U.S. MULTIFAMILY ENERGY EFFICIENCY POTENTIAL BY 2020

Prepared for The Energy Foundation

October 27, 2009

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Acknowledgements

The authors would like to thank John Wilson and Sue AnderBois of the Energy Foundation for the opportunity to address this important topic, and for guidance during its development. We are also indebted to Charlie Harak of the National Consumer Law Center and Michael Bodaken of the National Housing Trust for their extremely valuable insights into what specific topics needed to be addressed to serve the related policy deliberations. If the reader finds this report to be comprehensible as well as informative, it is in large part due to suggestions from these four people.

The primary author for this report was Nehemiah Stone, a Principal at the Benningfield Group, Inc.. Lynn Benningfield and Cyndi Shreve Wreford of the Benningfield Group, Inc. provided review and revisions that added clarity to the data and increased value to the findings. They helped make the whole report more accessible. Alice Crawford provided background research into the nature of the U.S. multifamily housing stock and helped to define the initial direction of the research.

Despite the best efforts of the reviewers, if the reader discovers any errors or inaccuracies within the report, they are entirely the authors' responsibility.

Executive Summary

Over 30% of the U.S. population and over 25% of U.S. households live in multifamily buildings. Yet when we talk about possible energy efficiency improvements in the residential sector, we seldom think of opportunities outside of single-family homes, and almost never consider technologies that are only appropriate for multifamily homes. In fact, almost every study of the potential for energy efficiency in the existing residential sector either excludes multifamily buildings or includes it as a non-specific part of the aggregate residential sector. This report is meant to help national and regional policy-makers understand the economic and achievable energy efficiency potential in the country's existing multifamily sector.

The historic lack of attention to multifamily buildings is troubling from a policy perspective, since multifamily housing (a) has a set of issues that need to be addressed to achieve energy efficiency gains that is very different from those for single-family homes, and (b) is inherently more energy efficient than single-family homes in so many ways. Policy-makers looking to garner savings in multifamily housing stock need to recognize that the geometry of multifamily buildings means that less of the savings will come from building envelope and HVAC measures, and more will come from water heating efficiency gains and appliances; and that there are significant opportunities for bundling energy uses to gain an economy of scale when making efficiency improvements (e.g., central hot water systems). Also, national Residential Energy Consumption Survey[1] data show that although multifamily units have a somewhat higher energy use per area (kBtu/square feet), they have significantly lower energy use per household or per capita. Households in buildings with over five apartments use only about 40% as much energy per household as those in single-family detached housing. Since most of the multifamily stock is in urban areas, transportation energy use is also significantly lower.

Another difference with energy policy implications is the fact that many of the appliances (refrigerators, washers, dryers) are the property of the building owner, not the household who pays the energy bills. Since the owner has no economic motivation for upgrading them, they tend to be older and less efficient appliances than in single-family homes. The irony is that renters pay a higher share of their monthly income for utilities, and yet they are less able to affect the efficiency of their homes. Approximately 86%

[1] The Residential Energy Consumption Survey (RECS) is conducted by the Energy Information Administration (EIA) with the help of Oak Ridge National Lab. The last complete RECS was conducted in 2005 and the data are available on EIA's web site.

of all single-family homes are owner-occupied, while 88% of multifamily households are renters, and renter-household incomes are roughly half those of owner-households (approximately $31k/yr vs. $61k/yr). So, even when tenants do own their refrigerators, washers, and dryers, the appliances are more likely to be older and less efficient. This represents a larger unmet need for upgrades to more efficient appliances among these households which, because of tenants' financial situations, will likely not change without higher public or utility intervention and funding than is needed for the single-family market. The fact that tenants are unable (when appliances are landlord owned) or cannot afford to upgrade the appliances is even more insidious when we recognize that low-income households spend nearly 20% of their monthly income on energy, compared to about 4% for the average household.

As this report shows, multifamily properties represent both unique opportunities and unique challenges for energy efficiency improvements. If the report's recommendations are adopted:

- The U.S. could conservatively achieve energy savings equivalent to the annual electrical output of 20 coal plants, AND the entire non-power plant natural gas usage of California, Oregon, and Washington states.
- Energy efficiency in the multifamily sector could be improved by about 30%.[2]
- We could avoid the emission of at least 50 to over 100 million tons of CO_2 per year – equivalent to the emissions associated with the current energy use of 4-8 million U.S. households.[3]
- At the lower end of the efficiency potential estimates, tenants and landlords could reap a $9 billion annual energy "dividend." This will have a proportionately higher value to low income renters since they pay roughly five times the percentage of their monthly household income for utilities compared to the average household.

The primary analytical approach involved in this study was a review of approximately 30 recent energy efficiency potential studies that focused on or at least included the residential sector. Because some of the studies divided the residential sector potential into single family and multifamily subsectors, we were able to develop multipliers that could be applied to the rest of the studies – those with only aggregate residential potential energy savings estimates. In this way, we were able to estimate the proportion of

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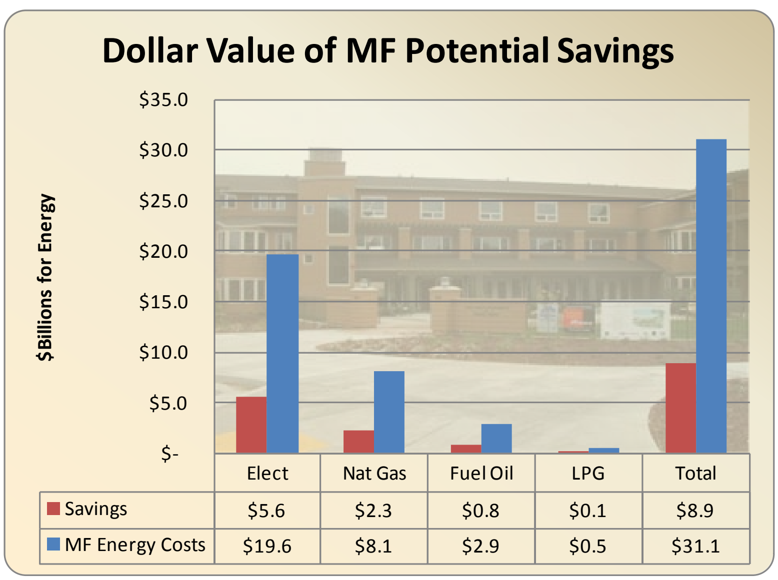
[2] This is the "achievable" energy efficiency potential, which means it is both economically reasonable and within normal budget constraints. The economic energy efficiency potential is estimated to be 59% of multifamily energy use. The technical potential is even larger: over 80%.

[3] These estimates are based on the achievable and economic potentials, respectively.

potential savings due to multifamily housing in those studies where it was not specifically studied or estimated. We made conservative adjustments to savings estimates by state, based on population growth and housing mix data (age, size, etc.) from the U.S. Census Bureau and the Department of Energy's Energy Information Administration. Because we made conservative assumptions at virtually every juncture (explained in the Appendix), the resulting multifamily energy efficiency potential estimates must be seen as close to the lower limit of an estimate of the real potential for energy efficiency gains in the U.S. multifamily sector.

We estimate that the achievable potential (the economic potential further bounded by reasonable expectations of budgets and adoption rates) by the year 2020 is over 51,000 gigawatt-hours of electricity and over 2,800 Million therms of natural gas (or the equivalent for those regions that use other fuels). That is roughly equal to the output of 20 average sized coal power plants[4] and the entire non-power plant natural gas usage of California, Oregon, and Washington. The potential savings would have a value of nearly $9 Billion annually to property owners and tenants, compared to current energy costs of over $31 Billion.[5]



	Elect	Nat Gas	Fuel Oil	LPG	Total
Savings	$5.6	$2.3	$0.8	$0.1	$8.9
MF Energy Costs	$19.6	$8.1	$2.9	$0.5	$31.1

Figure 1: U.S. Multifamily Energy Cost Savings Potential

[4] According to the National Energy Technology Lab, the average size of the 43 coal plants that were under construction, near construction, or in the permitting process in April 2009, was 517 MW.
[5] Based on 2005 RECS data from the U.S. EIA.

With the rate at which low and moderate income households spend disposable income locally, these energy savings could represent significant community economic activity stimuli.

Regional differences in population growth, number of existing multifamily units, age of the multifamily stock, and size of multifamily buildings will affect where the most cost-effective opportunities may be. New York, New Jersey, the West, and New England have the highest ratios of multifamily to single family units. Population growth is most rapid in the Southeast, Texas, and the West. The oldest multifamily housing stock is in New York, New Jersey, New England and the center of the Midwest. The South and the West have the highest proportions of large (5+ units/building) multifamily buildings. Therefore, it is reasonable to assume that the bulk of the savings will likely come from the South, the West, and the most metropolitan areas of the Northeast and Midwest.

Background and Purpose

At a time when the United States faces the need to achieve heroic energy and greenhouse gas emission reductions while cost-effectively stimulating the country's economy, it is important to clearly understand the potential for energy savings in every market sector and region. The purpose of this study is to provide an estimate of the achievable economic potential for energy savings in the existing multifamily housing sector in the United States and an estimate of the greenhouse gas emission reductions associated with those energy savings.

Housing is basic to human comfort and dignity. Although one could fill a large bookcase with shelves of books on the housing crisis, the mortgage meltdown, and the collapse of single-family home construction, little attention has been paid to the state of multifamily housing, where over a quarter of American families live. The potential for energy savings in this sector is huge and largely untapped. Not only will addressing this potential produce satisfying increases in tenants' comfort and economic well-being, but it can also provide a significant reduction in greenhouse gas emissions. This report will provide policy makers with a better understanding of the multifamily market sector in the United States and its potential for economically viable energy savings.

