143.210	91.363	2920.318	72.368	394.167	29.261		
	7024.422		1686.187	1075.728		1722.630		344.520	11853.487 Tot Site Elec	65.144 Reduction fr 1981
		3215.209			20718.177		4640.994		28574.380 Tot Site Gas	2452.707 Reduction fr 1981
									40427.866 Tot Site Engy	2517.851 Reduction fr 1981
									68514.620 Tot Source Engy	2865.047 Reduction fr 1981

Figure C47. Los Angeles energy simulation results for shallow envelope retrofit: “shallow window” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	164.768	10.492	394.167	29.261		
2/1/2002	546.288	250.064	129.351	82.522	85.707	12.049	356.022	26.429		
3/1/2002	604.819	276.856	143.210	91.363	75.773	17.048	394.167	29.261		
4/1/2002	547.002	250.169	138.591	88.416	40.058	34.660	381.452	28.317		
5/1/2002	604.819	276.856	143.210	91.363	7.176	39.516	394.167	29.261		
6/1/2002	585.309	267.925	138.591	88.416	0.014	85.858	381.452	28.317		
7/1/2002	604.819	276.856	143.210	91.363	0.000	167.861	394.167	29.261		
8/1/2002	604.819	276.856	143.210	91.363	0.000	175.015	394.167	29.261		
9/1/2002	585.309	267.925	138.591	88.416	0.000	173.008	381.452	28.317		
10/1/2002	604.819	276.856	143.210	91.363	7.234	71.770	394.167	29.261		
11/1/2002	585.309	267.925	138.591	88.416	44.921	35.617	381.452	28.317		
12/1/2002	565.799	258.994	143.210	91.363	126.262	10.397	394.167	29.261		
	7024.422		1686.187	1075.728		833.291		344.520	10964.147 Tot Site Elec	954.484 Reduction fr 1981
		3215.209			551.913		4640.994		8408.116 Tot Site Gas	22618.971 Reduction fr 1981
									19372.263 Tot Site Engy	23573.455 Reduction fr 1981
									43837.852 Tot Source Engy	27541.815 Reduction fr 1981

Figure C48. Los Angeles energy simulation results for deep envelope retrofit: “deep all” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	3386.312	67.506	394.167	29.261		
2/1/2002	546.288	250.064	129.351	82.522	2698.953	58.017	356.022	26.429		
3/1/2002	604.819	276.856	143.210	91.363	2785.015	61.943	394.167	29.261		
4/1/2002	547.002	250.169	138.591	88.416	2082.483	88.775	381.452	28.317		
5/1/2002	604.819	276.856	143.210	91.363	1479.774	114.158	394.167	29.261		
6/1/2002	585.309	267.925	138.591	88.416	1007.716	177.077	381.452	28.317		
7/1/2002	604.819	276.856	143.210	91.363	718.237	266.562	394.167	29.261		
8/1/2002	604.819	276.856	143.210	91.363	560.569	266.631	394.167	29.261		
9/1/2002	585.309	267.925	138.591	88.416	725.526	252.773	381.452	28.317		
10/1/2002	604.819	276.856	143.210	91.363	1316.685	158.590	394.167	29.261		
11/1/2002	585.309	267.925	138.591	88.416	2165.092	117.345	381.452	28.317		
12/1/2002	565.799	258.994	143.210	91.363	3117.604	75.256	394.167	29.261		
	7024.422		1686.187	1075.728		1704.633		344.520	11835.489 Tot Site Elec	83.142 Reduction fr 1981
		3215.209			22043.966		4640.994		29900.169 Tot Site Gas	1126.918 Reduction fr 1981
									41735.658 Tot Site Engy	1210.060 Reduction fr 1981
									69894.777 Tot Source Engy	1484.890 Reduction fr 1981

Figure C49. Los Angeles energy simulation results for deep envelope retrofit: “deep ceiling” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	519.381	16.098	394.167	29.261		
2/1/2002	546.288	250.064	129.351	82.522	346.593	17.327	356.022	26.429		
3/1/2002	604.819	276.856	143.210	91.363	340.327	21.985	394.167	29.261		
4/1/2002	547.002	250.169	138.591	88.416	211.678	39.825	381.452	28.317		
5/1/2002	604.819	276.856	143.210	91.363	84.871	41.622	394.167	29.261		
6/1/2002	585.309	267.925	138.591	88.416	24.852	90.130	381.452	28.317		
7/1/2002	604.819	276.856	143.210	91.363	5.651	183.667	394.167	29.261		
8/1/2002	604.819	276.856	143.210	91.363	1.178	196.272	394.167	29.261		
9/1/2002	585.309	267.925	138.591	88.416	9.561	194.715	381.452	28.317		
10/1/2002	604.819	276.856	143.210	91.363	69.188	85.863	394.167	29.261		
11/1/2002	585.309	267.925	138.591	88.416	223.842	47.358	381.452	28.317		
12/1/2002	565.799	258.994	143.210	91.363	436.167	16.493	394.167	29.261		
	7024.422		1686.187	1075.728		951.355		344.520	11082.211 Tot Site Elec	836.420 Reduction fr 1981
		3215.209			2273.290		4640.994		10129.493 Tot Site Gas	20897.594 Reduction fr 1981
									21211.704 Tot Site Engy	21734.014 Reduction fr 1981
									46077.733 Tot Source Engy	25301.934 Reduction fr 1981

Figure C50. Los Angeles energy simulation results for deep envelope retrofit: “deep envelope” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	1514.165	21.133	394.167	29.261		
2/1/2002	546.288	250.064	129.351	82.522	1161.035	23.338	356.022	26.429		
3/1/2002	604.819	276.856	143.210	91.363	1149.468	31.396	394.167	29.261		
4/1/2002	547.002	250.169	138.591	88.416	815.264	55.822	381.452	28.317		
5/1/2002	604.819	276.856	143.210	91.363	481.782	71.450	394.167	29.261		
6/1/2002	585.309	267.925	138.591	88.416	272.079	125.498	381.452	28.317		
7/1/2002	604.819	276.856	143.210	91.363	133.293	212.871	394.167	29.261		
8/1/2002	604.819	276.856	143.210	91.363	76.655	216.500	394.167	29.261		
9/1/2002	585.309	267.925	138.591	88.416	144.023	207.913	381.452	28.317		
10/1/2002	604.819	276.856	143.210	91.363	382.814	101.337	394.167	29.261		
11/1/2002	585.309	267.925	138.591	88.416	812.112	56.966	381.452	28.317		
12/1/2002	565.799	258.994	143.210	91.363	1329.229	20.211	394.167	29.261		
	7024.422		1686.187	1075.728		1144.434		344.520	11275.290 Tot Site Elec	643.341 Reduction fr 1981
		3215.209			8271.919		4640.994		16128.122 Tot Site Gas	14898.965 Reduction fr 1981
									27403.412 Tot Site Engy	15542.306 Reduction fr 1981
									53191.728 Tot Source Engy	18187.939 Reduction fr 1981

Figure C51. Los Angeles energy simulation results for deep envelope retrofit: “deep wall” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Totals kWh	Total Reductions kWh
1/1/2002	585.309	267.925	143.210	91.363	3116.311	67.314	394.167	29.261		
2/1/2002	546.288	250.064	129.351	82.522	2470.818	58.961	356.022	26.429		
3/1/2002	604.819	276.856	143.210	91.363	2538.524	65.651	394.167	29.261		
4/1/2002	547.002	250.169	138.591	88.416	1916.125	94.725	381.452	28.317		
5/1/2002	604.819	276.856	143.210	91.363	1364.897	123.645	394.167	29.261		
6/1/2002	585.309	267.925	138.591	88.416	937.000	186.620	381.452	28.317		
7/1/2002	604.819	276.856	143.210	91.363	674.095	270.914	394.167	29.261		
8/1/2002	604.819	276.856	143.210	91.363	529.836	269.944	394.167	29.261		
9/1/2002	585.309	267.925	138.591	88.416	682.852	255.706	381.452	28.317		
10/1/2002	604.819	276.856	143.210	91.363	1208.610	160.409	394.167	29.261		
11/1/2002	585.309	267.925	138.591	88.416	1985.022	116.240	381.452	28.317		
12/1/2002	565.799	258.994	143.210	91.363	2864.745	73.795	394.167	29.261		
	7024.422		1686.187	1075.728		1743.923		344.520	11874.779	Tot Site Elec
		3215.209			20288.836		4640.994		28145.039	Tot Site Gas
									40019.818	Tot Site Engy
									68116.648	Tot Source Engy
									43.852	Reduction fr 1981
									2882.048	Reduction fr 1981
									2925.900	Reduction fr 1981
									3263.018	Reduction fr 1981

