Energy Analysis Beyond Benchmarking for Multifamily Buildings: Results from Wisconsin's 30 Multifamily Buildings Study

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ABSTRACT

This study investigates whether software designed for the evaluation of single family dwellings might be useful in smaller multifamily buildings. Since small multifamily buildings, like single family homes, tend to be shell-dominated in their space conditioning energy use, there was reason to believe that the software tools might be relatively accurate in their predictions. These analysis tools are less expensive to employ, and have large bodies of experienced practitioners trained in HERS (Home Energy Rating System) programs across the country. This paper will discuss the accuracy and utility of applying a rating tool (REM/Rate®) designed for single family dwellings, to buildings with multiple living units.

In contrast to a previous study of single-family homes, we found no conclusive evidence of systematic bias in predicted heating use, but the small sample size here precludes accurate determination in this regard. Sample size considerations make it difficult to make robust conclusions in larger buildings, but the data provide some evidence that the error between REM/Rate and utility data is correlated with building size. Given that REM/Rate output is delivered in comparison with single-family construction codes, the software is less than ideal for design assessment in new construction or gut rehab programs that often must conform to multifamily or commercial building and energy codes.

We thus provide support for programs that would go beyond simple benchmarking of buildings and utilize relatively simple tools to identify cost-effective measures while capturing the interaction of planned measures. This points toward a more cost-effective method of assessing energy efficiency and planning energy retrofits in mid-sized residential buildings, and toward the opening of new service markets to experienced HERS raters.

Introduction

Energy efficiency programs to improve the performance of existing multifamily buildings are finally beginning to catch up to those in the single family building sector. Software tools and audit protocols now exist for auditors and other trained contractors to model and analyze large multifamily buildings, and they effectively capture the complexities of large residential buildings and their energy-consuming systems. However, most multifamily buildings in most areas of the country are of moderate size and complexity, and their construction is similar in many ways to that of single family homes. Retrofit work in these buildings may not require an elaborate modeling approach with a complex, DOE-2 based tool. In fact, the costs associated with this sort of detailed analysis may deter energy efficiency work that may be very effective and useful.

This paper summarizes the findings of an analysis of the accuracy and usefulness of simulating multifamily buildings with a common HERS tool (REM/Rate®) to identify energy efficiency opportunities. We obtained utility bills from 30 apartment buildings that had been evaluated with REM/Rate, and compared the energy use predicted by that software tool to the actual utility consumption. This paper builds on the field work of several capable analysts. In 1999 and 2000, Rich Marshall of the Wisconsin Energy Conservation Corporation conducted home energy rating (HERS) analyses on 30 multifamily buildings. He was assisted in his work on 7 of these buildings by Mike Hodges, Hans Hofman, and Joe Danes.

Following the collection of the HERS data, historical natural gas consumption information was collected with the assistance of utility personnel, and aggregated into a two-year consumption profile for each building. This data was then segregated across space heating and service hot water/other demands and was weather-normalized, using Princeton Scorekeeping Method (PRISM) software, a widely used load-separation tool (Fels, 1986; Fels et al. 1995). Since the buildings are all in a 7,500 HDD climate zone and few of the buildings were equipped with central air conditioning, our analysis is restricted to space heating loads. We then proceeded to compare the REM/Rate results of simulations for these multifamily buildings with the analysis of historical energy bills as analyzed through PRISM.

Program Approaches to Improving the Energy Use of Multifamily Buildings

Wisconsin and most other states with active energy efficiency programs have developed a core group of competent contractors ready and able to improve the performance of multifamily housing stock. The experience of the recent past has been that most current-technology energy upgrades are cost effective and return a reasonable profit to the property owner.

However, a major problem arises for building owners and developers in that they “don’t know what they don’t know”. Most of Wisconsin property owners believe their buildings are "well-insulated" and almost all believe their buildings to be "adequately insulated (61 and 86 percent, respectively). A significant minority (25%) of owners believe they cannot create any substantial energy improvements in their buildings (ECW, 1999). Interestingly, the same proportion of operators believe that tenants can reduce total building energy use on the order of 50% by adjusting their habits. That is, existing building owners and developers of new construction are unaware that they are less than fully informed about cost-effective energy efficiency opportunities.