Housing in the U.S. comes in a wide variety of sizes and configurations. Since the most common type of home is a single family residence, there is a natural tendency to focus on them and ignore the unique characteristics of multifamily (MF) housing. There are roughly 77.5 million single family (SF) homes in the U.S. and 26.25 million MF residences.[6] 64% of all U.S. housing was built before 1980 and only 5% was built in the 2005-09 period. See the table in Figure 2. From the 1940s through 1980s, a high percentage of residential new construction was multifamily (26%-33%). However, a relatively high percentage of those from the 1940s and 1950s have been taken out of service (demolished),[7] so multifamily housing from those two decades represents a relatively small part of the total stock (14%-20%) from the era. Each decade has had a different mix of MF and SF construction, but from the early 1990s, only about 15% of all housing production has been multifamily.[8]

Year Structure Built	*Total*	*Single-Family*	*Multi-family*	*MF % of Total*
2005-2009	3,678	3,014	446	12%
2000-2004	8,015	6,021	1,215	15%
1995-1999	7,821	5,211	1,156	15%
1990-1994	6,159	4,366	944	15%
1985-1989	7,726	4,834	2,176	28%
1980-1984	6,467	3,840	1,843	28%
1975-1979	12,411	7,919	3,743	30%
1970-1974	9,436	5,448	3,142	33%
1960-1969	13,397	9,559	3,450	26%
1950-1959	11,501	9,808	1,652	14%
1940-1949	6,817	5,426	1,353	20%
1930-1939	5,070	3,723	1,292	25%
1920-1929	4,582	3,133	1,449	32%
1919 or earlier	7,612	5,217	2,396	31%
Percent of Total		*70%*	*24%*	

Figure 2: Age of U.S. Housing Stock[9] (1,000s of Dwelling Units)

This means that the nation's multifamily housing stock is relatively older than its single-family stock and should have relatively more opportunities for energy savings potential. Nonetheless, few surveys or analyses have been performed to determine what that potential is. In a broad view, the greatest potential savings in natural gas will occur where (a) a large amount of natural gas is used and (b) the usage per household is also high. The table in Figure 3 shows the top-ranked fifteen states in each of these

[6] Data from the American Housing Survey – 2007, by U.S. Census Bureau.
[7] IBID.
[8] There are significant regional variations on this. For example, according to data from the California Department of Finance, MF new construction in California has comprised about 30% of the total residential units built since 2000.
[9] Data from American Housing Survey for the United States: 2007; Table 2-25. Totals do not add to 100% because data excludes mobile homes.

categories.[10] Nine states are on both lists (in bold). It is in those nine states where there is the greatest potential to realize savings in natural gas usage.

Total Res NG Use		***NG/Hshld***	
State	Rank	State	Rank
CA	1	AK	1
IL	**2**	**IL**	**2**
NY	**3**	**MI**	**3**
MI	**4**	UT	4
NJ	**5**	**CO**	**5**
PA	6	**NJ**	**6**
TX	7	**MN**	**7**
OH	8	**WI**	**8**
IN	**9**	KS	9
WI	**10**	IA	10
CO	**11**	**IN**	**11**
MN	**12**	NE	12
MA	**13**	**NY**	**13**
MO	14	**MA**	**14**
WA	15	RI	15

Figure 3: Residential Natural Gas Usage - Top 15 States by Total and by Household

In addition to the relative lack of understanding of the potential in the multifamily stock, there is a greater economic need for efficiency in this sector, and the need is growing. From 1975 to 2007, rents faced by households in multifamily buildings increased an average of 8.9% in real dollars across the U.S., but their utility costs increased an average of 20.4%. During this same time period, real household monthly income for renters actually fell by 2.8%. It is becoming increasingly difficult for many households in multifamily dwellings to meet the costs associated with their energy needs. Notably, homeowners have fared much better. Their average income rose 13%, while their mortgage costs rose only about ½ as much as their income, and their utility costs remained at about the same percentage of their income. The data for these comparisons is from Harvard's *State of the Nation's Housing 2008*.

Methodology

This report contains an analysis based primarily on 27 state and regional energy efficiency potential studies that had estimates of potential savings within the existing residential sector.[11] Most studies

[10] Data from the American Gas Association's ***Gas Facts 2006***. These data do not include figures for natural gas utilities with annual revenues under $25,000.

[11] Four additional studies provided further information, though in three cases the data were aggregated across the U.S., and the fourth did not provide clarity on the time period.

contained analysis on all sectors (i.e., included commercial and industrial), and all provided data specific to the residential sector. Additionally, five of them had data that were specific to the multifamily sector. One of the five was a regional study that provided state-specific estimates for the multifamily sector in nine states. Consequently, we had direct multifamily efficiency potential estimates for 13 states:

California
Illinois
Indiana
Iowa
Kentucky
Michigan,
Minnesota
Missouri
Ohio
Pennsylvania
Texas
Vermont
Wisconsin

These 13 states account for 46% of the U.S. population, 45% of the households, 43% of the multifamily units, 56% of the residential natural gas usage, and 41% of the residential electricity usage in the U.S. Counting all 27 of the studies, 83% of U.S. population and U.S. households were represented.

The studies were conducted over the past eight years and covered different periods. The study with the shortest periods covered one and five years; the longest was 43 years (2007-2040). Many of the studies were performed by the same organization (ACEEE),[12] and used consistent assumptions about energy price escalations, cost-effective technologies, technological change, customers' willingness to act, population growth, etc. However, there were several significant differences in the approaches taken in the studies. We describe the differences below.

First, most studies were explicit about the difference between technical potential, economic potential, and achievable potential, though some studies used a different name for one or another of the three types of potential.[13] Technical potential answers the question of how much could we save with available

[12] American Council for an Energy Efficient Economy
[13] For example, in a 2001 study for Iowa, Oak Ridge National Lab used the term "market potential," instead of "achievable potential."

technology if we were willing to spend whatever it takes. Economic potential answers the question of how much could we save if we were to adopt all energy efficiency measures that save more than they cost. Achievable potential includes consideration of what building owners and other decision makers will accept and take action on. In multifamily buildings this latter filter is complicated by the fact that often the person or company having to make the investment in the energy efficiency measure is (a) financially constrained, and (b) not the same entity whose bills will be reduced or whose comfort will be increased.

In some cases, all three types of potential were reported. In other cases only one or two were. In one instance, the report was not explicit about which type of potential was being described, but we had an estimate for that state from another report and only used the less explicit study for certain background information. In one regional study, only the economic potential was presented, but again, we had another study for most of the states included in it. In all cases, the measures included in the studies had a benefit cost ratio of better than 1.0 using the Total Resource Cost test (TRC).[14]

The appendix provides a more detailed explanation of the procedures we used to obtain an estimate of the multifamily savings potential from the collection of studies with residential estimates, but the following is a brief description of the process. Because the majority of the studies did not segregate an estimate for multifamily savings from the larger estimate of savings in the residential sector, we scaled the savings estimates using:

- the ratio of the state's multifamily units to total residential units
- a multiplier for each general region representing the relationship between the percent of the housing stock that is MF and the percent of the residential savings attributable to the MF sector based on those 13 states where the multifamily savings were directly reported[15]

Because the studies covered a wide range of time periods, we normalized their results to an eleven year time period to develop a uniform estimate of the potential across all studies by the year 2020.

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[14] The TRC is a test of cost-effectiveness applied to demand side management programs and measures. It includes the costs and benefits to society of adopting an efficiency measure or program. For a complete explanation of the TRC, consult the California Standard Practice Manual. http://www.calmac.org/events/SPM_9_20_02.pdf

[15] For example in California, 27.8% of the housing stock is MF, but only 19.5% of the residential energy efficiency potential is from the MF stock. That gives us a multiplier of 0.7014. For the other western states where only aggregate residential efficiency potential was reported, we multiplied it by (a) the MF percent of the housing stock, and (b) 0.7014. Multipliers for the Midwest, South, and Northeast were 1.087, 1.256, and 1.008, respectively.

Based on these studies, the energy efficiency potential for the existing multifamily sector by 2020 is 51,091 GWh of electricity and 2,810 million therms of natural gas (or the *equivalent* for multifamily buildings that rely on fuel oil or propane). For perspective, the 2005 RECS data estimated natural gas, fuel oil, and propane gas usage for rental multifamily units was approximately 9,900 million therms, and the electricity usage was approximately 175,800 GWH of electricity. The potential savings are therefore are about 28%-29% of the gas and electricity currently used in the multifamily housing stock.[16]

The TRC benefit cost ratio was explicitly provided for the residential sector in few cases and for the multifamily portion of the residential sector in even fewer. Therefore, it was not possible to develop a reasonable estimate of the benefit-cost ratio applicable to the savings potential from the combination of the studies. However, assuming the average benefit-cost ratio is a modest 1.5, the <u>net</u> benefits to the country of investing in energy efficiency for the multifamily sector could easily be over $4 Billion ($2.5B$^+$ in electricity, and $1.5B$^+$ in natural gas or equivalent).[17] Put another way, for an estimated investment of $8B for multifamily energy efficiency improvements made over the next 11 years, tenants and property owners would realize energy costs savings of approximately $9B annually. Importantly, most of the energy cost savings would accrue to low income households whose percentage of monthly income spent on utilities is about 5 times higher than for the average household.

The summary table that follows in Figure 4 shows how we arrived at estimates for the states where we could estimate the multifamily energy efficiency potential and how we turned the total for those states into a national estimate (last three rows). We developed each state estimate using one of three approaches.

1. For states with studies that provided multifamily-specific estimates, we simply normalized for the time period to the year 2020.
2. For states with studies that provided residential estimates that did not separate out the multifamily/single-family sectors, we
    a. normalized the estimate to 2020,
    b. normalized the estimate by the percentage of residential stock that is multifamily, and

[16] The prediction for 2020, absent additional energy efficiency efforts, is for 1,385,000 GWH in the whole residential sector; 210,047 GWH in the multifamily sector. The savings advocated in this report would represent 24% of the 2020 multifamily usage.
[17] These estimates are based on energy costs of $0.10/kWh and $1.10/therm. For an explanation of why we assumed a TRC B/C of 1.5, see the detailed explanation in the Appendix.

c. adjusted the estimate by a regional multiplier that correlates multifamily percentage of residential savings to multifamily percentage of residential housing stock, based on a state for which we had all the data.

3. To include the rest of the states not covered by one of the studies, we scaled up the multifamily savings potential estimates using the percentage of households represented by the studies to the total number of households in the U.S.

The methodology section in the Appendix provides a more complete explanation of the process. This paragraph provides a short summary of the third approach above (scaling up to the national estimates). Near the bottom of the table, the GWH and M Therm savings estimates are totaled (42,706 and 1166, respectively). Below that, we totaled the number of households in the states represented by the estimates (105,911,000 and 53,089,225, respectively). The next line shows the percentage of all households represented by the data. The number of households in the GWH column is higher than the number shown in the M Therms column because there were more studies with estimates of electricity savings than gas savings. To scale up these partial estimates to the total potential for the U.S. multifamily sector, we divided the partial savings by the percent of U.S. multifamily households that they represent (last row).