Figure C52. Los Angeles energy simulation results for deep envelope retrofit: “deep window” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Generation (Elect) kWh	Totals kWh	Total Reduction kWh
1/1/2002	585.309	267.925	143.210	91.363	3511.204	71.099	394.167	29.261	-615.841		
2/1/2002	546.288	250.064	129.351	82.522	2799.123	61.745	356.022	26.429	-648.046		
3/1/2002	604.819	276.856	143.210	91.363	2891.357	67.980	394.167	29.261	-933.298		
4/1/2002	547.002	250.169	138.591	88.416	2179.048	97.651	381.452	28.317	-1048.765		
5/1/2002	604.819	276.856	143.210	91.363	1567.831	127.130	394.167	29.261	-1113.775		
6/1/2002	585.309	267.925	138.591	88.416	1085.219	190.854	381.452	28.317	-1186.301		
7/1/2002	604.819	276.856	143.210	91.363	795.885	275.014	394.167	29.261	-1274.386		
8/1/2002	604.819	276.856	143.210	91.363	632.109	274.055	394.167	29.261	-1214.510		
9/1/2002	585.309	267.925	138.591	88.416	801.614	259.273	381.452	28.317	-1004.413		
10/1/2002	604.819	276.856	143.210	91.363	1401.562	164.303	394.167	29.261	-862.765		
11/1/2002	585.309	267.925	138.591	88.416	2267.329	120.651	381.452	28.317	-710.826		
12/1/2002	565.799	258.994	143.210	91.363	3238.530	78.244	394.167	29.261	-638.028		
	7024.422		1686.187	1075.728		1787.997		344.520	-5013.126424	6905.727	Tot Site Elec
		3215.209			23170.811		4640.994			31027.014	Tot Site Gas
										37932.741	Tot Site Engy
										55503.720	Tot Source Engy
										5012.904	Reduction (increas)
										0.073	Reduction fr 1981
										5012.977	Reduction fr 1981
										15875.946	Reduction fr 1981

Figure C53. Los Angeles energy simulation results for renewable energy: “pv” case.

Date/Time	Room Electricity kWh	Room Gas kWh	Lighting kWh	System Pumps kWh	Heating (Gas) kWh	Cooling (Electric) kWh	DHW (Gas) kWh	Exterior lighting kWh	Generation (Elect) kWh	Totals kWh	Total Reduction kWh
1/1/2002	585.309	267.925	143.210	91.363	3511.204	71.099	394.167	29.261	-615.841		
2/1/2002	546.288	250.064	129.351	82.522	2799.123	61.745	356.022	26.429	-648.046		
3/1/2002	604.819	276.856	143.210	91.363	2891.357	67.980	394.167	29.261	-933.298		
4/1/2002	547.002	250.169	138.591	88.416	2179.048	97.651	381.452	28.317	-1048.765		
5/1/2002	604.819	276.856	143.210	91.363	1567.831	127.130	394.167	29.261	-1113.775		
6/1/2002	585.309	267.925	138.591	88.416	1085.219	190.854	381.452	28.317	-1186.301		
7/1/2002	604.819	276.856	143.210	91.363	795.885	275.014	394.167	29.261	-1274.386		
8/1/2002	604.819	276.856	143.210	91.363	632.109	274.055	394.167	29.261	-1214.510		
9/1/2002	585.309	267.925	138.591	88.416	801.614	259.273	381.452	28.317	-1004.413		
10/1/2002	604.819	276.856	143.210	91.363	1401.562	164.303	394.167	29.261	-862.765		
11/1/2002	585.309	267.925	138.591	88.416	2267.329	120.651	381.452	28.317	-710.826		
12/1/2002	565.799	258.994	143.210	91.363	3238.530	78.244	394.167	29.261	-638.028		
	7024.422		1686.187	1075.728		1787.997		344.520	-12032.091	0.000	Tot Site Elec
		3215.209			23170.811		4640.994			31027.014	Tot Site Gas
										31027.014	Tot Site Engy
										33633.283	Tot Source Engy
										11918.631	Reduction (increas)
										0.073	Reduction fr 1981
										11918.704	Reduction fr 1981
										37746.384	Reduction fr 1981

Figure C54. Los Angeles energy simulation results for renewable energy: “pv + battery” case.

Appendix D

Total carbon assumptions and results.

EPA emission factors (at point of purchase)	elec				gas			
	#CO2e / MWh	kgCO2e / kWh	grid loss factor	emission rate (kgCO2e / kWh)	CO2 factor (kgCO2 / mmBtu)	CH4 factor (kgCH4 / mmBtu)	N2O factor (kgCH4 / mmBtu)	emission rate (kgCO2e / kWh)
	https://www.epa.gov		https://www.epa.gov		EPA Emission Factors April 2021 (CO2 + CH4 * 25 + N2O * 298)			
houston	822.000	0.373	0.052	0.393	53.060	0.025	0.030	0.181
los angeles	515.500	0.234	0.053	0.247	53.060	0.025	0.030	0.181
chicago	990.800	0.449	0.053	0.475	53.060	0.025	0.030	0.181
nyc	234.500	0.106	0.053	0.112	53.060	0.025	0.030	0.181
zero	0.000	0.000	0.000	0.000	53.060	0.025	0.030	0.181

Figure D1. Grid emission factors.

Report Summary

Created with Tally

Non-commercial Version 2021.11.01.01

Author

Allison Hyatt

Company

Harvard Graduate School of Design

Date

3/6/2022

Project

Thesis

Location

Cambridge, MA

Gross Area

220.8 m²

Building Life

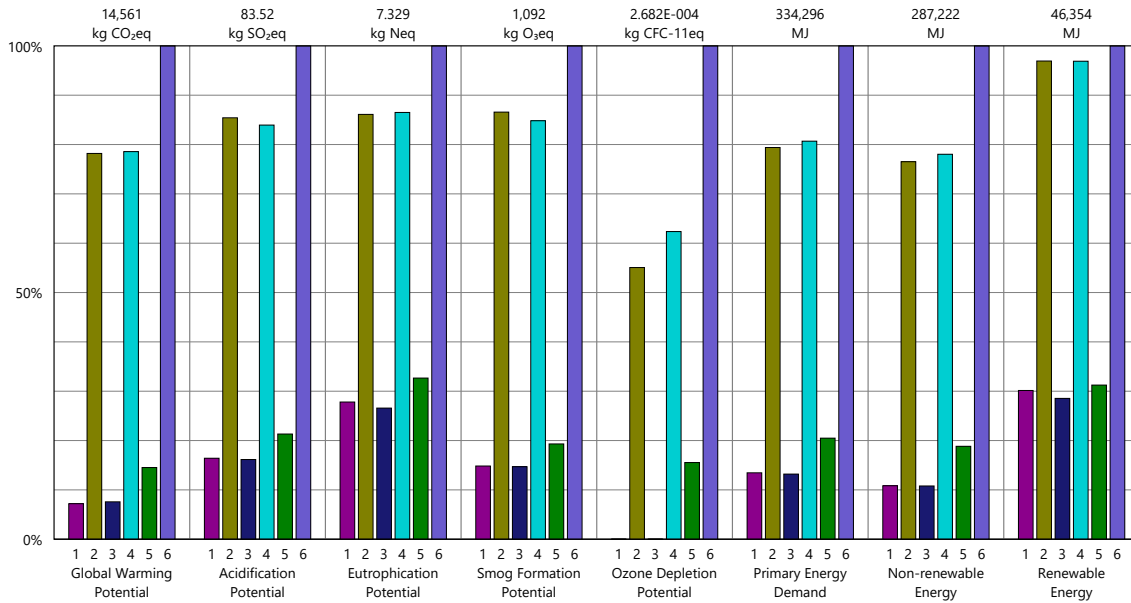
30 years

Boundaries

Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

Goal and Scope of Assessment

The building under study is the single-family detached house prototype DOE model in Houston, TX, Los Angeles, CA, and Chicago, IL. The scope includes building envelope upgrades to the wall insulation, roof insulation, air sealing, and windows for both a shallow and deep envelope case. The timeframe is limited to an assessment period of thirty years.



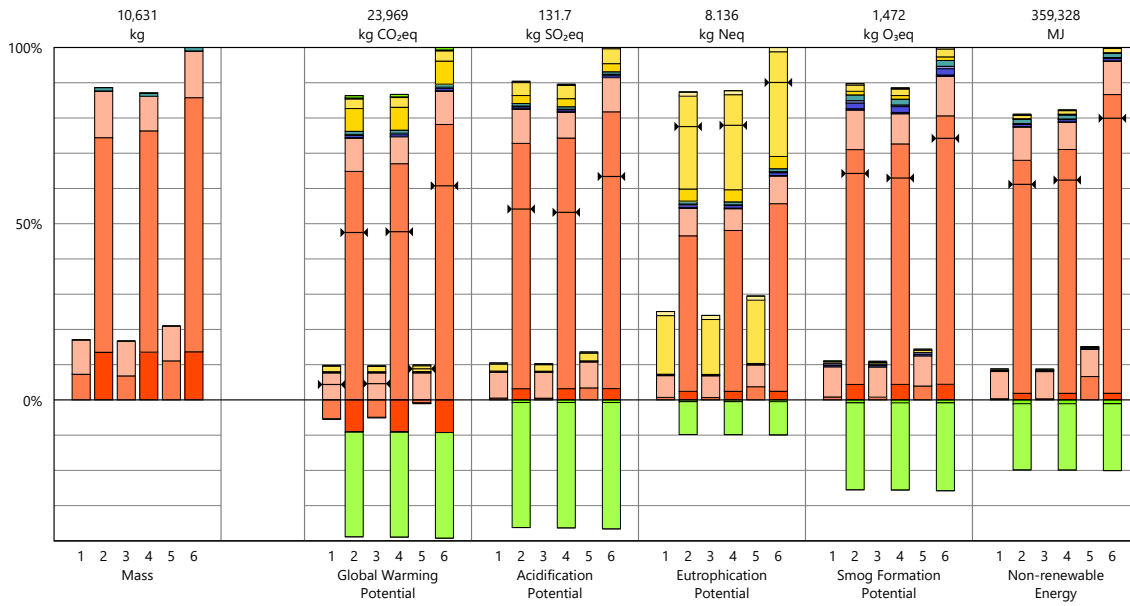
Legend

Design Options

- 2a_hous_2_shallow
- 2a_hous_3_deep
- 3b_la_2_shallow
- 3b_la_3_deep
- 5a_chi_2_shallow
- 5a_chi_3_deep

Figure D5. Tally report summary.