The Wisconsin multifamily program, a part of the state's "Focus on Energy" effort, has a goal of assisting building owners and developers in discovering energy efficiency options that they can voluntarily choose to include in their existing maintenance and rehab plans. To pursue this goal, the multifamily program is aiding apartment owners and developers in identifying specific measures that offer potential energy performance improvements. The program also is defining strategies which owners, developers, and contractors can use to approach the decision process of identifying energy improvements. By these means and efforts to publicize successes, owners and developers can discover conservation opportunities and measures that they did not know about or dismissed as ineffective.

Contractors or state personnel can adopt several methods to assist multifamily building owners and developers in identifying energy conservation opportunities. Among these approaches are: comparison of an existing building with lists of prescriptive measures; benchmarking energy use against a standardized scale; and modeling individual buildings with simulation tools. Each approach has advantages and drawbacks.

A well-developed multifamily energy efficiency program that relies on a prescriptive program design is the “Energy Efficient Affordable Housing” program in the Chicago metropolitan area. The state of Illinois operates this robust gut rehabilitation program[1] for walk-up multifamily buildings that specifies a list of prescriptive measures. To receive funding from the program, a property owner or developer must include all measures in his/her project. Among the measures on the list are: air tight drywall system, high efficiency furnace or boiler, windows with U-values of .35 or lower, wall insulation with R-values of 19 or greater, and envelopes passing blower door tests with fewer than .50 air changes per hour (natural).

Though these measures are highly laudable, this list of prescriptive measures or any list is unlikely to be optimal for all buildings. Since some buildings, for instance, may have very low space heating needs - as would a very tight, well-insulated building with extensive passive and active solar design - it may not be cost-effective to install a high efficiency furnace. In such a case, optimal design would suggest tradeoffs be made to achieve lower construction cost and rents while optimizing energy and operating costs. Nevertheless, using a list of prescriptive measures is an excellent way to reduce the costs of building analysis and design evaluation. It is especially useful in programs where (as in Illinois) a building is being completely rehabbed. This program model is also useful to many weatherization agencies, where an essentially uniform building stock is targeted, so that one comprehensive (and expensive) analysis can be replicated over many buildings.

Benchmarking is an analytical tool that the EPA has used for over five years in its commercial and institutional buildings program. Benchmarking involves only the analysis of historical billing information to classify the building's energy use in terms of the distribution of energy use by similar buildings. Many methods exist for analyzing a building's energy bills, most of them designed for commercial or industrial buildings. More complex methods use load separation algorithms, such as PRISM. A simple method suitable for small residential buildings is presented on ***Home Energy*** Magazine's consumer information web site (Cavallo, 2001). Though benchmarking can be quite simple, it is more time consuming than applying a list of pre-engineered prescriptive measures and, in some versions, may require the involvement of a trained consultant or engineer to identify usage levels that are abnormally high. Even when such expert analysis is used, benchmarking only indicates the location of the building within the national distribution of the energy use of similar buildings. Although one may infer that a building ranking low in the distribution (i.e., relatively high energy consumption) has opportunities for improvement, benchmarking alone does not provide the property owner or developer with information on what measures may be cost-effectively included in an upgrade of construction or rehab plans.

Benchmarking is often especially problematic in multifamily buildings. If the building is master metered, getting total consumption data is very simple. However, breaking that data out into usage categories that can inform an energy retrofit effort is often quite complicated. By contrast, in buildings that are individually metered, getting utility bill information from a large number of occupants is an onerous task. (In some states, it is illegal to master meter electricity except in very specific circumstances, and account holders usually must give explicit written permission to access their account information.) The resulting mass of data, if it can be obtained at all, may make it very difficult to find trends in consumption

[1] The "Illinois Energy Efficient Affordable Housing Program" funded and managed by the Illinois Department of Commerce and Community Affairs. Paul Knight and Maureen Davlin provided us with extensive information about this program, and its experience in more than 80 rehabbed (previously abandoned) walk-up apartment buildings in Chicago.

