Strategies and Costs to Exceed ASHRAE 90.1-2004 Requirements in a Multifamily Apartment Building

Prepared for

National Multi Housing Council
National Apartment Association
National Association of Realtors
Institute of Real Estate Management
CCIM Institute

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March 2008

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EXECUTIVE SUMMARY

Scope

Recent proposals to increase requirements by 30% to 50% over today's energy codes and standards may have a dramatic impact on certain types of multi-family buildings. Apartments, already some of the most sustainable residential buildings given their high density and efficient building systems, are of particular interest because of the role they play in providing affordable housing.

This study addresses how increases in energy efficiency standards will impact apartments in selected locations – Chicago, Houston, and Atlanta. These cities were selected to investigate impacts across multiple climate zones. Further, construction practices and infrastructure to support market preferences vary across these cities.

In this study, we focused on technologies and building systems which would be needed to surpass the 2004 edition of ASHRAE 90.1 – "Energy Standard for Buildings Except Low-Rise Residential Buildings" by 15%, 30%, and 50%. The technology packages which were modeled were in keeping with the realistic limits of what can be accomplished in building assemblies with commercially available envelope and HVAC systems.

Standard and Modeling Background

ASHRAE 90.1 is perhaps the most widely adopted energy conservation standard in the United States. As the title indicates, this standard regulates energy performance in a wide range of commercial buildings as well as some residential buildings. It is frequently referenced as an alternative compliance option in other energy codes, including the International Energy Conservation Code (IECC).

The most direct way to identify how a building performs relative to ASHRAE 90.1, or any other code, is to conduct computer simulations on a proposed building design and then compare it to a base code-compliant building. ASHRAE 90.1 offers a method called the "cost budget method" that permits this approach using energy simulation software. We selected a software package for the primary simulations called Energy Gauge Premier Summit Version 3.11, distributed by the University of Central Florida's Florida Solar Energy Center. Energy Gauge is somewhat unique in that it automatically generates a reference code-compliant building based on the inputs that a designer uses for their proposed design. The reference building design represents the costs that a building would incur for the items covered by 90.1 if the building is designed to comply with the *minimum* requirements of the standard. By automatically creating this reference building, this software tends to reduce user bias, which can be significant in modeling the energy use of the reference building.

Energy Simulation Results

The results of the energy simulations conducted in this project demonstrate significant barriers to reaching different levels of efficiency relative to the 2004 ASHRAE 90.1 standard. Table ES1 shows the reference design annual energy cost budget generated for a four-story building with 32 apartments of approximately 1000 square feet each.

Table ES1 - Annual Energy Costs for Reference Buildings

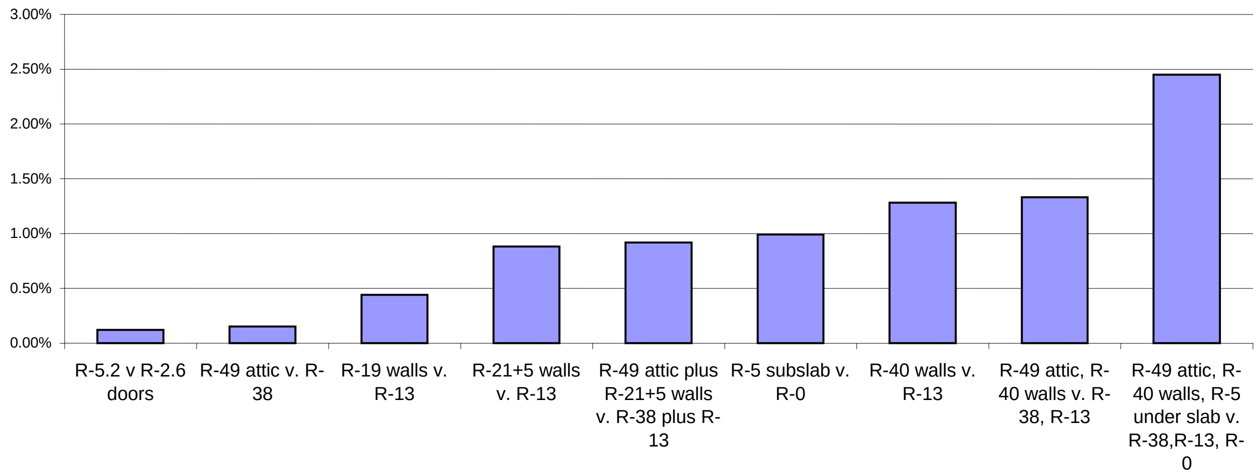
	Atlanta 90.1 Reference	**Chicago 90.1 Reference**	**Houston 90.1 Reference**
Electricity	$32,946	$25,323	$64,960
Natural gas		$31,628	
Total Cost Budget	$32,946	$56,951	$64,960

The total cost budget in Table ES1 is the starting point. To improve upon a building's performance, a building would have to incur a lower total cost budget than shown in the table. Note that Chicago's costs include natural gas for a hot air furnace whereas electric heat pumps are more typical in Houston and Atlanta.