Results per Life Cycle Stage, itemized by Division



Legend

Net value (impacts + credits)

Design Options

- Option 1 - 2a_hous_2_shallow
- Option 2 - 2a_hous_3_deep
- Option 3 - 3b_la_2_shallow
- Option 4 - 3b_la_3_deep
- Option 5 - 5a_chi_2_shallow
- Option 6 - 5a_chi_3_deep

Product [A1-A3]

- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing

Transportation [A4]

- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing

Maintenance and Replacement [B2-B5]

- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing

End of Life [C2-C4]

- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing

Module D [D]

- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing

Figure D6. Tally results per life cycle stage, itemized by division.

Calculation Methodology

LIFE CYCLE ASSESSMENT METHODS

The following provides a description of terms and methods associated with the use of Tally to conduct life cycle assessment for construction works and construction products. Tally methodology is consistent with LCA standards ISO 14040-14044, ISO 21930:2017, ISO 21931:2010, EN 15804:2012, and EN 15978:2011. For more information about LCA, please refer to these standards or visit www.choosetally.com.

Studied objects

The life cycle assessment (LCA) results reported represent an analysis of a single building, multiple buildings, or a comparative analysis of two or more building design options. The assessment may represent the complete architectural, structural, and finish systems of the building(s) or a subset of those systems. This may be used to compare the relative environmental impacts associated with building components or for comparative study with one or more reference buildings. Design options may represent a full or partial building across various stages of the design process, or they may represent multiple schemes of a full or partial building that are being compared to one another across a range of evaluation criteria.

Functional unit and reference unit

A functional unit is the quantified performance of a product, building, or system that defines the object of the study. The functional unit of a single building should include the building type (e.g. office, factory), relevant technical and functional requirements (e.g. regulatory requirements, energy performance), pattern of use (e.g. occupancy, usable floor area), and the required service life. For a design option comparison of a partial building, the functional unit is the complete set of building systems or products that perform a given function. It is the responsibility of the modeler to assure that reference buildings or design options are functionally equivalent in terms of scope and relevant performance. The expected life of the building has a default value of 60 years and can be modified by the modeler.

The reference unit is the full collection of processes and materials required to produce a building or portion thereof and is quantified according to the given goal and scope of the assessment over the full life of the building. If construction impacts are included in the assessment, the reference unit also includes the energy, water, and fuel consumed on the building site during construction. If operational energy is included in the assessment, the reference unit includes the electrical and thermal energy consumed on site over the life of the building.

Data source

Tally utilizes a custom designed LCA database that combines material attributes, assembly details, and architectural specifications with environmental impact data resulting from the collaboration between KieranTimberlake and thinkstep. LCA modeling was conducted in GaBi 8.5 using GaBi 2018 databases and in accordance with [GaBi databases and modeling principles](#).

The data used are intended to represent the US and the year 2017. Where representative data were unavailable, proxy data were used. The datasets used, their geographic region, and year of reference are listed for each entry. An effort was made to choose proxy datasets that are technologically consistent with the relevant entry.

Data quality and uncertainty

Uncertainty in results can stem from both the data used and their application. Data quality is judged by: its measured, calculated, or estimated precision; its completeness, such as unreported emissions; its consistency, or degree of uniformity of the methodology applied on a study serving as a data source; and geographical, temporal, and technological representativeness. The [GaBi LCI databases](#) have been used in LCA models worldwide in both industrial and scientific applications. These LCI databases have additionally been used both as internal and critically reviewed and published studies. Uncertainty introduced by the use of proxy data is reduced by using technologically, geographically, and/or temporally similar data. It is the responsibility of the modeler to appropriately apply the predefined material entries to the building under study.

System boundaries and delimitations

The analysis accounts for the full cradle to grave life cycle of the design options studied across all life cycle stages, including material manufacturing, maintenance and replacement, and eventual end of life. Optionally, the construction impacts and operational energy of the building can be included within the scope. Product stage impacts are excluded for materials and components indicated as existing or salvaged by the modeler. The modeler defines whether the boundary includes or excludes the flow of biogenic carbon, which is the carbon absorbed and generated by biological sources (e.g. trees, algae) rather than from fossil resources.

Architectural materials and assemblies include all materials required for the product's manufacturing and use including hardware, sealants, adhesives, coatings, and finishing. The materials are included up to a 1% cut-off factor by mass except for known materials that have high environmental impacts at low levels. In these cases, a 1% cut-off was implemented by impact.

Figure D7. Tally calculation methodology (1/3).

Calculation Methodology

LIFE CYCLE STAGES

The following describes the scope and system boundaries used to define each stage of the life cycle of a building or building product, from raw material acquisition to final disposal. For products listed in Tally as Environmental Product Declarations (EPD), the full life cycle impacts are included, even if the published EPD only includes the Product stage [A1-A3].

Product [EN 15978 A1 - A3]

This encompasses the full manufacturing stage, including raw material extraction and processing, intermediate transportation, and final manufacturing and assembly. The product stage scope is listed for each entry, detailing any specific inclusions or exclusions that fall outside of the cradle to gate scope. Infrastructure (buildings and machinery) required for the manufacturing and assembly of building materials are not included and are considered outside the scope of assessment.

Transportation [EN 15978 A4]

This counts transportation from the manufacturer to the building site during the construction stage and can be modified by the modeler.

Construction Installation [EN 15978 A5] (Optional)

This includes the anticipated or measured energy and water consumed on-site during the construction installation process, as specified by the modeler.

Maintenance and Replacement [EN 15978 B2-B5]

This encompasses the replacement of materials in accordance with their expected service life. This includes the end of life treatment of the existing products as well as the cradle to gate manufacturing and transportation to site of the replacement products. The service life is specified separately for each product. Refurbishment of materials marked as existing or salvaged by the modeler is also included.

Operational Energy [EN 15978 B6] (Optional)

This is based on the anticipated or measured energy and natural gas consumed at the building site over the lifetime of the building, as indicated by the modeler.

End of Life [EN 15978 C2-C4]

This includes the relevant material collection rates for recycling, processing requirements for recycled materials, incineration rates, and landfilling rates. The impacts associated with landfilling are based on average material properties, such as plastic waste, biodegradable waste, or inert material. Stage C2 encompasses the transport from the construction site to end-of-life treatment based on national averages. Stages C3-C4 account for waste processing and disposal, i.e., impacts associated with landfilling or incineration.

Module D [EN 15978 D]

This accounts for reuse potentials that fall beyond the system boundary, such as energy recovery and recycling of materials. Along with processing requirements, the recycling of materials is modeled using an avoided burden approach, where the burden of primary material production is allocated to the subsequent life cycle based on the quantity of recovered secondary material. Incineration of materials includes credit for average US energy recovery rates.

PRODUCT	CONSTRUCTION	USE	END-OF-LIFE	MODULE D
A1. Extraction A2. Transport (to factory) A3. Manufacturing	A4. Transport (to site) A5. Construction Installation	B1. Use B2. Maintenance B3. Repair B4. Replacement B5. Refurbishment B6. Operational energy B7. Operational water	C1. Demolition C2. Transport (to disposal) C3. Waste processing C4. Disposal	D. Benefits and loads beyond the system boundary from: 1. Reuse 2. Recycling 3. Energy recovery

Life-Cycle Stages as defined by EN 15978. Processes included in Tally modeling scope are shown in bold. Italics indicate optional processes.

Figure D8. Tally calculation methodology (2/3).

Calculation Methodology

ENVIRONMENTAL IMPACT CATEGORIES

A characterization scheme translates all emissions and fuel use associated with the reference flow into quantities of categorized environmental impact. As the degree that the emissions will result in environmental harm depends on regional ecosystem conditions and the location in which they occur, the results are reported as impact potential. Potential impacts are reported in kilograms of equivalent relative contribution (eq) of an emission commonly associated with that form of environmental impact (e.g. kg CO₂eq).