A third approach to identifying energy conservation opportunities is building modeling. By creating a more or less comprehensive computer/mathematical model of the energy-consuming and energy-loss features of a building and site climate information, reasonable predictions can be made about that building's energy demands. The addition of utility rates and local market costs for various energy retrofits can allows some modeling tools to perform quite sophisticated financial analysis, as well. Modeling a building with a software tool has the advantage of permitting objective and interactive evaluation of alternative construction or rehab upgrades. For instance, a building can be modeled within a software tool according to its original plans, and then the input parameters of the model can be altered to estimate the cost and energy use impacts of using different windows, heating systems, or other energy using systems. Moreover, such modeling examines the structure within a systematic whole building approach. Such simulation permits one to identify optimal tradeoffs between systems and the most cost-effective energy measures. In most energy modeling software tools, one can compare, or rate, the building's energy use to a "standardized" building in a manner similar to benchmarking.

The advantages associated with the modeling approach must be balanced with its drawbacks. In particular, modeling is generally more costly than benchmarking. Modeling requires implementation by trained individuals. It is common for HERS ratings to cost $300 or more for a single family home. Rating a multifamily building could be expected to command a higher fee. In addition to the direct cost of modeling a building, there are costs associated with the creation of the infrastructure for the HERS industry. Rater training, quality control systems, creation and maintenance of software libraries, and archiving of ratings are all tasks that are important to the ongoing functioning of an effective HERS network. These costs are, at present, frequently borne by an energy efficiency program operated at a utility or state agency level.

Choosing between the alternative approaches for identifying energy efficiency opportunities will be an important decision for utility program managers and government agency implementers. Wisconsin is not alone in seeking an effective means of addressing apartment buildings. An *ad hoc* task force is working with EPA to examine the alternatives for a national program that will bring the Energy Star label to multifamily buildings. Whether the EPA's multifamily program will use the benchmarking approach as in its commercial buildings effort or use energy modeling as in its single family program will probably be determined sometime in 2004. But in making the decision, both state and federal governments will need to consider both the benefits and the costs of the different approaches.

A Multifamily Building Dataset

As noted above, the analysis of this project has the goal of informing the decision of Wisconsin officials as to the benefits of applying the rating approach to identifying energy efficiency opportunities in multifamily buildings. The project focuses the analysis on a dataset of 30 multifamily buildings which were rated by expert HERS raters.

This sample is by no means ideal for the analysis at hand. These buildings do not constitute any sort of random sample; they were submitted to the program voluntarily, usually through with the assistance of staff from local utility companies. The sizes of the buildings are diverse, but biased towards smaller buildings. The building sample extends from a duplex that is just 2976 square feet to a seven-story, 84 unit building with 68,229 square feet of conditioned space.

Rating apartment buildings in REM/Rate, not surprisingly, required some adjustments in typical HERS procedures. Having one very experienced rater (Rich Marshall) do the majority of the field work reduced problems with variations in individual raters' judgments. All the raters involved were forced to create a number of custom elements and building layers not typical in single-family homes in Wisconsin, with unknown accuracy. In the version of REM/Rate available when these rating were done, multiple individual heating or cooling systems had to be aggregated to one large input value[2], with unknown affects on the modeling of cycle inefficiencies and standby losses.

Assessing infiltration losses for this study proved to be a challenge. Raters in this study attempted blower door tests with multiple blower doors with mixed results. In some cases, very leaky buildings of only moderate size forced raters well down into the "Can't Make 50" correction tables used to estimate leakage areas when buildings cannot be depressurized to 50 pascals. More than half of the buildings were too large or complex to be tested. In these building ratings, infiltration assumptions were made based on engineering data available regarding the installed ventilation systems.