MF Density Rank		U.S. Census Bureau Data			MF/Total	Res EE Potential		Scalers		MF EE Potential Estimate	
		08 Population	07 Households	07 MF Units		GWH	M Therms	MF:Energy	Period	GWH	M Therms
37	Maine	1,316,456	696,611	101,737	14.6%			1.008		0	0
18	New Hampshire	1,315,809	594,052	120,323	20.3%			1.008		0	0
29	Vermont	621,270	311,434	51,975	16.7%	567		1.008	1.3750	131	0
4	Massachusetts	6,497,967	2,722,190	828,490	30.4%			1.008		0	0
5	Rhode Island	1,050,788	450,884	125,639	27.9%			1.008		0	0
10	Connecticut	3,501,252	1,438,436	375,582	26.1%			1.008		0	0
	New England	14,303,542	6,213,607	1,603,746	25.8%	12,745		1.010	1.1000	3,655	0
2	New York	19,490,297	7,939,846	3,125,175	39.4%			1.008		0	0
11	New Jersey	8,682,661	3,499,406	912,321	26.1%	5,172	1,052	1.008	0.7333	997	203
35	Pennsylvania	12,448,279	5,477,864	838,349	15.3%	21,692		1.008	1.2222	4,090	0
30	Delaware	873,092	388,616	63,610	16.4%			1.008		0	0
12	Maryland	5,633,597	2,318,456	542,821	23.4%			1.008		0	0
1	Dist. of Columbia	591,833	284,221	160,329	56.4%			1.008		0	0
20	Virginia	7,769,089	3,274,394	625,911	19.1%	7,732	98	1.008	1.0000	1,490	19
51	West Virginia	1,814,468	882,685	85,369	9.7%			1.256		0	0
	Appalachia	8,212,155	3,601,338	713,750	19.8%	16,758	840	1.256	0.5500	2,294	115
40	North Carolina	9,222,414	4,125,308	584,166	14.2%			1.256		0	0
41	South Carolina	4,479,800	2,021,947	282,779	14.0%	8,122		1.256	1.2222	1,744	0
26	Georgia	9,685,744	3,961,474	688,003	17.4%	2,908	595	1.256	2.2000	1,396	286
7	Florida	18,328,340	8,718,385	2,349,637	27.0%	11,628		1.256	0.7333	2,886	0
38	Kentucky	4,269,245	1,906,096	277,164	14.5%	3,625	308	1.256	1.1000	728	62
36	Tennesse	6,214,888	2,724,729	403,827	14.8%			1.256		0	0
45	Alabama	4,661,900	2,137,018	275,708	12.9%			1.256		0	0
50	Mississippi	2,938,618	1,254,908	136,467	10.9%			1.256		0	0
34	Michigan	10,003,422	4,527,655	694,479	15.3%	4,298	981	1.307	0.5500	474	108
23	Ohio	11,485,910	5,064,900	924,029	18.2%	21,037		1.087	0.7333	3,059	0
31	Indiana	6,376,792	2,778,394	436,342	15.7%			1.087		491	42
25	Wisconsin	5,627,967	2,560,099	454,203	17.7%	2,476	83	1.087	1.2222	584	20
9	Illinois	12,901,563	5,246,005	1,400,451	26.7%	9,000		1.087	0.7857	2,052	116
22	Minnesota	5,220,393	2,304,467	421,852	18.3%	2,242	334	1.087	0.5550	248	37
49	Arkansas	2,855,390	1,287,429	144,722	11.2%			1.256		0	0
42	Louisiana	4,410,796	1,859,179	248,022	13.3%			1.256		0	0
43	Oklahoma	3,642,361	1,623,010	216,220	13.3%	14,806		1.256	1.2222	3,028	0
16	Texas	24,326,974	9,432,672	2,025,878	21.5%	5,461		1.256	0.7857	1,157	0
44	New Mexico	1,984,356	862,067	111,803	13.0%	2,819		1.256	1.2222	561	0
32	Iowa	3,002,555	1,329,596	206,179	15.5%	1,774	208	1.087	0.5500	164	19
33	Missouri	5,911,605	2,647,274	410,093	15.5%			1.087		569	32
39	Kansas	2,802,134	1,219,439	173,912	14.3%	3,807	210	1.087	0.5500	325	18
27	Nebraska	1,783,432	780,804	134,923	17.3%			1.087		0	0
15	North Dakota	641,481	310,548	68,839	22.2%			1.087		0	0
28	South Dakota	804,194	357,240	59,894	16.8%			1.087		0	0
47	Montana	967,440	435,533	53,479	12.3%			1.087		0	0
46	Wyoming	532,668	242,332	30,802	12.7%			1.087		0	0
14	Colorado	4,939,456	2,127,156	481,046	22.6%			1.087		0	0
24	Utah	2,736,424	925,242	168,278	18.2%	698	25	1.087	0.9167	127	5
21	Arizona	6,500,180	2,667,502	498,323	18.7%			0.701		0	0
8	Nevada	2,600,167	1,102,379	296,872	26.9%			0.701		0	0
6	California	36,756,666	13,308,346	3,705,455	27.8%	10,500	400	0.701	1.1000	2,256	86
3	Hawaii	1,288,198	506,737	181,641	35.8%			0.701		0	0
48	Idaho	1,523,816	631,071	72,467	11.5%			0.701		0	0
19	Oregon	3,790,060	1,609,595	320,478	19.9%	55,556		0.701	0.5500	4,267	0
13	Washington	6,549,224	2,744,069	630,213	23.0%			0.701		0	0
17	Alaska	686,293	282,234	58,831	20.8%			0.701		0	0
	AL, NC and TN	20,099,202	8,987,055	1,263,701	14.1%	36,451		1.256	0.6111	3,934	0
Total	United States	315,549,844	133,080,981	28,893,082	21.7%					42,706	1,166
									households included	106,911,000	53,089,225
									percent of households included	83.6%	41.5%
									Expanded Multifamily Energy Efficiency Potential Estimate	**51,091**	**2,810**
										GWH	**M Therms**

Figure 4: Summary of Residential Efficiency Potential Studies

Characteristics of Multifamily Housing

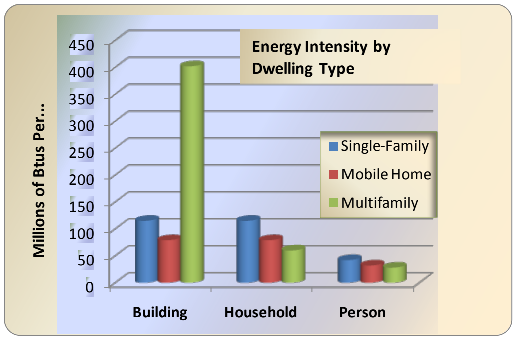

Figure 5: Energy Intensity per Building, per Household, and per Person by Dwelling Type

One of the first things to note about multifamily housing as compared to single family homes (SF) is that they use more energy per building, but significantly less per household and less per person.[18]

The table in Figure 6 compares energy use per household by housing type. All of the percentages in the table are relative to the energy used in single-family detached dwellings, which use 14% more energy per household than the average of all homes in the U.S. Multifamily dwellings use 38%-72% of the energy that single-family homes do. The other notable detail from the table is that the disparity between SF and MF appears to be growing over time.

Housing Type	1997		2001	
	Mbtu	% S.F.D.	Mbtu	% S.F.D.
U.S. Means	**100.9**	**86%**	**92.2**	**85%**
Single-Family Detached	117.9	n.a.	108.5	n.a.
Single-Family Attached	94.9	80%	100.4	93%
Apartments in Buildings with 2 to 4 Units	91.9	78%	78.1	72%
Apartments in Buildings with 5 or More Units	48.7	41%	41.0	38%

Figure 6: Energy Intensity by Housing Type and Comparison to Single-Family Detached Energy Intensity [19]

Although multifamily buildings are more efficient on a per-person and per-household basis when compared to single-family homes, there is still substantial room for improvement. This is primarily because multifamily new construction has had less attention from energy codes than single-family construction. It is only a fairly recent phenomenon that analyses on energy code measures have included

[18] Data are from EIA Residential Energy Consumption Survey.
[19] Sources: Energy Information Administration, Residential Energy Consumption Surveys, 1997, and 2001

multifamily characteristics at a similar level of specificity as has generally been applied to single-family construction analyses. Additionally, over 70% of the nation's existing multifamily units were built before there were any building energy codes (1978). Though California was the first state to enact such a code in 1978, because of permitting and construction timelines, few if any multifamily buildings before 1980 were even subject to the code.

A number of quantitative differences between dwelling unit types help explain the differences in energy intensity. For one, multifamily units are generally smaller than SF homes. The average new apartment has about 1000 square feet of conditioned floor area (CFA), while the average new SF home has more than twice that. However, average apartment size has been growing.

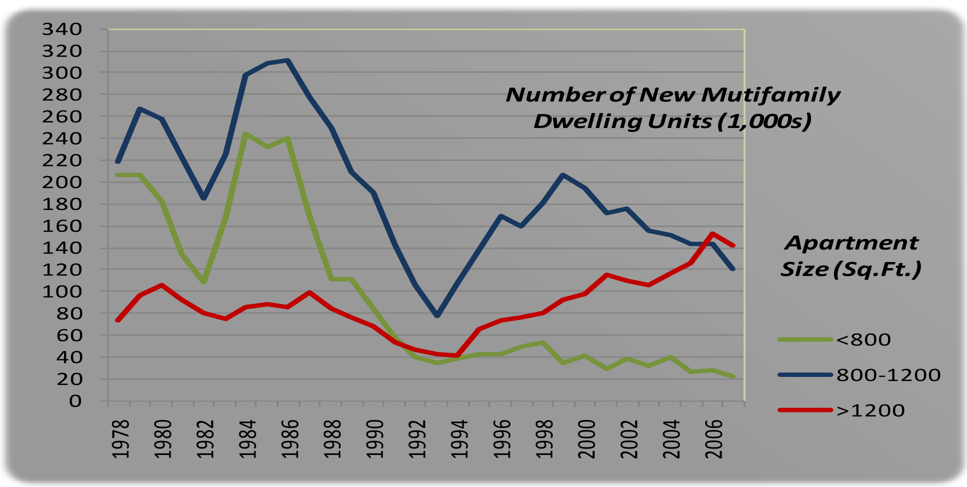

Figure 7: Average U.S. Apartment Size - 1978-2007 New Construction (U.S. Census Bureau)

Secondly, multifamily units have a smaller amount of surface area exposed to the weather, and therefore, less area for gaining or losing heat. A typical SF home will have a wall-to-conditioned floor area (CFA) ratio of about 95%. They also have a floor and ceiling that are "exposed" to earth and sky, respectively. Due to the large number of shared or adiabatic walls in multifamily buildings, a typical apartment will have an exposed-wall-to-CFA ratio of about 30%-55% (depending upon whether it is in the middle of a wall or at the corner of the building), and usually only a floor or a ceiling (or neither) exposed to the exterior. One significant impact of this is that the principal energy use is often water heating, not space heating or cooling.[20] Energy efficiency measures focused exclusively on the envelope and HVAC

[20] This varies significantly by region. For example, most of California's population is within fifty miles of the coast. In most costal climates, MF water heating energy use is as large as or larger than the heating and cooling budgets

equipment will not likely produce deep energy reductions to the same degree they would in SF homes. The geometry of multifamily buildings also means that there is a lower roof area to floor area ratio, and therefore relatively less room for installation of photovoltaic arrays.