The following list provides a description of environmental impact categories reported according to the TRACI 2.1 characterization scheme, the environmental impact model developed by the US EPA to quantify environmental impact risk associated with emissions to the environment in the United States. TRACI is the standard environmental impact reporting format for LCA in North America. Impacts associated with land use change and fresh water depletion are not included in TRACI 2.1. For more information on TRACI 2.1, reference Bare 2010, EPA 2012, and Guinée 2001. For further description of measurement of environmental impacts in LCA, see Simonen 2014.

Acidification Potential (AP) kg SO₂eq

A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H⁺) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline, and the deterioration of building materials.

Eutrophication Potential (EP) kg Neq

A measure of the impacts of excessively high levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems, increased biomass production may lead to depressed oxygen levels caused by the additional consumption of oxygen in biomass decomposition.

Global Warming Potential (GWP) kg CO₂eq

A measure of greenhouse gas emissions, such as carbon dioxide and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may, in turn, have adverse impacts on ecosystem health, human health, and material welfare.

Ozone Depletion Potential (ODP) kg CFC-11eq

A measure of air emissions that contribute to the depletion of the stratospheric ozone layer. Depletion of the ozone leads to higher levels of UVB ultraviolet rays reaching the earth's surface with detrimental effects on humans and plants. As these impacts tend to be very small, ODP impacts can be difficult to calculate and are prone to a larger margin of error than the other impact categories.

Smog Formation Potential (SFP) kg O₃eq

A measure of ground level ozone, caused by various chemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in sunlight. Human health effects can result in a variety of respiratory issues, including increasing symptoms of bronchitis, asthma, and emphysema. Permanent lung damage may result from prolonged exposure to ozone. Ecological impacts include damage to various ecosystems and crop damage.

Primary Energy Demand (PED) MJ (lower heating value)

A measure of the total amount of primary energy extracted from the earth. PED tracks energy resource use, not the environmental impacts associated with the resource use. PED is expressed in energy demand from non-renewable resources and from renewable resources. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account when calculating this result.

Non-Renewable Energy Demand MJ (lower heating value)

A measure of the energy extracted from non-renewable resources (e.g. petroleum, natural gas, etc.) contributing to the PED. Non-renewable resources are those that cannot be regenerated within a human time scale. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account when calculating this result.

Renewable Energy Demand MJ (lower heating value)

A measure of the energy extracted from renewable resources (e.g. hydropower, wind energy, solar power, etc.) contributing to the PED. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account when calculating this result.

Figure D9. Tally calculation methodology (3/3).

LCI Data

END-OF-LIFE [C2-C4]

A Life Cycle Inventory (LCI) is a compilation and quantification of inputs and outputs for the reference unit. The following LCI provides a summary of all energy, construction, transportation, and material inputs present in the study. Materials are listed in alphabetical order along with a list of all Revit families and Tally entries in which they occur, along with any notes and system boundaries accompanying their database entries. Each entry lists the detailed scope for the LCI data sources used from the GaBi LCI database and identifies the LCI data source.

For LCI data sourced from an Environmental Product Declaration (EPD), the product manufacturer, EPD identification number, and Program Operator are listed. Where the LCI source does not provide data for all life cycle stages, default North American average values are used. This is of particular importance for European EPD sources, as EPD data are generally only provided for the product stage, and North American average values are used for the remaining life cycle stages.

Where specific quantities are associated with a data entry, such as user inputs, energy values, or material mass, the quantity is listed on the same line as the title of the entry.

TRANSPORTATION [A4]

Default transportation values are based on the three-digit material commodity code in the 2012 Commodity Flow Survey by the US Department of Transportation Bureau of Transportation Statistics and the US Department of Commerce where more specific industry-level transportation is not available.

Transportation by Barge

Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by barge.

LCI Source:
GLO: Average ship, 1500t payload capacity/ canal ts (2017)
US: Diesel mix at filling station ts (2014)

Transportation by Container Ship

Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by container ship.

LCI Source:
GLO: Container ship, 27500 dwt payload capacity, ocean going ts (2017)
US: Heavy fuel oil at refinery (0.3wt.% S) ts (2014)

Transportation by Rail

Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by cargo rail.

LCI Source:
GLO: Rail transport cargo - Diesel, average train, gross tonne weight 1000t / 726t payload capacity ts (2017)
US: Diesel mix at filling station ts (2014)

Transportation by Truck

Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by diesel truck.

LCI Source:
US: Truck - Trailer, basic enclosed / 45,000 lb payload - 8b ts (2017)
US: Diesel mix at filling station ts (2014)

Figure D10. Tally Life Cycle Inventory data (1/5).

LCI Data (continued)

END-OF-LIFE [C2-C4]

Specific end-of-life scenarios are detailed for each entry based on the US construction and demolition waste treatment methods and rates in the 2016 WARM Model by the US Environmental Protection Agency except where otherwise specified. Heterogeneous assemblies are modeled using the appropriate methodologies for the component materials.

End-of-Life Landfill

Scope:

Materials for which no recycling or incineration rates are known, no recycling occurs within the US at a commercial scale, or which are unable to be recycled are landfilled. This includes glass, drywall, insulation, and plastics. The solids contents of coatings, sealants, and paints are assumed to go to landfill, while the solvents or water evaporate during installation. Where the landfill contains biodegradable material, the energy recovered from landfill gas utilization is reflected as a credit in Module D.

LCI Source:

US: Glass/inert on landfill ts (2017)
US: Biodegradable waste on landfill, post-consumer ts (2017)
US: Plastic waste on landfill, post-consumer ts (2017)

Concrete End-of-Life

Scope:

Concrete (or other masonry products) are recycled into aggregate or general fill material or they are landfilled. It is assumed that 55% of the concrete is recycled. Module D accounts for both the credit associated with off-setting the production aggregate and the burden of the grinding energy required for processing.

LCI Source:

US: Diesel mix at refinery ts (2014)
GLO: Fork lifter (diesel consumption) ts (2016)
EU - 28 Gravel 2/32 ts (2017)
US: Glass/inert on landfill ts (2017)

Metals End-of-Life

Scope:

Metal products are modeled using the avoided burden approach. The recycling rate at end of life is used to determine how much secondary metal can be recovered after having subtracted any scrap input into manufacturing (net scrap). Net scrap results in an environmental credit in Module D for the corresponding share of the primary burden that can be allocated to the subsequent product system using secondary material as an input. If the value in Module D reflects an environmental burden, then the original product (A1-A3) contains more secondary material than is recovered.

LCI Source:

Aluminum - RNA: Primary Aluminum Ingot AA/ts (2010)
Aluminum - RNA: Secondary Aluminum Ingot AA/ts (2010)
Brass - GLO: Zinc mix ts (2012)
Brass - GLO: Copper (99.99% cathode) ICA (2013)
Brass - EU-28: Brass (CuZn20) ts (2017)
Copper - DE: Recycling potential copper sheet ts (2016)
Steel - GLO: Value of scrap worldsteel (2014)
Zinc - GLO: Special high grade zinc IZA (2012)

Wood End-of-Life

Scope:

End of Life waste treatment methods and rates for wood are based on the 2014 Municipal Solid Waste and Construction Demolition Wood Waste Generation and Recovery in the United States report by Dovetail Partners, Inc. It is assumed that 63.5% of wood is sent to landfill, 22% to incineration, and 14.5% to recovery.

LCI Source:

US: Untreated wood in waste incineration plant ts (2017)
US: Wood product (OSB, particle board) waste in waste incineration plant ts (2017)
US: Wood products (OSB, particle board) on landfill, post-consumer ts (2017)
US: Untreated wood on landfill, post-consumer ts (2017)
RNA: Softwood lumber CORRIM (2011)

Figure D11. Tally Life Cycle Inventory data (2/5).

LCI Data

PRODUCT [A1-A3]

Materials and components are listed in alphabetical order along with a list of all Revit families and Tally entries in which they occur. The masses given here refer to the quantity of each material used over the building's life-cycle, which includes both Product [A1-A3] and Use [B2-B5] stages.

Additional provided data describing scope boundaries for each life cycle stage may be useful for interpretation of the impacts associated with the specific material or component. Each material or component is listed with its service life, or period of time after installation it is expected to meet the service requirements prior to replacement or repair. This value is indicated in parentheses next to the mass of the material associated with the listed Revit family. Values for transportation distance or service life shown with an asterisk (*) indicate user-defined changes to default values. Values for service life shown with a dagger (†) indicate materials identified by the modeler as existing or salvaged.

Aluminum extrusion, AEC - EPD 4,571.0 kg

Used in the following Revit families:

new_wall_polyiso_3in_hous	1,517.1 kg (30 yrs)
new_wall_polyiso_4in_la	1,521.0 kg (30 yrs)
new_wall_polyiso_7in_chi	1,532.9 kg (30 yrs)

Used in the following Tally entries:
Fiber cement panel

Description:
Extruded aluminum part. Industry-wide EPD from the Aluminum Extruders Council.