Finally, there is the matter of assessing common area energy usage and interactions. In this study, the field work did not incorporate a detailed electrical audit, and common area space heating was not broken out as a separate use category. In smaller buildings with minimal common area, assessing the building in this manner as though it were just a very large home would not be expected to affect the accuracy of the rating to any great degree. In a building with significant hall area, the impact on model accuracy could be significant.

Table 1 lists all the buildings originally in this study. Also given in these tables is the estimated (PRISM) weather-normalized natural gas usage for space heat, the REM/Rate weather-normalized space heating use prediction and the REM/Rate rating[3].

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[2] More recent versions of REM/Rate are more apartment friendly, allowing duplicate small furnaces, water heaters, etc., for condominiums and individual apartments.

[3] REM/Rate compares buildings to a "reference building" of appropriate dimensions that meets the 1993 Model Energy Code. A rating of "80" indicates a building that uses energy in conformance with MEC 93, while a higher rating indicates lower energy consumption (higher efficiency) than established by MEC 93.

Table 1. Summary Data of All Subject Buildings

Identifier	Units	Floor Area	Infiltration Measured (m) or Estimated (e)	PRISM Estimated Space Heating (Standard Error)	PRISM Btu/Ft^2	REM/Rate Btu/Ft^2	REM/Rate Error (percent)	REM/Rate Rating
A1	4	9,306	28,300 (e)	no estimate	**	57,801	**	65
A2	16	16,724	80,300 (e)	no estimate	**	40,947	**	76
A3	10	9,364	10, 458 (m)	3109 (573)	33,202	66,160	99.3	57
A4	6	4,052	17,500 (e)	2894 (237)	71,422	83,540	17.0	59
A5	4	5,398	6,591(m)	3037 (345)	56,262	57,240	1.7	73
A6	2	2,976	13,000 (e)	3444 (300	115,726	109,610	-5.3	43
B1	8	8,265	9,700 (e)	no estimate	**	14,700	**	74
B2	7	5,006	17,200 (e)	142 (54)	**	32,361	**	72
B3	8	10,368	32,300 (e)	939 (151)	**	39,901	**	70
B4	8	10,512	6,473(m)	3426 (472)	32,591	33,760	3.6	77
B5	8	8,385	9,963(m)	4858 (241)	57,937	71,520	23.4	67
B6	8	10,784	12,903(m)	3736 (295)	34,644	44,620	28.8	69
B7	8	9,528	32,000 (e)	3580 (488)	37,573	34,560	-8.0	76
B8	4	5,022	4,135(m)	2226 (244)	44,325	45,460	2.6	46
B9	8	10,584	27,900 (e)	4560 (221)	43,084	30,350	-29.6	81
B10	4	5,880	5,610	2654 (175)	45,136	37,600	-16.7	80
C1	12	12,420	38,750 (e)	5832 (430)	46,957	26,600	-43.4	82
C2	16	38,400	119,000 (e)	4986 (148)	12,984	19,490	50.1	86
C3	12	9,158	12,400 (e)	183 (44)	**	26,960	**	69
C4	19	20,625	64,000 (e)	6703 (617)	32,499	27,850	-14.3	78
C5	18	26,584	81,000 (e)	8141 (610)	30,624	32,320	5.5	75
D1	24	16,832	47,100 (e)	no estimate	**	31481	**	86
D2	20	33,724	97,800 (e)	2212 (100)	**	32,727	**	78
D3	20	12,800	4,350(m)	9307 (696)	72,711	93,500	28.7	46
D4	29	7,635	34,800 (e)	6004 (815)	78,638	115,280	46.6	52
D5	29	31,176	95,000 (e)	10353 (920)	33,208	23,120	-30.4	81
D6	20	24,668	75,000 (e)	7224 (787)	29,285	24,100	-17.7	82
E1	18	19,819	55,500 (e)	5880 (610)	29,669	39,130	31.9	71
E2	83	68,229	145,000 (e)	22525 (1125)	33,014	13,630	-58.7	NR
E3	48	33,692	98,500 (e)	no estimate	**	29,042	**	80

** Buildings dropped from the analysis

The space heating estimates shown were developed and weather-normalized using PRISM load separation software. The load separation method used in PRISM divides the historical energy bills into baseload energy use and winter-weather sensitive (space heating) components, and weather-normalizes the obtained values. In the process, PRISM establishes a statistically-derived balance point for the building. Thus, PRISM energy consumption values do have a standard error associated with them, reported above.