Infiltration and exfiltration properties are also much different in multifamily housing. Rather than being concerned with infiltration to the exterior, multifamily HVAC designers must address heat and air transfer from dwelling space to dwelling space, and from the conditioned dwelling unit to common areas. There are common ventilation systems, utilized to exhaust kitchen, bathroom, and laundry rooms that can contribute substantially to energy use as well.

One major benefit of multifamily buildings is that systems can more easily be integrated for cost and energy savings. For instance, a central domestic hot water (CDHW) system with an insulated re-circulation loop is inherently more energy efficient than a multitude of individual water heaters – and costs less up front. It is also easier to achieve significant energy savings from CDHW systems than from individual units, through use of controls that manage the re-circulation pump (demand controls) or the boiler operation (temperature modulation controls). As another example, a four-pipe fan coil HVAC system can even take advantage of the fact that the units on the east side of the building may need to be cooling in the morning, while those on the west are still heating; and vice versa in the evening.

Cooking and refrigeration comprise a larger portion of the energy budget in multifamily homes. Appliances in SF homes are almost always owned by the occupant, whereas in MF, appliance ownership is less common. Further, almost all SF homes have a washer and dryer, while apartment buildings often have central laundry facilities or no on-premises laundry at all. Each of these differences will impact energy efficiency decisions that require appliance replacements.

There is another significant economic difference between SF and MF. Higher income households tend to own and occupy SF homes. The 2007 average income for owners was $61,284, and for renters it was $31,338.[21] In fact, 86% of all single-family homes are owner-occupied, while 88% of multifamily households are renters. Likewise, qualified affordable housing[22] ***tends*** to be MF. These are both general

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combined. However, in the upper Midwest or the humid South, heating or cooling respectively, will be larger. However, even there, the relative importance of DHW will be greater in multifamily buildings than in single-family.

[21] "The State of the Nation's Housing 2008," Harvard.

[22] "Qualified affordable housing" means housing for which the owner or renter is receiving or has received assistance from a state, local, or federal affordable housing program (e.g., LIHTCs, HUD Section 8 vouchers). It excludes market rate housing even if the rents are "affordable" by regional economic definitions.

tendencies with significant exceptions. One notable exception is that there are quite a few owner-occupied older SF homes with qualified low-income, mostly elderly households. In most cases, the income level of the occupants will partially determine the ability to participate in a retrofit targeting energy savings (except of course, where the utility company or other entity pays the full cost of the upgrades). One irony in this is that households in multifamily dwelling also tend to pay higher utility rates.[23] The ability of multifamily property owners to pay for efficiency upgrades has also been hit by the recent financial crises. Delinquency rates on multifamily mortgages are higher than at any time since the 1989-93 downturn, and things are expected to get worse.[24]

This leads directly to the question of ownership, and how that impacts decision making. SF homes are typically built to sell, whereas most MF is built to be held. That means the developers in these two markets are very different groups. More importantly for this study, the owners of the buildings are also very different groups with very different motivations, financial considerations, and costing horizons. Multifamily properties are meant to be income producing, and are appraised as such. Though one of the primary considerations for affordable housing is to keep rents low, they still have to show a positive monthly cash position. Single family homes, on the other hand, are appraised as owner-occupied property. Therefore, the costs and benefits of improvements are analyzed very differently from single-family homes, and from each other. For market-rate multifamily, the deciding factor is the ability to attract renters and maximize profits. For affordable multifamily, the primary consideration is providing affordable housing with enough net monthly income to support continued operation. Whereas single-family home owners take a much less structured approach to energy efficiency – generally valuing them as purchases instead of investments. Investment decisions must be approached with these considerations in mind.

Multifamily buildings represent the classic example of split incentives. If tenants are paying their own utility bills, the owner of the building is seldom able to recoup her/his investments in energy efficiency.[25] The tenant, who would benefit from improvements that could reduce her energy costs, is generally not in a position to make the investment. Solutions to this dilemma include:

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[23] According to U.S. EIA RECS data, the average household in single-family housing pays \$0.097/kWh, while those in multifamily housing pay \$0.105/kWh to \$0.112/kWh. This is largely due to the distribution of housing types and the fact that MF housing is concentrated in urban areas.

[24] June 22, 2009 Multi-Housing News article, quoting Jamie Woodwell, V.P. t the Mortgage Bankers Association.

[25] One exception to this dilemma is the case of central water heating systems, where the owner both makes the investment and reaps the benefits of bill savings.

- Programs that cover the full cost of the energy efficiency upgrades, so that the owner need not make the investment
- Providing recognition for tenants' reduced energy costs through increasing rents by a roughly equivalent amount, which allows the owner to recoup the investment
- More complex arrangements that ensure tenants and property owners share the benefits (e.g., on-bill financing or shared savings contracts)

To this end, HUD, multifamily property owners, and other stakeholders should work with utilities to direct much more utility energy efficiency funding to multifamily properties. This market sector is currently under-served. If the multifamily market were to receive its fair share of the roughly $2 billion per year that is the current utility energy efficiency funding level, the resulting $100M to $200M[26] annually could easily address the split incentive problem.

Certain discrete financial/economic events may impact an owner's decision to make an energy efficiency improvement. For example, with a LIHTC[27] project, there is an effective opportunity 15 years after construction, because the equity partner (the one who originally bought the LIHTCs) is no longer obligated to remain part of the partnership. This will generally require the managing partner to obtain new loans to cash out the equity partner. At that time, they have the ability to add additional debt to finance energy efficiency upgrades, especially when those upgrades improve the monthly net income.

A few things set affordable housing in particular apart from market rate housing. These include marketing, vacancy rates, and regulatory requirements. Local public housing authorities (PHAs) maintain waiting lists of eligible households looking to get into qualified affordable housing. In San Diego, the waiting list is estimated to be four to seven years long, and with only enough funds and housing to help the elderly, military families, or those with special needs.[28] Most PHAs have waiting lists nearly as long, and many close their lists for a year or two at a time. Therefore, an owner of affordable housing has no need to advertise so there is no marketing advantage to being more energy efficient. Likewise, vacancy rates are lower (2-3% versus 4-6% for market rate apartments) and there is less turnover than in any but

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[26] Residential customers account for over 40% of electricity use and 50% of natural gas use, and multifamily units account for about 25% of the existing housing stock. Therefore, 5% - 10% of total DSM funding is a conservative estimate of the multifamily market sector's fair share.

[27] "LIHTC" means Low Income Housing Tax Credit, a federal program governed by the IRS and administered by each state.

[28] SD Housing Authority *Frequently Asked Questions* at: http://www.sdcounty.ca.gov/sdhcd/faq/faqs_page.html#16

the oldest market rate rental housing. According to the National Multi-Housing Council,[29] many "moderate rent" (lower end market rate rentals) units have a 50% annual turn-over rate. Turnover for affordable housing tenants is under 10%; very similar to single-family housing and much lower than market rate renters.[30]

Summary of Existing Data

National Level Estimates

At a meta-level, we can quickly estimate the potential electricity and natural gas savings potential for the residential sector, and then, making a few assumptions, reach a rough estimate of the efficiency potential for the multifamily sector. We then compare those to more robust estimates built up from 30 state, regional, and national residential energy efficiency potential studies. In the Energy Information Administration's (EIA's) Annual Energy Outlook for 2008, EIA estimates the national electricity usage to be 3,717,000 GWHs (approximate value: $367B). They estimate the residential sector to consume 38% of that, or 1,412,460 GWHs (approximate value: $168B).[31] In a 2004 meta-analysis of economic and achievable potential based on 11 state and regional studies, ACEEE concluded that the mean of the economic potential in the residential sector was 25%. This yields a residential potential estimate of 353,115 GWH (approximate value: $42B). Assuming that the potential savings per unit for multifamily is approximately the same as for single family, we can multiply the total potential electricity savings by the percentage of the national housing stock that is multifamily, or 24%. This gives us a rough estimate of 84,750 GWH as the electrical efficiency potential for the nation's multifamily sector. This number provides a good reference point for the estimation of potential provided in this report, 51,000 GWH by 2020, and provides support for the contention that our estimate is conservative.

We can develop the same kind of rough estimate for the multifamily natural gas efficiency potential. In 2005, ACEEE analyzed the national potential for natural gas savings through energy efficiency[32] and found that the residential sector had the potential for 600,000 MMcf of savings (approximate value:

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[29] NMHC letter to U.S. Department of the Treasury, Tax Analysis Office. March 21, 2000.

[30] "Myths and Facts about Affordable and High Density Housing." California Department of Housing and Community Development. November 2002.

[31] "Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S. (2010-2030)." Electric Power Institute. January 2009.

[32] "Impacts of Energy Efficiency and Renewable Energy on Natural Gas Markets." Elliott and Shipley. April 2005.

$6.8B) by 2020.[33] Making the same assumption as above about the percentage of savings potential being roughly equal to the percentage of multifamily housing in the residential stock, we can estimate that the achievable energy efficiency potential for natural gas in the multifamily sector is 1,440 million therms. Since the ACEEE estimate does not include fuels other than natural gas, it may underestimate the potential by about 20%. The adjusted estimate (1,713 M Therms of natural gas *equivalent* efficiency potential at an approximate value of $1.9B) is about 61% of the estimate we developed in this study. That suggests that our natural gas potential savings estimate is in the ball park, but probably not conservative.