Life Cycle Inventory:
For information and quantities, see EPD

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 663 km

End-of-Life Scope:
95% Recovered
5% Landfilled (inert material)

Module D Scope:
Product has 36.4% scrap input while remainder is processed and credited as avoided burden

LCI Source:
RNA: Aluminum extrusion, mill finish - AEC (A1-A3) ts-EPD (2015)
RNA: Primary Aluminum Ingot AA/ts (2010)
RNA: Secondary Aluminum Ingot AA/ts (2010)

EPD Source:
[11240237.101.1](#)

EPD Designation Holder:
Aluminum Extruders Council (AEC)

EPD Program Operator:
UL Environment

EPD Expiration:
10/4/2021

Cellulose insulation, blown 4,567.4 kg

Used in the following Revit families:

reno_clg_attic_cellulose_7in	97.7 kg (30 yrs)
reno_clg_attic_cellulose_8in	732.9 kg (30 yrs)
reno_wall_core_cellulose	3,736.9 kg (30 yrs)

Used in the following Tally entries:
Cellulose insulation, blown

Description:
Blown-in cellulose insulation

Life Cycle Inventory:
Waste paper fibers
Boric acid
Boraxpentahydrate

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 1020 km

End-of-Life Scope:
100% Landfilled (biodegradable waste)

LCI Source:
DE: Cellulose fibre blowing insulation material (EN15804 A1-A3) ts (2017)

Exterior grade plywood, US 4,327.9 kg

Used in the following Revit families:

new_wall_polyiso_3in_hous	1,436.4 kg (30 yrs)
new_wall_polyiso_4in_la	1,440.2 kg (30 yrs)
new_wall_polyiso_7in_chi	1,451.4 kg (30 yrs)

Used in the following Tally entries:
Plywood, exterior grade

Description:
Plywood, unfinished

Life Cycle Inventory:
Proxied by interior grade plywood

Product Scope:
Cradle to gate, uncoated

Transportation Distance:
By truck: 468 km

End-of-Life Scope:
14.5% Recovered
22% Incinerated with energy recovery
63.5% Landfilled (wood product waste)

Module D Scope:
Recovered wood products credited as avoided burden.

LCI Source:
RNA: Softwood plywood CORRIM (2011)

Fasteners, stainless steel 45.7 kg

Used in the following Revit families:

new_wall_polyiso_3in_hous	15.2 kg (30 yrs)
new_wall_polyiso_4in_la	15.2 kg (30 yrs)
new_wall_polyiso_7in_chi	15.3 kg (30 yrs)

Used in the following Tally entries:
Fiber cement panel

Description:
Stainless steel part, appropriate for use as fasteners and specialized hardware (bolts, rails, clips, etc.). Data based on industry-wide EPDs for primary and secondary metal from the World Steel Association.

Life Cycle Inventory:
100% Stainless steel

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 1001 km

End-of-Life Scope:
98% Recovered
2% Landfilled (inert material)

Module D Scope:
Product has 58% scrap input while remainder is processed and credited as avoided burden

LCI Source:
RER: Stainless steel Quarto plate (304) Eurofer (2010)
GLO: Steel turning ts (2017)
US: Electricity grid mix ts (2014)
RER: Stainless steel flat product (304) - value of scrap Eurofer (2010)

Figure D12. Tally Life Cycle Inventory data (3/5).

LCI Data (continued)

Fiber cement board	6,688.1 kg	Life Cycle Inventory: Double-pane glass IGU (Air filled, with spacer and sealant)
Used in the following Revit families:		Product Scope: Cradle to gate
new_wall_polyiso_3in_hous	2,219.7 kg (30 yrs)	Transportation Distance: By truck: 940 km
new_wall_polyiso_4in_la	2,225.5 kg (30 yrs)	End-of-Life Scope: 100% Landfilled (inert waste)
new_wall_polyiso_7in_chi	2,242.8 kg (30 yrs)	LCI Source: DE: Double glazing unit ts (2017), modified to exclude coating and argon
Used in the following Tally entries: Fiber cement panel		
Description: Medium density fiber cement board, for interior and exterior, as cladding material for curtain-type ventilated facades, roofing, for decorative interior finishing, drywall, foundation base, or permanent formwork. Default thickness 5/16".		
Life Cycle Inventory: 40% Cement 10% Cellulose 25% Sand 25% Fly ash		Glazing, triple, insulated (air)
Product Scope: Cradle to gate, excluding any coatings		2,167.2 kg
Transportation Distance: By truck: 172 km		Used in the following Revit families: Fixed
End-of-Life Scope: 100% landfilled (10% biodegradable waste, 90% inert waste)		2,167.2 kg (30 yrs)
Module D Scope: Credit associated with energy recovered from landfill gas utilization		Used in the following Tally entries: Glazing, triple pane IGU
LCI Source: DE: Fly ash (EN15804 A1-A3) ts (2017) US: Portland cement PCA/ts (2014) DE: Cellulose fibre boards (EN 15804 A1-A3) ts (2017) US: Silica sand (Excavation and processing) ts (2017)		Description: Glazing, triple, insulated (air filled), 1/8" (4 mm) float glass clear, inclusive of sealant, and spacers
		Life Cycle Inventory: Triple-pane glass IGU (Air filled, with spacer and sealant)
		Product Scope: Cradle to gate
		Transportation Distance: By truck: 940 km
		End-of-Life Scope: 100% Landfilled (inert waste)
		LCI Source: DE: Insulation glass compound (3 panes) ts (2017), modified to exclude coating and argon
Fluid applied synthetic polymer air barrier	1,585.3 kg	Paint, exterior acrylic latex
Used in the following Revit families:		457.1 kg
new_wall_polyiso_3in_hous	526.2 kg (30 yrs)	Used in the following Revit families:
new_wall_polyiso_4in_la	527.5 kg (30 yrs)	new_wall_polyiso_3in_hous
new_wall_polyiso_7in_chi	531.6 kg (30 yrs)	new_wall_polyiso_4in_la
Used in the following Tally entries: Fluid applied synthetic polymer air barrier		new_wall_polyiso_7in_chi
Description: Liquid-applied rubberized membrane		151.7 kg (10 yrs)
Life Cycle Inventory: 34% Calcium carbonate 30% Polymer blend (SBS) 1% Silica 5% Titanium dioxide 30% Water		152.1 kg (10 yrs)
Product Scope: Cradle to gate for materials only, neglects manufacturing requirements		153.3 kg (10 yrs)
Transportation Distance: By truck: 555 km		Used in the following Tally entries: Fiber cement panel
End-of-Life Scope: 70% Landfilled (plastic waste) (excludes water evaporation)		Description: Acrylic-based latex paint for exterior applications. Associated reference table includes primer.
LCI Source: US: Styrene-butadiene rubber (SBR) ts (2017) US: Silica sand (flour) ts (2017) US: Tap water from groundwater ts (2017) US: Titanium dioxide pigment ts (2017) US: Limestone flour (5mm) ts (2017) US: Electricity grid mix ts (2014)		Life Cycle Inventory: 20.5% Binding agent 35% Pigments and fillers 40% Water 4.5% Organic solvents
		Product Scope: Cradle to gate, including emissions during application
		Transportation Distance: By truck: 642 km
		End-of-Life Scope: 100% to landfill (plastic waste)
		LCI Source: DE: Application paint emulsion (building, exterior, white) ts (2017)
Glazing, double, insulated (air)	2,862.9 kg	PIR rigid foam insulation, roof, R=20.5, PIMA - EPD
Used in the following Revit families:		5,880.3 kg
Fixed	2,862.9 kg (30 yrs)	Used in the following Revit families:
Used in the following Tally entries: Glazing, double pane IGU		new_clg_attic_polyiso_12in
Description: Glazing, double, insulated (air filled), 1/8" (4 mm) float glass clear, inclusive of sealant, and spacers		new_clg_attic_polyiso_4in
		new_clg_attic_polyiso_8in
		new_wall_polyiso_3in_hous
		new_wall_polyiso_4in_la
		new_wall_polyiso_7in_chi
		1,213.1 kg (30 yrs)
		404.4 kg (30 yrs)
		1,617.5 kg (30 yrs)
		563.5 kg (30 yrs)
		753.3 kg (30 yrs)
		1,328.5 kg (30 yrs)
		Used in the following Tally entries: Polyisocyanurate (PIR), board

Figure D13. Tally Life Cycle Inventory data (4/5).

LCI Data (continued)

Description:
 Polyisocyanurate rigid foam roof insulation with glass-fiber reinforced facers, R-value of 20.5, 3.5" thickness (89 mm). Industry-wide EPD from the Polyisocyanurate Insulation Manufacturers Association.