REM/Rate "scores" a building against the 1993 Model Energy Code. The program does not use consumption or billing data to normalize or "true up" model results.[4] A REM/Rate rating, completed by an experienced rater, involves only two to four hours worth of building assessment and data entry, based on assumed or measured insulation levels, measured infiltration from

[4] The most recent version of the software allows the entry of historical bill information. It is used only to create a "reconciliation report" that explicitly reports divergence between REM/Rate's predicted energy use and the historical bill data.

blower door tests, and nameplate data from installed mechanicals. These variables are then interactively calculated across hourly average climactic values.

Some buildings in the original study were dropped from this analysis. Because heating with electricity presents very different usage characteristics than with natural gas, inclusion of the buildings with electric space heating would bias the sample. With only five such buildings, there was not enough data on this subset to constitute a reliable second sample pool. For this reason, the five electrically heated buildings were not included in the analysis that follows. Moreover, the PRISM estimates for four buildings (C3, B2, D2, and B3) were unbelievably small (less than 10,000 Btu per square foot) and suggest that the natural gas bills were either incomplete or some of the space heating was performed with electricity. These buildings also were left out of the statistical analysis.

Testing the REM/Rate Estimates

In this project, the REM/Rate results of the ratings conducted on the multifamily buildings are to be compared to the PRISM results that were taken from the historical bills. To do this, one must find common ground between the two analytic tools. PRISM, unfortunately, does not generate a rating. However, REM/Rate produces an estimate of the energy used for space heating. Table 1 presents the estimated/predicted space heating requirements under normal weather conditions, for the buildings as modeled with REM/Rate. Table 1 also contains the PRISM estimates. Both the REM/Rate and the PRISM estimates are normalized for the size of the building by dividing by the square feet of conditioned space. Finally, Table 1 shows the computed error of the REM/Rate estimate compared to the PRISM estimate, as a percentage.

Analysis of 247 Wisconsin homes (Pigg and Nevius, 2000) demonstrated that REM/Rate, at least as used in Wisconsin in single family homes, exhibits some systematic bias toward overestimating heating usage for poorly insulated, leaky homes. It is also generally understood that PRISM itself has a small bias to inflate space heating use slightly, as it erroneously calculates some seasonally variable non-heating energy use as though it were space heating energy (Fels et al., 1986).