Within a two-year period, more than 30% of multifamily units receive an inspection or property needs assessment for one purpose or another.[34] As a result of these inspections, approximately 4% of the multifamily housing stock (~820,000 units) are repaired or renovated in those two years. This represents a fairly easy entry point for energy efficiency upgrades for those units, though if this were the only set of units to be upgraded, it would take over 25 years to reach the full multifamily stock. The multifamily energy efficiency potential estimated in this report could not be reached by 2020 at that rate. In the same Census Bureau survey, owners of nearly 60% of the multifamily units (~12 million units) reported renovations of some sort in the previous five years. Of those, at least 4.28 million units had renovations to heating, air-conditioning or plumbing systems, indicating a lost opportunity of over 400 M Therms and 4,500 gigawatt-hours if the renovations did not maximize the cost-effective improvements possible.[35] That represents a potential of over $800M/yr in lost energy savings.

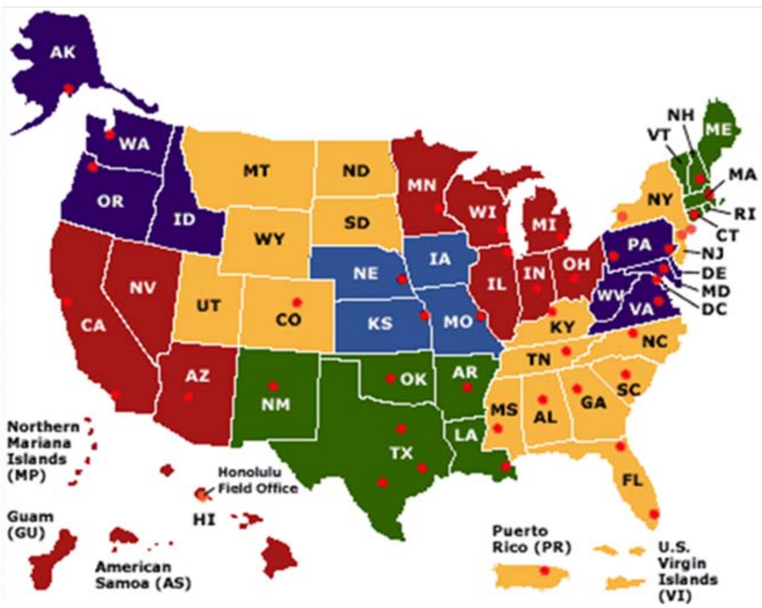
Regional Energy Efficiency Potential Estimates

To gain a better understanding of the multifamily energy efficiency potential, we also examined it on a regional basis.

The U.S. Department of Housing and Urban Development divides the country into ten regions for purposes of addressing the country's housing needs. Since one of the more important possible uses of this study is the provision of data that will help HUD target its resources for the multifamily sector, we

[33] 1 MMcf (million cubic feet) of natural gas is equivalent to 10,000 therms.
[34] U.S. Census Bureau, Housing and Household Economic Statistics Division, Table 68. Owners surveyed did not include public housing agencies.
[35] Based on an assumption of 40% improvement over existing conditions.

chose to use the same regional designations.[36] Much of the regional data upon which this report relied was available by HUD Regions. Because some regional studies define the regions differently (notably those by regional energy alliances like the Southwest Energy Efficiency Project), it is not always possible to make a perfect correlation of those data with the HUD Regional data. The map and table in Figure 8 show HUD's regional designations and provide a list of the states in each region, the population of the region, the number of multifamily units, and the ratio of multifamily units to single-family units. Although Region 3 has among the lowest multifamily-to-single-family ratio of any region, the District of Columbia has by far the highest ratio, at 129 MF units per 100 SF units. The national mean is 27 multifamily units per 100 single-family homes.



36 We considered several other regional divisions. For an explanation of those and why we found them to be less useful than HUD's regions, please see the Appendix.

Reg.	HUD Region	States	Population (thousands)	MF Units (thousands)	MF:SF Ratio
1	New England	VT, NH, ME, MA, RI, CT	14,304	1,604	0.35
2	New York, New Jersey	NY, NJ	28,173	4,037	0.55
3	Central Eastern Seaboard	PA, DE, MD, DC, VA, WV	29,130	2,316	0.22
4	Southeast	KY, TN, NC, SC, GA, AL, MS, FL	59,801	4,998	0.23
5	Midwest	MN, WI, MI, IL, IN, OH	51,616	4,331	0.24
6	South Central	NM, TX, OK, AR, LA	37,220	2,747	0.22
7	Central	NE, IA, KS, MO	13,500	925	0.18
8	Rocky Mountains	MT, ND, SD, WY, UT, CO	10,622	862	0.24
9	West/Southwest	CA, NV, AZ, HI	47,145	4,682	0.36
10	Northwest	OR, WA, ID, AK	12,549	1,082	0.26

Figure 8: U.S. HUD Regions (population and housing data from the U.S. Census Bureau, 2008)

Although the regional data are useful, there are some interesting details at the state level too. For example in Region 6, Texas is the only state with a relatively high MF:SF ratio (27 MF to 100 SF). The other four states in the region have 13 to 15 multifamily units to every 100 single-family homes. Likewise, in Region 1, the multifamily units are clustered at the southern end of the region in Massachusetts, Connecticut, and Rhode Island. Maine, New Hampshire and Vermont have only 17, 25, and 20 multifamily units respectively, to 100 single-family units, whereas Connecticut, Rhode Island and Massachusetts have 35 to 44.

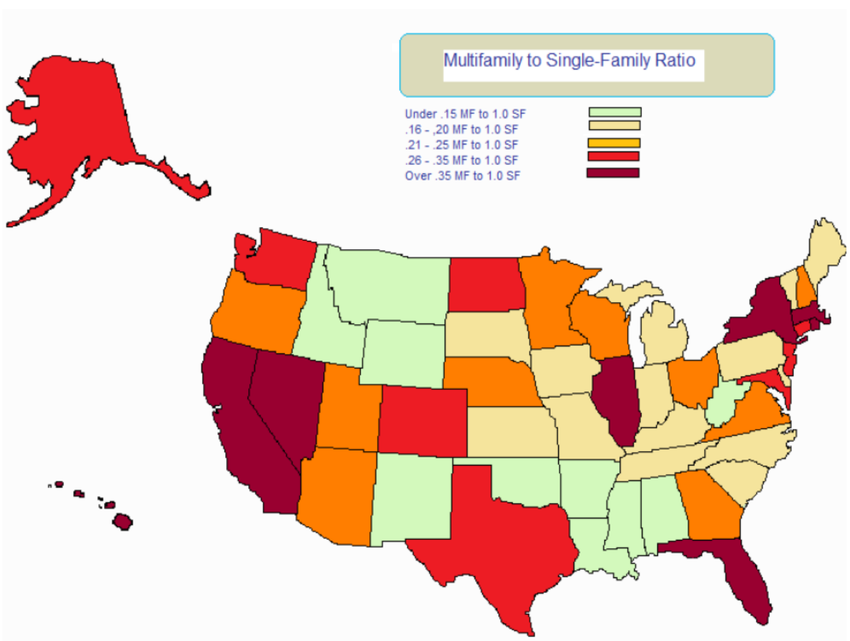


Figure 9: MF:SF Ratio State-by-State (based on U.S. Census data)

However, the raw numbers of multifamily units can mask important differences that could represent the best opportunities for multifamily energy savings. Since it is often more cost effective to perform efficiency upgrades on larger properties (lower transaction and transportation costs per unit), it is worth looking at differences in the number of units per building across the regions. A state-by-state analysis of the Census Bureau data on number of units (“2 to 4” vs. “5 and over”) shows a significant range of size distributions. Region 1 has a higher percentage of smaller multifamily buildings than larger ones (only 46% of units are in buildings with 5 or more units). So even though it has the third highest MF:SF ratio, the bulk of the multifamily units are four-plexes or smaller. All other regions have more units in larger buildings than smaller ones. On average across the nation, 66% of multifamily units are in buildings with five or more units. The regions with the highest percentage of larger building are 9 (74%), 6 (72%), 8 & 10 (70%), and 4 (69%). Next to Region 1, Region 7 has the lowest percentage of units in larger buildings (60%), but Regions 2 & 5 are close with just 62%. In general, there appears to be the greatest opportunity for efficiency gains across the South and in the West (Regions 4, 6, 8-10), which have 52% of the national total units in larger buildings and just 39% of those in smaller buildings. Although it is wise to look at larger buildings when trying to maximize impact, it should be noted that Region 2 (NY&NJ) has the third lowest percentage of its multifamily units in larger buildings, but the units in larger buildings still total over three million.

Population growth rate was accounted for in many of the residential efficiency potential studies we relied upon, though it is not clear what growth rate assumptions researchers used. In most of the populated regions of the country, land prices are already causing developers and planners to rethink how to house most of the expected growth. The *California Energy Efficiency Potential Study* (2007 Itron) included one scenario where the population growth in California resulted in a significant shift in the mix of housing toward a higher percentage of multifamily residences. Without changing any assumptions about population, technologies available, nor prices of inputs (energy, remodeling, and new construction costs), Itron estimated a shift in the assumptions of the number of multifamily units increased the efficiency potential in the overall residential sector from 37% to 49% of the base case usage by 2050. Therefore, the estimated savings in Figure 11 are likely very conservative in those regions with high population growth. From Figure 10 it is obvious that these states are also mostly in the South and West.