Life Cycle Inventory:
 For information and quantities, see EPD

Product Scope:
 Cradle to gate

Transportation Distance:
 By truck: 250 km

End-of-Life Scope:
 100% Landfilled (plastic waste)

LCI Source:
 RNA: Polyisocyanurate rigid foam board roof insulation, R=20.5 (A1-A3) ts-EPD (2013)

EPD Source:
[EPD10043](#)

EPD Designation Holder:
 Polyisocyanurate Insulation Manufacturers Association

EPD Program Operator:
 NSF International

EPD Expiration:
 2/6/2020

Window frame, vinyl, divided operable **1,966.3 kg**

Used in the following Revit families:
 Fixed 1,966.3 kg (30 yrs)

Used in the following Tally entries:
 Window frame, vinyl

Description:
 Vinyl divided operable window frame inclusive of steel bracing

Life Cycle Inventory:
 46% PVC part
 54% metal reinforcement (Zinc-coated steel)

Product Scope:
 Cradle to gate, excludes hardware, casing, sealant

Transportation Distance:
 By truck: 496 km

End-of-Life Scope:
 100% Landfilled (plastic waste)

LCI Source:
 DE: Window frame PVC-U (EN15804 A1-A3) ts (2017)

Figure D14. Tally Life Cycle Inventory data (5/5).

Row Labels	Sum of Acidification Potential Total (kgSO2eq)	Sum of Eutrophication Potential Total (kgNeq)	Sum of Global Warming Potential Total (kgCO2eq)	Sum of Ozone Depletion Potential Total (CFC-11eq)	Sum of Smog Formation Potential Total (kgO3eq)	Sum of Primary Energy Demand Total (MJ)	Sum of Non-renewable Energy Demand Total (MJ)	Sum of Renewable Energy Demand Total (MJ)	Sum of Mass Total (kg)
2a_hous_2_shallow	13.71	2.04	1,048.70	2.54E-08	162.06	45,009.78	31,132.43	13,975.59	1,816.59
[A1-A3] Product	10.38	0.56	558.40	2.54E-08	138.03	42,711.72	28,920.22	13,887.68	1,816.59
Ceilings	0.13	0.01	-241.85	7.21E-11	2.32	2,447.78	228.65	2,227.92	146.57
Walls	0.56	0.05	-1,033.84	3.08E-10	9.90	10,463.69	977.45	9,523.84	626.57
Windows	9.69	0.50	1,834.09	2.50E-08	125.82	29,800.25	27,714.12	2,135.92	1,043.45
[A4] Transportation	0.41	0.03	88.67	3.04E-12	13.58	1,289.41	1,258.55	31.18	
Ceilings	0.04	0.00	8.16	2.80E-13	1.25	118.71	115.87	2.87	
Walls	0.16	0.01	34.89	1.20E-12	5.34	507.45	495.30	12.27	
Windows	0.21	0.02	45.61	1.56E-12	6.98	663.25	647.38	16.04	
[B2-B5] Maintenance and Replacement	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Ceilings	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Walls	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
[C2-C4] End of Life	2.98	1.45	422.43	1.47E-11	10.95	1,369.71	1,280.69	90.28	
Ceilings	0.49	0.26	71.38	1.19E-12	1.17	110.52	103.33	7.28	
Walls	2.11	1.10	305.14	5.07E-12	4.99	472.43	441.73	31.14	
Windows	0.37	0.09	45.91	8.44E-12	4.79	786.76	735.63	51.86	
[D] Module D	-0.05	0.00	-20.80	-2.43E-11	-0.49	-361.06	-327.04	-33.56	
Ceilings	-0.01	0.00	-3.94	-4.60E-12	-0.09	-68.45	-62.00	-6.36	
Walls	-0.04	0.00	-16.85	-1.97E-11	-0.40	-292.61	-265.04	-27.19	
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	
2a_hous_3_deep	71.35	6.31	11,385.62	1.48E-04	945.54	265,421.60	219,779.84	44,929.67	9,423.03
[A1-A3] Product	108.68	4.43	15,605.71	1.48E-04	1,210.19	367,656.85	278,182.66	88,746.05	9,321.89
Ceilings	7.72	0.50	1,844.67	8.33E-05	93.70	48,626.21	45,436.61	3,198.39	955.30
Walls	88.18	3.28	11,498.99	6.50E-05	951.52	282,708.60	198,841.23	83,104.39	6,955.24
Windows	12.79	0.64	2,262.05	2.52E-08	164.97	36,322.04	33,904.81	2,423.26	1,411.34
[A4] Transportation	1.19	0.10	257.30	8.81E-12	39.40	3,741.62	3,652.08	90.48	
Ceilings	0.09	0.01	19.20	6.58E-13	2.94	279.24	272.56	6.75	
Walls	0.80	0.07	173.60	5.95E-12	26.58	2,524.54	2,464.13	61.05	
Windows	0.30	0.02	64.49	2.21E-12	9.87	937.84	915.39	22.68	
[B2-B5] Maintenance and Replacement	0.92	0.07	205.22	1.09E-10	24.09	4,547.61	4,086.29	457.36	101.14
Ceilings	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Walls	0.92	0.07	205.22	1.09E-10	24.09	4,547.61	4,086.29	457.36	101.14
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
[C2-C4] End of Life	8.27	2.52	2,268.12	6.27E-11	47.29	5,597.86	5,235.53	366.29	
Ceilings	1.06	0.47	106.97	7.73E-12	5.88	720.30	673.49	47.48	
Walls	6.77	1.95	2,099.05	4.36E-11	35.13	3,813.41	3,567.04	248.67	
Windows	0.45	0.10	62.10	1.14E-11	6.28	1,064.15	995.00	70.14	
[D] Module D	-47.72	-0.80	-6,950.72	-6.13E-07	-375.43	-116,122.34	-71,314.72	-44,730.51	
Ceilings	-0.01	0.00	-3.94	-4.60E-12	-0.09	-68.45	-62.00	-6.36	
Walls	-47.71	-0.80	-6,946.78	-6.13E-07	-375.34	-116,053.89	-71,314.72	-44,724.15	
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	
3b_la_2_shallow	13.49	1.95	1,104.12	2.54E-08	160.52	44,140.26	31,003.81	13,231.69	1,767.73
[A1-A3] Product	10.33	0.56	639.02	2.54E-08	137.26	41,895.79	28,844.01	13,145.04	1,767.73
Ceilings	0.09	0.01	-161.23	4.81E-11	1.54	1,631.85	152.44	1,485.28	97.72
Walls	0.56	0.05	-1,033.84	3.08E-10	9.90	10,463.69	977.45	9,523.84	626.57
Windows	9.69	0.50	1,834.09	2.50E-08	125.82	29,800.25	27,714.12	2,135.92	1,043.45
[A4] Transportation	0.40	0.03	85.95	2.94E-12	13.16	1,249.84	1,219.93	30.22	
Ceilings	0.03	0.00	5.44	1.86E-13	0.83	79.14	77.24	1.91	
Walls	0.16	0.01	34.89	1.20E-12	5.34	507.45	495.30	12.27	
Windows	0.21	0.02	45.61	1.56E-12	6.98	663.25	647.38	16.04	
[B2-B5] Maintenance and Replacement	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Ceilings	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Walls	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
[C2-C4] End of Life	2.81	1.36	398.64	1.43E-11	10.56	1,332.87	1,246.25	87.86	
Ceilings	0.33	0.17	47.59	7.91E-13	0.78	73.68	68.89	4.86	
Walls	2.11	1.10	305.14	5.07E-12	4.99	472.43	441.73	31.14	
Windows	0.37	0.09	45.91	8.44E-12	4.79	786.76	735.63	51.86	
[D] Module D	-0.05	0.00	-19.48	-2.27E-11	-0.46	-338.24	-306.37	-31.43	
Ceilings	-0.01	0.00	-2.63	-3.07E-12	-0.06	-45.63	-41.33	-4.24	
Walls	-0.04	0.00	-16.85	-1.97E-11	-0.40	-292.61	-265.04	-27.19	
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	
3b_la_3_deep	70.11	6.34	11,439.49	1.67E-04	926.45	269,714.09	224,112.77	44,910.77	9,260.21
[A1-A3] Product	107.58	4.41	15,696.27	1.68E-04	1,194.77	372,597.61	283,034.82	88,856.32	9,158.80
Ceilings	7.72	0.50	1,844.67	8.33E-05	93.70	48,626.21	45,436.61	3,198.39	955.30
Walls	90.17	3.41	12,017.51	8.45E-05	975.25	294,171.14	209,884.08	83,522.01	7,160.05
Windows	9.69	0.50	1,834.09	2.50E-08	125.82	29,800.25	27,714.12	2,135.92	1,043.45
[A4] Transportation	1.12	0.09	241.35	8.27E-12	36.95	3,509.67	3,425.69	84.87	
Ceilings	0.09	0.01	19.20	6.58E-13	2.94	279.24	272.56	6.75	
Walls	0.82	0.07	176.53	6.05E-12	27.03	2,567.18	2,505.75	62.08	
Windows	0.21	0.02	45.61	1.56E-12	6.98	663.25	647.38	16.04	
[B2-B5] Maintenance and Replacement	0.92	0.07	205.75	1.09E-10	24.15	4,559.45	4,096.94	458.55	101.40
Ceilings	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Walls	0.92	0.07	205.75	1.09E-10	24.15	4,559.45	4,096.94	458.55	101.40
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
[C2-C4] End of Life	8.34	2.57	2,264.89	6.14E-11	46.98	5,471.17	5,117.07	357.93	
Ceilings	1.06	0.47	106.97	7.73E-12	5.88	720.30	673.49	47.48	
Walls	6.91	2.00	2,112.01	4.52E-11	36.31	3,964.11	3,707.96	258.60	
Windows	0.37	0.09	45.91	8.44E-12	4.79	786.76	735.63	51.86	
[D] Module D	-47.85	-0.80	-6,968.77	-6.15E-07	-376.41	-116,423.81	-71,561.75	-44,846.91	
Ceilings	-0.01	0.00	-3.94	-4.60E-12	-0.09	-68.45	-62.00	-6.36	
Walls	-47.84	-0.80	-6,964.83	-6.15E-07	-376.31	-116,355.36	-71,499.75	-44,840.54	
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	
5a_chi_2_shallow	17.81	2.39	2,115.28	4.17E-05	210.96	68,484.15	54,099.83	14,482.87	2,220.95
[A1-A3] Product	14.17	0.81	1,601.66	4.17E-05	183.73	65,800.94	51,524.20	14,372.92	2,220.95
Ceilings	3.92	0.26	801.41	4.16E-05	48.01	25,537.00	22,832.63	2,713.16	550.94
Walls	0.56	0.05	-1,033.84	3.08E-10	9.90	10,463.69	977.45	9,523.84	626.57
Windows	9.69	0.50	1,834.09	2.50E-08	125.82	29,800.25	27,714.12	2,135.92	1,043.45
[A4] Transportation	0.44	0.04	94.19	3.23E-12	14.42	1,369.67	1,336.90	33.12	
Ceilings	0.06	0.01	13.68	4.69E-13	2.09	198.97	194.21	4.81	
Walls	0.16	0.01	34.89	1.20E-12	5.34	507.45	495.30	12.27	
Windows	0.21	0.02	45.61	1.56E-12	6.98	663.25	647.38	16.04	
[B2-B5] Maintenance and Replacement	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Ceilings	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Walls	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
[C2-C4] End of Life	3.26	1.55	440.22	1.80E-11	13.31	1,674.60	1,565.77	110.38	
Ceilings	0.77	0.36	89.17	4.46E-12	3.52	415.41	388.41	27.38	