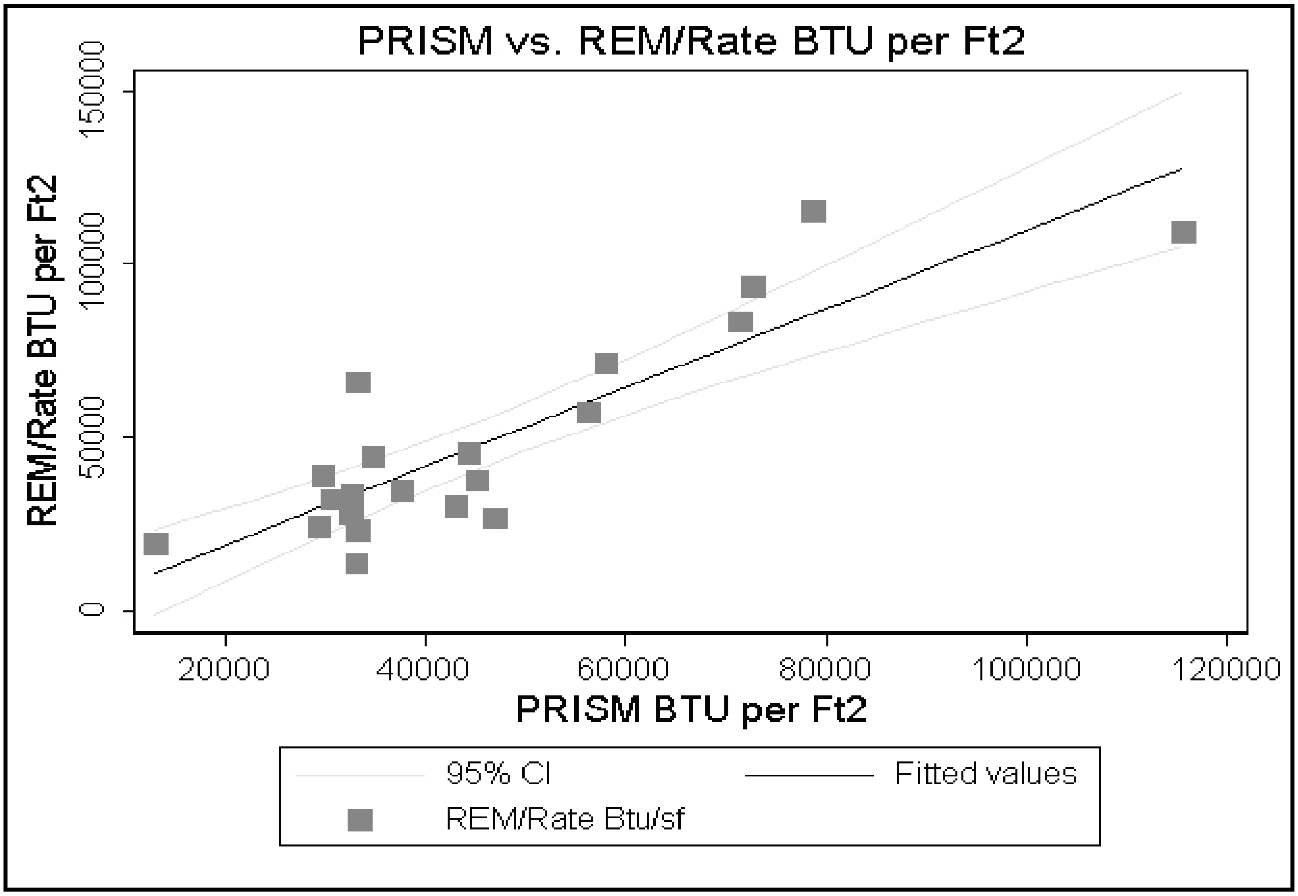
The space heating estimates in Table 1 offer two avenues for testing how well the REM/Rate estimates fit the estimates from the analysis of historical bills in PRISM. The first approach is to regress the REM/Rate estimates adjusted by the size of the building against the PRISM estimate after adjusting for the building size. That is, a regression line is computed using the "Btu/ft^2" columns of Table 1. Table 2 and Figure 1 summarize these results.[5]

Table 2. Regression Results of REM/Rate Btu/Ft^2 vs. PRISM Btu/Ft^2

Dependent Variable:	REM/Rate Btu/ft2					
Independent variables	**Coefficient**	**Std. Error**	**t**	**P> |t|**	**95% Confidence Interval**	
Prism Btu/ft2	1.136	.1467	7.74	0.000	.8287	1.443
Constant	-3521.	7537.	-0.47	0.646	-19296.	12253.
Adjusted R^2	0.747					
N	21					

[5] All statistical analysis performed with Stata v. 8.0.

Figure 1. Regression Results of REM/Rate Btu/Ft^2 vs. PRISM Btu/Ft^2 (95% C.I.)



These results suggest a reasonably strong linear relationship between the two space heat estimates. In terms of systematic bias, the confidence envelope for the regression fit (Figure 1) includes the 1:1 line of congruence; this indicates a lack of evidence that the REM/Rate and PRISM estimates differ systematically.