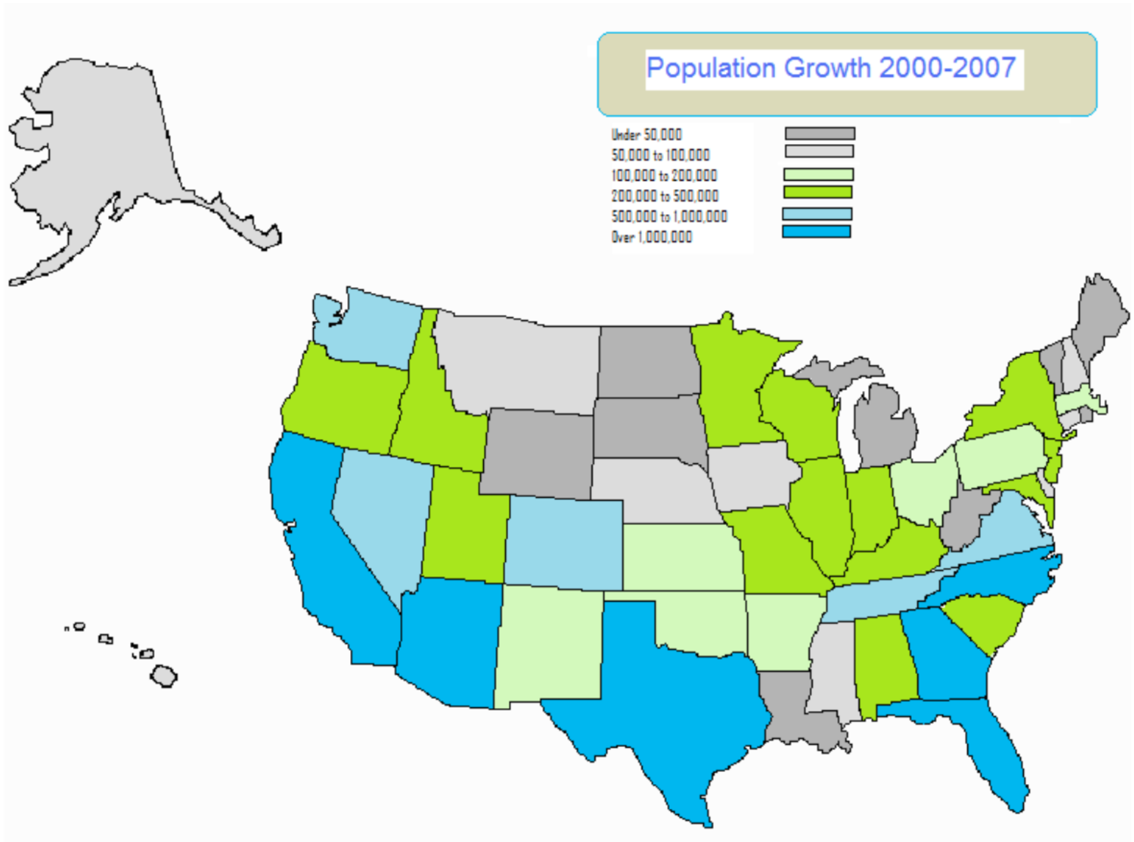


Figure 10: Population Growth by State

When we look at the table shown in Figure 4, we see that the multifamily potential by 2020 is over 51,000 GWH and over 2800 Million Therms. The table in Figure 11 shows what the potential is by region based on a compilation of the residential potential studies we reviewed. It is difficult to completely reconcile some of these regional estimates with the discussion of regional data in the previous two paragraphs. For example, there is only one region that seems to have a lower multifamily EE potential than Region 9, and yet Region 9 is in the heart of the West where we would expect a relatively larger potential. Likewise, the Midwest has a MF:SF ratio that is about 10% below the national average, and only *average* prospects for population growth, but its multifamily efficiency potential is only exceeded by two other regions; (Regions 3 & 4 for electricity savings, and Regions 2 & 4 for gas savings). We suspect that this is due mostly to variations in the methodology of the various studies. It would be valuable to perform a national study using a consistent set of assumptions and data.

Estimated Multifamily Energy Efficinecy Potential by Region		*GWH*	*M Therms*
Region 1: ME, NH, VT, MA, RI, CT	**Estimated Potential**	**3,786**	**130**
	Percent of National Total	**7.4%**	**4.4%**
Region 2: NY, NJ	**Estimated Potential**	4,411	897
	Percent of National Total	8.7%	30.2%
Region 3: PA, DE, MD, DC, VA, WV	**Estimated Potential**	10,160	215
	Percent of National Total	19.9%	7.2%
Region 4: NC, SC, GA, FL, KY, TN, AL, MS	**Estimated Potential**	10,988	779
	Percent of National Total	21.5%	26.2%
Region 5: MI, OH, IN, IL, WI, MN	**Estimated Potential**	**6,907**	**410**
	Percent of National Total	**13.5%**	**13.8%**
Region 6: TX, LA, AR, OK, NM	**Estimated Potential**	**5,539**	**237**
	Percent of National Total	**10.9%**	**8.0%**
Region 7: IA, MO, NE, KS	**Estimated Potential**	**1,239**	**81**
	Percent of National Total	**2.4%**	**2.7%**
Region 8: ND, SD, MT, WY, CO, UT	**Estimated Potential**	608	22
	Percent of National Total	1.2%	0.7%
Region 9: CA, NV, AZ, HI	**Estimated Potential**	**2,850**	**109**
	Percent of National Total	**5.6%**	**3.7%**
Region 10: OR, WA, ID, AK	**Estimated Potential**	4,500	93
	Percent of National Total	8.8%	3.1%

Figure 11: Multifamily EE Potential by Region and Regional Percentage of Total

As stated above, our methodology involved applying results of studies carried out in a particular region to the all states in that region. In those cases where there was no multifamily-specific data within a region, we used data from the closest state(s). Because of this approach, variations in estimated energy efficiency potential based solely on variations in the researchers' assumptions and methodologies would propagate to all the states in that region. To test the theory that variations in potential studies' methodologies were a major source of the apparent regional differences from expectations (i.e., apparent over- and under-estimations for particular regions), we also developed an estimate using GWH and M Therm savings per multifamily household developed as a national average from all the studies. In other words, we applied the same EE potential per multifamily unit to each state and each region. In this case, the Region 9 estimated potential increased to 17% of the national total. All other regions changed somewhat. For example, Region 2 increased to about 15%, Region 3 decreased to about 8%, Region 4 to about 18%, and Region 10 dropped to about 4%. Using this methodology also increased the total estimated GHW potential by about 10% (to 55171 GWH), but cut the therm savings about in half (to 1507 M Therms).

Estimated Multifamily Energy Efficincey Potential by Region		GWH	M Therms
Region 1: ME, NH, VT, MA, RI, CT	Estimated Potential	3,208	88
	Percent of National Total	5.8%	5.8%
Region 2: NY, NJ	Estimated Potential	8,075	221
	Percent of National Total	14.6%	14.6%
Region 3: PA, DE, MD, DC, VA, WV	Estimated Potential	4,633	127
	Percent of National Total	8.4%	8.4%
Region 4: NC, SC, GA, FL, KY, TN, AL, MS	Estimated Potential	9,996	273
	Percent of National Total	18.1%	18.1%
Region 5: MI, OH, IN, IL, WI, MN	Estimated Potential	8,663	237
	Percent of National Total	15.7%	15.7%
Region 6: TX, LA, AR, OK, NM	Estimated Potential	5,493	150
	Percent of National Total	10.0%	10.0%
Region 7: IA, MO, NE, KS	Estimated Potential	1,850	51
	Percent of National Total	3.4%	3.4%
Region 8: ND, SD, MT, WY, CO, UT	Estimated Potential	1,725	47
	Percent of National Total	3.1%	3.1%
Region 9: CA, NV, AZ, HI	Estimated Potential	9,365	256
	Percent of National Total	17.0%	17.0%
Region 10: OR, WA, ID, AK	Estimated Potential	2,164	59
	Percent of National Total	3.9%	3.9%

Figure 12: Estimated Multifamily EE Potential Based on an Average of Estimates from All Studies

Potential Greenhouse Gas Impacts

We estimated the greenhouse gas (GHG) emissions reductions that should result from these energy savings. To estimate the CO_2 emission reduction resulting from the estimated electricity savings shown in Figure 11, we relied on a joint report of the Department of Energy and the Environmental Protection Agency. [37] The report is nearly nine years old, but it contains more detail than any other source we could find. It provides a regional average Lb.CO_2 per kWh for ten regions of the U.S. Unfortunately, the ten regions are not entirely contiguous with HUD's ten regions. However, the differences are relatively minor and any uncertainties introduced by the different region definitions would not affect the calculations by more than a few percent.[38] The Lb.CO_2/kWh emission rates (ERs) from the DOE/EPA

[37] "Carbon Dioxide Emissions from the Generation of Electric Power in the United States." July 2000.

[38] For example, Minnesota is separated from the rest of the Midwest in the DOE/EPA report, which means a kWh saved there ought to result in a reduction of 1.746 pounds of GHG emissions. However, the energy savings from

report range from 0.435 on the west coast to a high of 1.746 for the region that includes ND, SD, MN, NE, IA, KS, and MO. ERs across the three southern regions range from 1.342 to 1.529, while New England's and the Mid Atlantic's are 1.077 and 1.058, respectively. Using these data, we estimate that the GHG emissions reductions resulting from the multifamily electricity energy efficiency potential across all the regions is approximately 33 million tons of CO_2 by 2020.

Estimated CO2 Reductions (M Tons) from MF EE, by Region	*Electricity*	*Gas*	*Total*
Region 1: ME, NH, VT, MA, RI, CT	2.0	0.8	2.8
Region 2: NY, NJ	2.3	5.2	7.6
Region 3: PA, DE, MD, DC, VA, WV	8.0	1.3	9.3
Region 4: NC, SC, GA, FL, KY, TN, AL, MS	7.4	4.6	11.9
Region 5: MI, OH, IN, IL, WI, MN	5.5	2.4	7.9
Region 6: TX, LA, AR, OK, NM	4.2	1.4	5.6
Region 7: IA, MO, NE, KS	1.1	0.5	1.6
Region 8: ND, SD, MT, WY, CO, UT	0.5	0.1	0.6
Region 9: CA, NV, AZ, HI	0.6	0.6	1.3
Region 10: OR, WA, ID, AK	1.0	0.5	1.5
United States Total	32.6	17.8	50.4

Figure 13: Estimated GHG Reduction (1,000,000 Tons) from MF EE Potential

The greenhouse gas emissions calculator on DOE's Energy Information Agency web site uses the assumption that use of 1 therm of natural gas produces 10 pounds of CO_2. PG&E's calculator uses the assumption of 13.446 $LbCO_2$ per therm. Several other web sites showed a range of 11 to 13.45 (the IPCC uses 13.01) $LbCO_2$ per therm, with 11.7 being recommended by U.S EPA. In the analysis that is the basis of the table in Figure 13, we used 11.7 $LbCO_2$/therm, which provides an estimated reduction of 17,800,000 tons/year of CO_2 emissions (the annual equivalent of removing 34 million cars from America's highways, based on the US EPA estimate of 5.2 tons CO_2 per year per car). Across the range

Minnesota, using the HUD regions, are counted as being part of the Midwest. DOE/EPA's ER for that region, indicates that a kWh results in only 1.579 pounds of CO_2 emissions. If Minnesota's emissions reductions had been calculated using the higher ER, it would increase by 9.5%, raising the national estimate by 6/100 of a percent.

of possible values (10 to 13.45 LbCO_2/therm) the total GHG emissions reduction could be 14.9 to 20.0 tons of CO_2 from the multifamily natural gas efficiency potential.