Figure D15. Envelope retrofits' embodied emissions by life cycle stage. End of Life and Module D omitted.

Walls	2.11	1.10	305.14	5.07E-12	4.99	472.43	441.73	31.14	
Windows	0.37	0.09	45.91	8.44E-12	4.79	786.76	735.63	51.86	
[D] Module D	-0.05	0.00	-20.80	-2.43E-11	-0.49	-361.06	-327.04	-33.55	
Ceilings	-0.01	0.00	-3.94	-4.60E-12	-0.09	-68.45	-62.00	-6.36	
Walls	-0.04	0.00	-16.85	-1.97E-11	-0.40	-292.61	-265.04	-27.19	
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	
5a_chi_3_deep	83.52	7.33	14,560.69	2.68E-04	1,092.20	334,296.44	287,221.90	46,353.75	10,630.87
[A1-A3] Product	120.49	5.17	18,775.17	2.69E-04	1,351.11	436,548.86	345,246.50	90,564.54	10,528.67
Ceilings	11.51	0.75	2,887.94	1.25E-04	139.40	71,715.43	68,040.59	3,683.63	1,359.67
Walls	96.19	3.78	13,625.18	1.44E-04	1,046.74	328,511.39	243,301.09	84,437.64	7,757.66
Windows	12.79	0.64	2,262.05	2.52E-08	164.97	36,322.04	33,904.81	2,443.26	1,411.34
[A4] Transportation	1.27	0.10	273.36	9.36E-12	41.86	3,975.29	3,880.16	96.13	
Ceilings	0.11	0.01	24.72	8.47E-13	3.79	359.51	350.90	8.69	
Walls	0.85	0.07	184.15	6.31E-12	28.20	2,677.94	2,613.86	64.76	
Windows	0.30	0.02	64.49	2.21E-12	9.87	937.84	915.39	22.68	
[B2-B5] Maintenance and Replacement	0.93	0.07	207.35	1.10E-10	24.34	4,594.90	4,128.78	462.11	102.19
Ceilings	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
Walls	0.93	0.07	207.35	1.10E-10	24.34	4,594.90	4,128.78	462.11	102.19
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	0.00
[C2-C4] End of Life	9.06	2.80	2,326.98	7.24E-11	54.21	6,492.90	6,072.42	425.26	
Ceilings	1.34	0.58	124.76	1.10E-11	8.24	1,025.19	958.57	67.58	
Walls	7.27	2.12	2,140.12	4.99E-11	39.69	4,403.56	4,118.86	287.54	
Windows	0.45	0.10	62.10	1.14E-11	6.28	1,064.15	995.00	70.14	
[D] Module D	-48.22	-0.81	-7,022.17	-6.20E-07	-379.31	-117,315.50	-72,105.96	-45,194.29	
Ceilings	-0.01	0.00	-3.94	-4.60E-12	-0.09	-68.45	-62.00	-6.36	
Walls	-48.21	-0.81	-7,018.23	-6.20E-07	-379.22	-117,247.05	-72,043.96	-45,187.93	
Windows	0.00	0.00	0.00	0.00E+00	0.00	0.00	0.00	0.00	
Grand Total	270.00	26.36	41,653.89	6.25E-04	3,497.73	1,027,066.32	847,350.58	177,884.34	35,119.37

Figure D16. Envelope retrofits' embodied emissions by life cycle stage (cont.). End of Life and Module D

Appendix E

Life Cycle Cost calculations.

Equations E1 – E8, published by DOE, describe how to calculate each cashflow considered in the LCC calculations per the “Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes” [37]:

$$\text{down payment} = R_{DP} * C \quad (\text{E1})$$

Where, C – The “first cost” incurred at the onset (year zero).

$$\text{mortgage fee} = R_{MF} * C * (1 - R_{DP}) \quad (\text{E2})$$

$$\text{property tax}_y = R_p * C * (1 + E_H)^y \quad (\text{E3})$$

$$ES_y = ES_0 * (1 + E_F)^y \quad (\text{E4})$$

Where, ES_y – Energy savings at year, y (kWh);

ES_0 – Energy savings at year zero (kWh);

E_F – Fuel price escalation factor.

$$\text{mortgage payment} = \frac{(1 - R_{DP}) * C * 12}{\left[\frac{\left(1 + \frac{R_{MI}}{12}\right)^{12T} - 1}{\frac{R_{MI}}{12} * \left(1 + \frac{R_{MI}}{12}\right)^{12T}} \right]} \quad (\text{E5})$$

$$\text{tax deduction}_y = R_{IT} * \left\{ \text{property tax}_y + \text{mortgage payment} * R_{MI} * \left[\frac{(1 + R_{MI})^{T-y+1} - 1}{R_{MI} * (1 + R_{MI})^{T-y+1}} \right] \right\} \quad (\text{E6})$$

Where, R_{IT} – Marginal income tax rate.

$$RC_{m,y} = \begin{cases} 0, & y \bmod L \neq 0 \\ (1 + E_H)^y * FC_m, & y \bmod L = 0 \end{cases} \quad (\text{E7})$$

Where, $RC_{m,y}$ – Replacement cost of efficiency measure that has an expected life L less than the analysis period;

m – Retrofit measure, m , with a service life, L , that is less than the analysis period, P ;

FC_m – First cost of measure m ;

$y \bmod L$ – Modulo operator, which gives the remainder after dividing y by L .

$$RV_m = (1 + E_H)^P * FC_m * \left(\frac{P \bmod L}{L} \right) \quad (\text{E8})$$

Where, RV_m – Residual value for efficiency features with remaining useful life at the end of the analysis period;

Appendix H

Result rankings by city.

Each retrofit intervention is ranked from best (top) to worst (bottom) based on the metric of reduced kWh / \$ spent (column 1) or reduced CO2e / \$ spent (columns 2 – 7). Each column represents a different decarbonization scenario (columns 2 – 5) or a different assigned TVC (columns 6 and 7). Retrofit interventions in red text result in a carbon increase. Cells highlighted in green indicate an improvement in rank, whereas cells highlighted in red represent a decrease in rank from the previous decarbonization or TVC scenario.