A simple analysis of the mean difference between the REM/Rate and PRISM estimates of heating use per square foot suggest a slight positive bias to the REM/Rate estimates, but a paired t-test on this difference is not statistically significant (Table 3).

Table 3. T-test for (REM/Ratebtuft2 - prismbtuft2) = 0

Variable	Obs	Mean	Std. Error	Std. Dev.	95% Confidence Interval	
REM/Rate Btu/ft^2	21	49023.	6510.	29833.	35443.	62603.
Prism Btu/ft^2	21	46261.	4994.	22887.	35843.	6679.
Difference	21	2761.	3265.	14963.	-4049.	9573.
	Ho: mean(REM/Ratebtuft2 - prismbtuft2) = mean(diff) = 0					
	Ha: mean(diff) < 0		Ha: mean(diff) = 0		Ha: mean(diff) > 0	
	t = 0.8459		t = 0.8459		t = 0.8459	
	P < t = 0.7962		P > |t| = 0.4076		P > t = 0.2038	

Of course, a lack of evidence of a difference is not the same as evidence that there is no systematic bias, especially given the small study group size. But the REM/Rate and PRISM results in this analysis are noticeably more congruent than found in the earlier single-family study, in which REM/Rate consistently overestimated the amount of space heating energy demanded by homes that were relatively inefficient.

Systematic error appears to be less of a concern here than the ability of REM/Rate to accurately predict space heating for individual buildings. In this regard, heating usage for some buildings in the study was significantly under- or over-predicted. Use of this software might bring with it some small systematic bias, but the scatter of the data suggests that bringing more precision to the modeling process would be of greater utility. Our field experience with REM/Rate is that "truing up" an original software model against existing utility bills is very useful in getting the greatest advantage from it. The refined model allows prediction of the interaction of retrofit measures that is very valuable to the operation of energy efficiency programs, while improving the accuracy of the cost-benefit analyses provided to building owners or operators.

This greatly limits the utility of REM/Rate in new construction programs geared toward apartments and condominiums, but it is not the most important limiting factor. Many energy efficiency programs geared toward new construction establish their goals relative to the local/state energy code, or in comparison to a national model code or standard. REM/Rate is optimized for comparisons to the 1993 Model Energy Code, instead of the International Energy Code or other commercial building code. While it is not impossible to transform REM/Rate output values in order to make such a comparison, many designers prefer to simply work through REM/Design or other software written specifically for that task.

It is unlikely that the variance in energy predictions found in this study is solely the result of software issues. In REM/Rate modeling of single family homes, the fundamental objective is to predict energy use based only on the behavior of the structure, and not of the occupants. That means that HERS models, at least as done in Wisconsin, do not include a lighting analysis, assessment of plug loads, or modeling of similar lifestyle-driven energy impacts. In the interest of consistency, these apartment building models were conducted in the same manner. While standardized assumptions about these energy uses are an advantage in modeling single-family homes, small apartment buildings have common-area features that produce greater variations in energy use. The smallest buildings in this sample have no common area lighting or heat at all. In the largest buildings, common area use (especially lighting) is of course substantial.

An analyst planning a retrofit project (especially with utility bills in hand) would of course have to take into account such high-use systems. An energy model that was trued up to account for those use patterns would allow planning of those retrofits, while providing a good understanding of the responses of other systems in the building to the planned retrofit.

An earlier study (Cavallo, 1999) found that even a wide variation in the ratings for an inefficient house did not have a major impact on the choices in the rating tool's improvement analysis. That is to say, if one wanted to make use of REM/Rate in order to better define improvement measures that would be appropriate for the building, the relatively larger inaccuracies that may be associated with larger or more wasteful buildings would not diminish the benefits of using the rating tool. Cost-benefit calculations might not be perfectly accurate. However, it is highly unlikely that non-beneficial energy upgrades would appear to be acceptable in REM/Rate, or that the order of priority of measures might be incorrect. REM/Rate will still demonstrate that window replacement is rarely, if ever, a cost-effective energy retrofit (much to the chagrin of all landlords!)