The total carbon dioxide emissions reduction from the achievable (lowest level estimate) multifamily energy efficiency potential is over 50 million tons of CO_2 per year. To put that into perspective, that is the annual equivalent to the CO_2 emissions of over 9.3 million Honda Civic Hybrids (estimated 43 MPG) driving 2000 miles per month.[39] It is also roughly equivalent to the average CO_2 annual output from over four million U.S. households (or about 24 million world households). Emissions reductions associated with higher levels of energy efficiency improvements (e.g., economic potential and technical potential, respectively) would be roughly two or three times greater: 102 or 146 Million Tons of CO2, respectively.

Although these numbers are large enough to garner attention, they are only related to the use of multifamily buildings. They don't include the transportation efficiency gains related to multifamily buildings. Since the goal of this study was to identify the energy efficiency potential in existing multifamily buildings, it might not be appropriate to include transportation benefits. However, it is worth noting in closing, that multifamily households are generally close to a wider range of transportation options than single-family households, and therefore use significantly less energy for transportation. Consequently, they produce less CO_2. Since transportation accounts for about 30% of all US greenhouse gas emissions, the savings associated with multifamily households' transportation modes is likely quite significant. The following graphic is an example of the difference between CO_2 emissions for transportation among urban and suburban households. The picture for most urban areas looks much the same as this one (Figure 14) for New Jersey/New York/Connecticut.

[39] Using the US EPA assumptions of 48 mpg and 12,000 miles per year results in Honda Civic Hybrid emissions of 3.7 tons of CO_2 emissions per car per year. So the potential MF GHG emissions savings would then be equivalent to removing 13.5 million Honda Civic Hybrids from the road. It would also be equivalent to removing 4.76 million Hummers from the road – 19 times as many Hummers as have been sold in the US this decade.

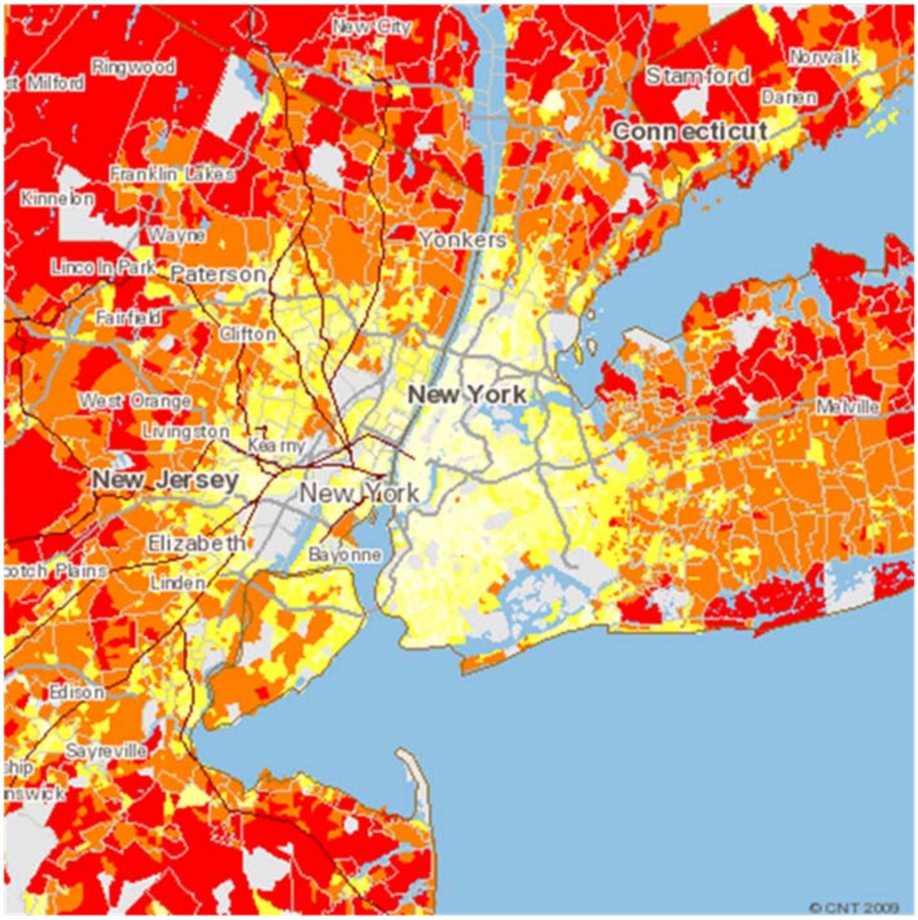


Figure 14: Automobile GHG Emissions Per Household (source Center for Neighborhood Technology)

The range is from 0-3.3 tons per household for the lightest yellow, to over 8.5 tons per household for the brightest orange. Households in the suburbs produce many times the CO_2 from transportation that households in urban centers do.

Appendix A: Regional Considerations

Using HUD's regions provides a useful way to conceptualize where the opportunities are, but there are many other regional definitions we could have used, and for which other useful data are available. For example, much of the U.S Census data describes the country as four regions: Northeast, South, Midwest and West. However, aggregating the nation's multifamily efficiency potential into just four regions would have masked too many important distinctions.

We could also have used the Federal Reserve Banks' districts. The FRBs track housing data and analyze the impact of the economic factors will affect building owners' degree of willingness to invest in upgrades. However, their data are not easily applied to the questions involved in estimating multifamily energy efficiency potential. For example, many of the district boundaries run through states rather than cleanly following state boundaries. Most of the residential efficiency potential studies on which we were able to rely were specific to an individual state. Of those that aggregated estimates across states, all but one still used state boundaries. It would have been extremely difficult to apply those data to the FRB districts in a way that would have allowed us to make accurate estimates of regional potential.

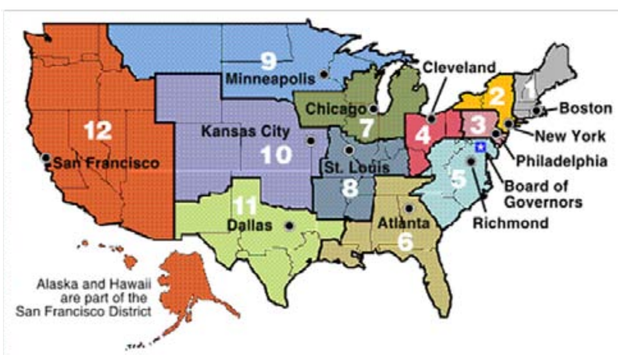


Figure 15: Federal Reserve Board Districts

We could also have used the regional maps of the various independent system operators of the electrical grid. They produce sophisticated forecasts of energy use and growth, often with very useful building sector distinctions. However, other than the New England Regional Transmission Organization (RTO) and the New York Independent System Operator (ISO), they all present the same issue as the FRB districts – the boundaries are not contiguous with state boundaries. (Note that even California's ISO and Texas' ISO (Ercot) leave out significant portions of their respective states.)   Even more limiting is the fact that the ISOs do not fully cover the entire United States.

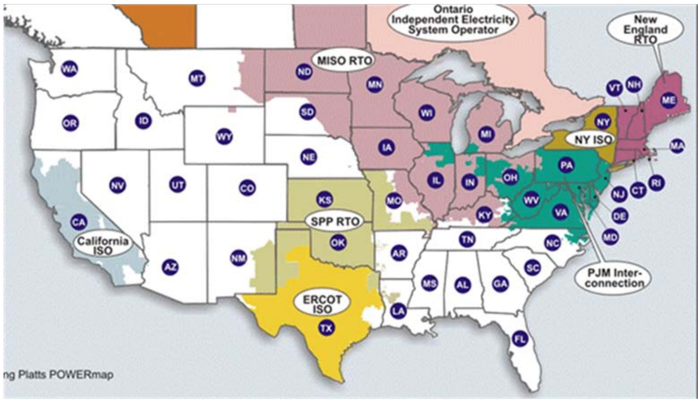


Figure 16: Map of the U.S. Independent System Operators

Regional energy efficiency organizations, including the Northwest Energy Efficiency Alliance (NEEA), the Midwest Energy Efficiency Alliance (MEAA), the Southeast Energy Efficiency Alliance (SEEA), the Northeast Energy Efficiency Partnerships (NEEP), and the Southwest Energy Efficiency Project (SWEEP) also provide a logical segmentation option. However, there are few bright lines defining what geography the alliances cover. There are clear exceptions to this; for example, NEEA specifically covers Oregon, Washington, Idaho, and Montana. Additionally, there are states that are not well represented in any of the alliances' analyses. According to the listing of member states shown on DOE's web site, the alliances only cover 41 of the states, and Kentucky is listed as being covered within both MEEA and SEEA.

Appendix B: Methodology

This report contains an analysis based on thirty energy efficiency potential studies that had estimates of potential savings within the existing residential sector. Most studies contained analysis on all sectors (e.g., commercial and industrial), all provided data specific to the residential sector, but only five had data that were specific to the multifamily sector. One of the five studies provided estimates for the multifamily sector in nine states. Consequently, we had direct multifamily efficiency potential estimates for fourteen states: California, Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, Pennsylvania, Texas, Vermont, and Wisconsin. These fourteen states account for 46% of the U.S. population, 45% of the households, 43% of the multifamily units, 56% of the residential natural gas usage, and 41% of the residential electricity usage in the United States. Without counting three studies that addressed the U.S. as a whole, the balance of the studies (27) included states that together represent 83% of both the U.S. population and U.S. households.

Figure 17 provides a list of the energy efficiency potential studies on which we relied. There is a more complete citation for each in the References section. The table indicates (last four columns) which studies only had residential-specific data and which had multifamily-specific data. It also shows the coverage of each study: state or region, fuel types, the type of potential estimated in the studies, the number of years each covered, and the specific period of coverage. The studies were conducted over the past eight years and covered different periods. The shortest period covered was one and five years (two estimates); the longest was 43 years (2007-2040). The mean length of the study periods was 14.8 years (median = 15 years). The median year for publication for the studies is 2007.