CHICAGO												
reduced kWh / \$		reduced kgCO2e / \$	reduced kgCO2e_camx / \$	reduced kgCO2e_nyup / \$	reduced kgCO2e_zero / \$	reduced kgCO2e_tvoc3 / \$	reduced kgCO2e_tvoc7 / \$					
-7765.903	shallow_all	-1286.184	shallow_all	-1262.289	shallow_all	-1248.163	shallow_all	-863.427	shallow_all	-566.658	shallow_all	
-159.136	deep_infil	-26.138	deep_infil	-24.81	deep_infil	-24.026	deep_infil	-23.371	deep_infil	-17.568	deep_infil	
-104.354	shallow_env	-17.368	shallow_env	-17	shallow_env	-16.782	shallow_env	-16.6	shallow_env	-11.691	shallow_env	
-92.857	shallow_infil	-15.476	shallow_infil	-15.271	shallow_infil	-15.15	shallow_infil	-15.049	shallow_infil	-10.414	shallow_infil	
-83.883	shallow_wall	-14.015	shallow_wall	-13.672	shallow_wall	-13.469	shallow_wall	-13.3	shallow_wall	-9.455	shallow_wall	
139.407	deep_env	22.089	deep_env	21.509	deep_env	21.166	deep_env	20.88	deep_env	14.538	deep_env	
102.792	deep_wall	16.021	deep_wall	15.583	deep_wall	15.325	deep_wall	15.109	deep_wall	10.435	deep_wall	
71.011	deep_all	11.268	deep_all	11.089	deep_all	10.984	deep_all	10.896	deep_all	7.403	deep_all	
62.179	pv_dc	7.636	pv_dc	3.64	elec_htg	6.298	elec_htg	8.516	elec_htg	4.692	pv_dc	
26.249	pv_dc+batt	2.771	shallow_clg	3.317	pv_dc	5.663	elec_all	7.661	elec_all	2.142	pv_dc+batt	
18.431	shallow_clg	3.465	pv_dc+batt	3.261	elec_all	2.535	shallow_clg	2.638	elec_wh	1.775	shallow_clg	
11.967	deep_wdw	1.913	deep_wdw	2.623	shallow_clg	2.131	deep_wdw	2.462	shallow_clg	1.248	deep_wdw	
8.272	deep_clg	1.05	deep_clg	2.05	deep_wdw	1.959	elec_wh	2.328	elec_cook	0.763	shallow_wdw	
7.704	shallow_wdw	1.185	shallow_wdw	1.578	pv_dc+batt	1.468	elec_cook	2.198	deep_wdw	0.603	deep_clg	
5.423	elec_wh	-0.228	elec_wh	1.196	shallow_wdw	1.202	shallow_wdw	1.207	shallow_wdw	-0.171	elec_wh	
-8.234	elec_all	-0.801	elec_all	1.147	elec_wh	0.953	deep_clg	0.923	deep_clg	-0.566	elec_all	
-9.934	elec_htg	-0.855	elec_htg	0.989	deep_clg	0.764	pv_dc	-0.468	pv_dc+batt	-0.604	elec_htg	
-10.392	elec_cook	-1.308	elec_cooking	0.436	elec_cooking	0.463	pv_dc+batt	-1.367	pv_dc	-0.882	elec_cooking	
											-0.581	elec_cooking

Figure H1. Chicago retrofit rankings.

HOUSTON											
reduced kWh / \$		reduced kgCO2e / \$	reduced kgCO2e_camx / \$	reduced kgCO2e_nyup / \$	reduced kgCO2e_zero / \$	reduced kgCO2e_tvoc3 / \$	reduced kgCO2e_tvoc7 / \$				
-1062.52	shallow_infil	-163.987	shallow_infil	-149.307	shallow_infil	-135.81	shallow_infil	-124.546	shallow_infil	-110.355	shallow_infil
-112.557	deep_clg	-12.024	shallow_env	-11.757	shallow_env	-11.511	shallow_env	-11.306	shallow_env	-8.166	shallow_env
-72.048	shallow_env	-10.938	deep_clg	-10.787	deep_clg	-10.649	deep_clg	-10.533	deep_clg	-7.221	shallow_wdw
-63.505	shallow_wall	-10.643	shallow_wall	-10.477	shallow_wall	-10.325	shallow_wall	-10.197	shallow_wall	-4.83	deep_clg
83.558	pv_dc	9	pv_dc	7.395	deep_wall	7.259	deep_wall	8.53	elec_htg	5.606	pv_dc
55.597	deep_wall	7.543	deep_wall	6.85	shallow_all	6.656	shallow_all	7.146	deep_wall	4.732	shallow_clg
51.4	deep_env	7.061	shallow_all	6.551	deep_env	6.643	elec_htg	6.494	shallow_all	4.548	deep_wall
43.767	shallow_all	6.902	deep_env	5.414	shallow_clg	6.227	deep_env	6.084	elec_all	4.214	deep_env
29.549	pv_dc+batt	5.42	shallow_clg	5.138	pv_dc	5.408	shallow_clg	5.957	deep_env	4.085	shallow_clg
28.592	deep_infil	4.128	deep_infil	4.382	elec_htg	4.481	elec_all	5.403	shallow_clg	2.744	deep_infil
24.45	shallow_clg	3.201	pv_dc+batt	3.469	elec_all	3.283	deep_infil	3.354	elec_wh	1.886	deep_all
22.973	deep_all	3.084	deep_all	3.688	deep_infil	2.752	deep_all	2.945	deep_infil	1.747	pv_dc+batt
6.759	elec_all	1.922	elec_htg	2.911	deep_all	2.702	elec_wh	2.619	deep_all	1.233	elec_all
5.212	elec_wh	1.905	elec_all	1.921	elec_wh	2.369	elec_cook	0.677	deep_wdw	1.206	elec_htg
4.986	deep_wdw	1.071	elec_wh	1.835	pv_dc+batt	1.587	pv_dc	0.453	shallow_wdw	0.733	elec_wh
3.83	shallow_wdw	0.696	deep_wdw	1.122	elec_cook	0.682	deep_wdw	-0.468	pv_dc+batt	0.425	deep_wdw
2.835	elec_htg	0.505	shallow_wdw	0.689	deep_wdw	0.58	pv_dc+batt	-0.674	elec_cook	0.302	shallow_wdw
-9.008	elec_cook	-0.234	elec_cook	0.486	shallow_wdw	0.468	shallow_wdw	-1.376	pv_dc	-0.16	elec_cook

Figure H2. Houston retrofit rankings.

LOS ANGELES												
reduced kWh / \$		reduced kgCO2e / \$	reduced kgCO2e_camx / \$	reduced kgCO2e_nyup / \$	reduced kgCO2e_zero / \$	reduced kgCO2e_tvoc3 / \$	reduced kgCO2e_tvoc7 / \$					
-82.007	shallow_infil	-14.651	shallow_infil	-14.651	shallow_infil	-15.099	shallow_infil	-15.473	shallow_infil	-9.86	shallow_infil	
-63.845	deep_clg	-8.558	shallow_env	-8.558	shallow_env	-8.492	shallow_env	-8.437	shallow_env	-5.793	shallow_env	
-51.408	shallow_env	-7.558	shallow_wall	-7.558	shallow_wall	-7.364	shallow_wall	-7.202	shallow_wall	-5.12	shallow_wall	
-47.02	shallow_wall	-6.993	deep_clg	-6.993	deep_clg	-6.512	deep_clg	-6.11	deep_clg	-3.832	deep_clg	
-33.213	pv_dc	-1.843	pv_dc	-1.843	pv_dc	-0.432	pv_dc	39.347	deep_infil	-0.996	pv_dc	
272.388	deep_infil	41.751	deep_infil	41.751	deep_infil	40.441	deep_infil	21.413	shallow_all	27.951	deep_infil	
133.762	shallow_all	21.788	shallow_all	21.788	shallow_all	21.583	shallow_all	10.987	shallow_clg	14.614	shallow_all	
104.859	pv_dc+batt	11.828	shallow_clg	11.828	shallow_clg	11.37	shallow_clg	8.679	deep_env	8.446	shallow_clg	
67.611	shallow_clg	9.225	deep_env	9.225	deep_env	8.927	deep_env	7.256	elec_htg	5.786	deep_env	
66.891	deep_env	6.881	deep_wall	6.881	deep_wall	6.384	deep_wall	6.434	deep_wall	4.251	deep_wall	
51.174	deep_wall	6.721	pv_dc+batt	6.721	pv_dc+batt	5.975	elec_htg	5.319	elec_all	3.225	pv_dc+batt	
28.647	deep_all	4.44	elec_htg	4.44	elec_htg	4.301	elec_all	3.674	deep_all	2.886	elec_htg	
13.132	elec_htg	3.919	deep_all	3.919	deep_all	3.785	deep_all	2.299	elec_wh	2.45	deep_all	
8.52	elec_all	3.08	elec_all	3.08	elec_all	2.259	pv_dc+batt	2.212	elec_cook	2.01	elec_all	
5.428	deep_wdw	0.953	elec_wh	0.953	elec_wh	1.687	elec_wh	0.765	deep_wdw	0.634	elec_wh	
5.325	shallow_wdw	0.783	deep_wdw	0.783	deep_wdw	1.487	elec_cook	0.71	shallow_wdw	0.493	deep_wdw	
3.006	elec_wh	0.74	shallow_wdw	0.74	shallow_wdw	0.773	deep_wdw	0.746	pv_dc	0.46	shallow_wdw	
-7.247	elec_cook	0.619	elec_cook	0.619	elec_cook	0.723	shallow_wdw	-1.465	pv_dc+batt	0.415	elec_cooking	
											0.262	shallow_wdw

Figure H3. Los Angeles retrofit rankings.