Originally, it was thought that the predictive error of our apartment building results might be linked to building size, and that may in fact be true. A regression of the prediction error against building size finds a weak relationship that is significant at confidence level just below 90 percent (Table 4).

Table 4. Regression Results of REMerrorBtu/Ft^2 vs. Floor Area

Dependent Variable:	REMerror Btu/ft2					
Independent Variables:	**Coefficient**	**Std. Error**	**t**	**P> |t|**	**95% Confidence Interval**	
Floorarea	-.3571	.2097	-1.70	0.105	-.7960	.0818
Constant	8626.	4647.	1.86	0.079	-1100.	18351.

One can see in Table 1 above that each of the 3 buildings with over 30,000 square feet of floor space has more than the average percentage deviation of the sample. For instance, the 68,229 square foot building E2 had a regression estimate for the space heat usage per square foot of 33,980 BTUs while the REM/Rate estimate was 13,630. The difference between the two estimates is .2035, or a percentage deviation from the regression estimate of nearly 60 percent. The average deviation was slightly over 25 percent. The other two buildings with over 30,000 square feet of floor space, D5 and C2, also had larger than average deviations for the sample. It seems likely that a rating tool like REM/Rate, which was developed for use on single family homes, may not be as accurate for larger multifamily buildings, and failure to fully capture this effect is because of the small number of larger buildings in the sample. One should also recognize that if the larger buildings in the sample have larger than average percentage deviations, then the smaller buildings, such as those with 10 or fewer units and representing more than 60 percent of the multifamily building stock, must in general have smaller than average percentage deviations.

Of course, it is reasonable that REM/Rate would be problematic as an analysis tool in high-rise or large buildings. They are, after all, not at all like a wood-frame, low rise residential building. As buildings get larger, internal loads take on greater importance as compared to the influence of shell losses. Systems like structural steel framing, central ventilation/exhaust systems, elevator and garbage shafts substantially change the heat/air dynamics and energy behavior of these buildings. Finally, it is important to note that these large buildings, as is typical, could not be tested for infiltration, but instead were modeled with infiltration values assigned based on the engineering data available on their central ventilation systems.

Using REM/Rate in Existing Buildings (But Not New Construction)

Our analysis shows that it is reasonable to use REM/Rate as a predictive tool for retrofit planning in smaller apartment buildings, especially if full advantage is taken of the information provided by historic utility usage. It provides useful and reliable baseline information for planning retrofit work in low-rise, wood frame buildings. The ability to estimate the interactive results of multiple retrofit measures is especially useful.

How big a building is too big? This data set is not large enough to provide a definitive answer to that question. However, our experience in this study provides us with substantial confidence for buildings that are only two stories high. In our considered opinion, reliance solely on model results becomes questionable in larger residential buildings with elevators or other vertical shafts, or very large common areas. Mixed use buildings with commercial space or multiple zones are difficult to model, as well.

In buildings with minimal common area, use of REM/Rate in new construction programs could be quite effective once a baseline against the appropriate code was established. Where codes allow energy analysis to be performed at the unit level, it may well be the tool of choice, given the established base of skilled REM/Rate users. A number of energy analysts report effective use especially in evaluating garden apartments or row houses.[6] However, using REM/Rate to as a multifamily new construction tool in buildings with "stacked" living units may not be particularly helpful, given the complexities of code issues. At least in Wisconsin, the code requirements for multifamily buildings are less stringent than for single family homes, to a degree that REM/Rate output is not especially useful to inform design decisions.

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PRISM - developed by Princeton University, Advanced Version 1.0 used in project

REM/Rate v. 10.21 - copyright held by Architectural Energy Corporation, 2001.

[6] The ENERGY STAR new construction program in New Jersey, for example, uses REM/Rate extensively in this style of building.