Many of the studies were performed by the same organization (ACEEE), so several of them used consistent assumptions about energy price escalations, cost-effective technologies, technological change, customers' willingness to act, population growth, etc. However, there were several significant differences in the approaches taken in the studies that need to be described. First, most studies were explicit about the difference between technical potential, economic potential, and achievable potential, though some studies used a different name for one of the types of potential. For example, in a report for Kentucky, the University of Louisville and ACEEE used the terms "Minimally Aggressive Potential," and "Moderately Aggressive Potential," and defined those terms with cost parameters that make them functionally equivalent to "Achievable Potential" and "Economic Potential," respectively. In some cases, all three types of energy efficiency potential were reported. In other cases only one or two were. In one instance, the report was not explicit on which type of potential was being described, but we had an estimate for that state from another report and only used the less explicit study for certain background information. In one regional study, only the economic potential was presented, but again, we had another study for most of the states included in it. In all cases, the measures included in the studies had a benefit cost ratio of better than 1.0 (using the TRC test), and if the study provided an estimate of achievable energy efficiency potential, we used that.

Author(s)	Client	Year	State/Region	Fuel	Study Type			Yrs	Period	Multifamily		Residential (comb)	
					Econ	Tech	Ach			GWh	MTherms	GWh	MTherms
Nadel, Shipley, Elliot	ACEEE	2004	U.S.	Meta	X	X	X	n.a.	**meta**			0	0
Siddiqui	EPRI	2009	U.S.	Electric			X	20	**2010-30**				
Optimal Energy, Inc.	NEEP	2005	New England	Electric			X	10	**10 yrs**			12,745	
Rufo, North	CEC	2006	California	Electric	X	X	X	43	**2007-50**	9,572		49,006	231
Itron and KEMA	PG&E	2008	California	Elct & NG	X	X	X	18	**2008-2026**			10,000	400
KEMA		2003	California	Elct & NG	X	X	X	10	**2003-13**			10,500	250
Elliott	ACEEE	2005	U.S.	N.G.			X	15	**2005-2020**				6,000
Elliott, Fairey	ACEEE	2007	Florida	Electric	X	X	X	15	**2008-2023**			11,628	
ICF	GA Env Facilities Auth	2005	Georgia	Elct & NG			X	5	**2005-2010**			2,908	595
Southeast EE Alliance	Appalachia Rgnl Comm	2009	WV, & parts of AL, GA, KY, MD, MS, NY, NC, OH, PA, SC, TN, VA	Elct & NG	x			20	**2010-2030**			16,758	840
Hadley	Iowa Energy Center	2001	Iowa	Elct & NG			x	20	**2000-2020**			850	10
Worek & Mueller	Illinois DCEO	2007	Illinois	Electric		X		14	**2006-2020**			9,000	
Randy Gunn, Summit Blue	Kansas Energy Council	2008	Kansas	Elct & NG	X	X	X	20	**2008-2028**			3,807	210
Kentucky Pltn Prevtn Ctr	KY Gov Off. Energy Plcy	2007	Kentucky	Elct & NG	X	X	X	9	**2008-2017**			3,625	308
MEEA (inc. the 9 states below)	**Xcel**	**2006**	**Midwest**	**Elct & NG**		**X**	**X**	**20**	**2006-2026**	7,343	850	36,717	5,002
MEEA			Illinois			X	X	20	2006-2026	1,029	211	5,146	1,239
MEEA			Indiana			X	X	20	2006-2026	893	75	4,466	444
MEEA			Iowa			X	X	20	2006-2026	355	35	1,774	208
MEEA			Kentucky			X	X	20	2006-2026	932	29	4,662	172
MEEA			Michigan			X	X	20	2006-2026	860	167	4,298	981
MEEA			Minnesota			X	X	20	2006-2026	448	57	2,242	334
MEEA			Ohio			X	X	20	2006-2026	1,325	159	6,623	935
MEEA			Wisconsin			X	X	20	2006-2026	467	59	2,334	345
MEEA			Missouri			X	X	20	2006-2026	1,034	59	5,172	345
Pigg, ECW	State of Michigan	2006	Michigan	Electric				n.a.	**n.a.**	804		4,019	
KEMA	Rutgers Ctr for EEEP	2004	New Jersey	Elct & NG	X	X	X	15	**2005-2020**			5,172	1,052
NWPPC (6th Plan)	Bonneville	2009	OR, WA, ID, MT	Electric	X		X	20	**2008-2028**			55,556	
Applied Energy Group	Midwest Energy, Inc.	2007	Oklahoma	Electric	X	X	X	9	**2008-2017**			14,806	
Green Energy Econ Grp	Ctzns for Penn's Future	2007	Pennsylvania	Electric	X		X	9	**2008-2017**			21,692	
GDS Associates	So Carolina Elct Coops	2007	So Carolina	Electric	X	X	X	9	**2008-2017**			8,122	
ETC Group/SWEEP	NM EM&NR Dept	2008	New Mexico	Elct & NG			X	9	**2008-2017**			2,819	239
Rnwbl E Policy Project	Pwrng the So Adv Cmmt	2002	AL, GA, FL, NC, SC, TN	Electric			X	18	**2002-2020**			95,924	
Optimal Energy, Inc.	NRDC	2007	Texas	Electric			X	14	**2007-2021**	1,474		5,461	
SWEEP	Utah Gov E Advisor	2007	Utah	Elct & NG			X	12	**2008-2020**			698	25
ACEEE	Energy Foundation	2008	Virginia	Electric			X	17	**2008-2025**			13,378	
VA Dept Mines, Mnrls, & E	VA Governor	2007	Virginia					10	**2008-2018**			7,732	98
GDS Associates	VT Dept of Pub Service	2007	Vermont	Electric		X	X	8	**2007-2015**	95		567	
EC of Wisconsin	WI Governor's Office	2005	Wisconsin				X	9	**2006-2015**			2,476	83
ACEEE		2009	Ohio	Electric	X		X	15	**2010-2025**			21,037	
ACEEE		2009	Pennsylvania	Electric	X		X	15	**2010-2025**	1,500			

Figure 17: List of EE Potential Studies Referenced

Technical potential answers the question of how much could we save with available technology if we were willing to spend what it took. Economic potential answers the question of how much could we save if we were to adopt all energy efficiency measures that save more than they cost. Achievable potential includes consideration of what building owners and other decision makers will accept and take action on. In multifamily buildings, this latter filter is complicated by the fact that in many cases, the person or company having to make the investment in the energy efficiency measure is (a) financially constrained and (b) often not the same entity whose bills will be reduced and whose comfort will be increased.

Because the majority of the studies did not segregate an estimate for multifamily savings from the larger estimate of savings in the full residential sector, we scaled the savings estimates using:

- the ratio of the state's multifamily units to total residential units
- a multiplier for each general region representing the relationship between the percent of the housing stock that is MF and the percent of the residential savings attributable to the MF sector based on those fourteen states where the multifamily savings were directly reported

For example in California, 27.8% of the housing stock is MF, but only 19.5% of the residential energy efficiency potential is from the MF stock. That gives us a MF E multiplier of 0.7014 (0.195/0.278)

MF E Multiplier = (MF GWH/Res GWH)/(MF Households/All Households)

For the other states in the West, we have total residential efficiency potential but none of the studies indicate what portion of the residential potential is attributable to the multifamily sector. In this case, we multiplied the full residential potential by (a) the percent of the housing stock that is multifamily in those states and (b) 0.7014, the multiplier from the California study. The multifamily energy multipliers for the Midwest, South, and Northeast were 1.087, 1.256, and 1.008, respectively. The states from which we were able to calculate multipliers were California, Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, Texas, Vermont, and Wisconsin.[40] There were no states from which we could develop multipliers in Regions 3 and 10, so we used those from Regions 2 and 9, respectively.

[40] Note that this also means that we did not need to apply MF E multipliers to the estimates for these states, though we still normalized to 11 years from the time period of their studies.

Since the various potential studies were for different time periods, we also had to normalize to one time period. What this report provides is an estimate of multifamily energy efficiency potential by the year 2020, or eleven years. The ratios we used were straight line relationships between length of study period and energy savings potential.[41] This is a conservative approach when applied to longer study periods, but it could result in an overestimation of savings when applied to shorter study periods. In other words, it is conservative to estimate that in eleven years, we could only achieve half of what a study indicated for a 22 year period, and it would be an over-estimation to assume we could achieve twice as much in ten years as a study indicates for five years. Therefore, if most of the studies were for shorter periods than 11 years, it would be likely that we could develop an overestimation of the national savings potential by 2020. The median period of the studies was 15 years, and the savings estimates were conservatively reduced in significantly more cases than they were potentially overestimated. Additionally, the average annual savings in those studies with longer time periods (and therefore conservatively accounted for in this study) were approximately 40% higher than those with time periods under eleven years (i.e., those where savings were potentially overestimated when expanding to eleven years).

MF GWH Potential for State A =
Res GWH $_{\text{study period}}$ * (11/Yrs in Study Period)* (# MF Households/# of Res Households)*(MF E Multiplier)

For example, the New Jersey study period was 15 years. There are 3,499,406 households in New Jersey, and 912,312 of those are in multifamily units. The New Jersey study indicated a residential savings potential of 5,172 GHW. The MF E multiplier we used for the Northeast (based on Vermont) was 1.008. Therefore, the MF GWH Potential for New Jersey is:
5,172 GWH * (11/15) * (912,312/3,499,406) * 1.008 = 977 GWH

Based on these studies, the energy efficiency potential for the existing multifamily sector by 2020 is 51,091GWH of electricity and 2,810 million therms of natural gas (or NG-equivalent for those buildings using fuel oil or propane). The TRC benefit cost ratio was explicitly provided for the residential sector in only a few cases. For the multifamily portion of the residential sector, it was provided even less often. Therefore, it was not possible to develop a reasonable estimate of the benefit-cost ratio applicable to the

[41] For example, if a study period was 15 years, we assumed that only 11/15 (73.3%) of the savings would be achieved in the 11 year period from 2009-2020.

savings potential from the combination of the studies. However, assuming the average benefit-cost ratio is a modest 1.5, the net benefits to the country of investing in energy efficiency for the multifamily sector could easily be over $4 Billion ($2.5B$^+$ in electricity, and $1.5B$^+$ in natural gas or equivalent) by 2020.[42] We believe that a TRC B/C ratio of 1.5 is appropriate because several recent studies by ACEEE and others have shown that energy use can be cut by over 25% at a cost of less than $0.08/kWh, and the national average residential electricity cost in 2009 is $0.112/kwh. The cost of the efficiency savings could be as high as $0.075 for a TRC B/C ratio of 1.5.

[42] These estimates are based on energy costs of $0.10/kWh and $1.10/therm.

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