Improvements to the Building Envelope Provide only Modest Gains

Because improvements to the opaque envelope (walls, roofs, floors) are typically the first items targeted for code changes, it is important to understand how they could impact the performance of a building. The chart below illustrates selected envelope improvements from the simulations in Atlanta. Most envelope improvements, when assessed in isolation, provided less than 1% energy savings. Even combining multiple improvements to the envelope resulted in less than a total of 2.5% improvement. Similar results were found in Chicago and Houston. The only exception seems to be the addition of R-5 subslab insulation in Chicago, which produced about a 3-1/2% savings over R-0 subslab insulation.

Figure ES1 - Improvement due to selected component changes over base building (Atlanta)



It is not possible to save the same energy multiple times, so it is not accurate to simply add the results of different simulations to arrive at a combined savings estimate. The different systems tend to interact with each other. Thus, only when multiple options are evaluated simultaneously in a simulation do the results reflect their combined contribution.

From Figure ES1, it became obvious that the traditional approach of adding more and more insulation would not get us very far toward the goals of 30% and 50% improvement. More emphasis has to be placed on higher efficiency heating and cooling equipment.

Significant Better-than-Code Gains Require Significant HVAC Upgrades

Table ES2 shows the results of the most promising options and the highest levels of improvement that were obtained. Note that a specific building configuration would not always provide exactly 15%, 30% or 50% improvements. Thus, the table shows the options that are enough to surpass the stated goals, but they often go beyond the goal.

Missing from the table is an entry close to the 15% threshold for Atlanta. This is because none of the options we explored could reach this goal without moving up to a ground source heat pump (GSHP), and this technology provided such a significant improvement that it met both the 15% and 30% thresholds in Atlanta.

Table ES2 - Building System Packages to Exceed 90.1 Requirements for three U.S. Cities

Atlanta	**% better than 90.1**
GSHP (3.7 COP, 16.9 EER)	31
R-49 attic, R-21+5 walls, advanced windows (U=0.3, SHGC=0.19), R-5.2 door, R-5 subslab insulation, GSHP (COP 3.7, EER 16.9)	39
Chicago	
96 AFUE furnaces	15
GSHP (3.7 COP, 16.9 EER)	37
R-49 attic, R-40 walls, R-5 subslab insulation, GSHP (3.7 COP, 16.9 EER)	46
Houston	
SEER 15 HP w/ 8.3 HSPF, R-40 walls, R-49 attic, advanced windows (U=0.3, SHGC=0.19)	15
GSHP (3.7 COP, 16.9 EER)	41
R-40 walls, R-49 attic, advanced windows, GSHP (3.7 COP, 16.9 EER)	48

None of the improvements we explored were able to achieve the 50% goal, although the modeling for Houston approached this threshold. Reaching the 15% threshold in Houston and Chicago was achievable by using high efficiency conventional HVAC equipment. For the 30% level in Houston and Chicago, as well as the 15% level in Atlanta, only the use of a GSHP allowed the efficiency goal to be reached.

Payback Periods for the Required Upgrades present Challenges

To illustrate the potential impact on costs and payback, Table ES3 shows these values for the building simulations in Atlanta.

As mentioned earlier, GSHPs played a significant role in meeting many of our performance goals. These systems come with a significant increase in upfront cost. It many cases, the payback period for this technology will exceed the life of the system, or at least the time when significant replacement components are needed.

Table ES3 – Cost and payback for selected improvements in Atlanta

Building system package	% better than 90.1	Simple payback in years[1]
GSHP (3.7 COP, 16.9 EER)	31 (closest set of improvements achieving at least 30%)	16 (25)
R-49 attic, R-21+5 walls, advanced windows (U=0.3, SHGC+0.19), R-5.2 door, R-5 subslab insulation, GSHP (COP 3.7, EER 16.9)	39 (maximum achieved in simulations)	14 (21)

[1]Costs and thus payback of GSHPs vary greatly. The paybacks are based on an average of the high and low end of estimated costs. The payback associated with the high end of the cost estimates is shown in ( ).

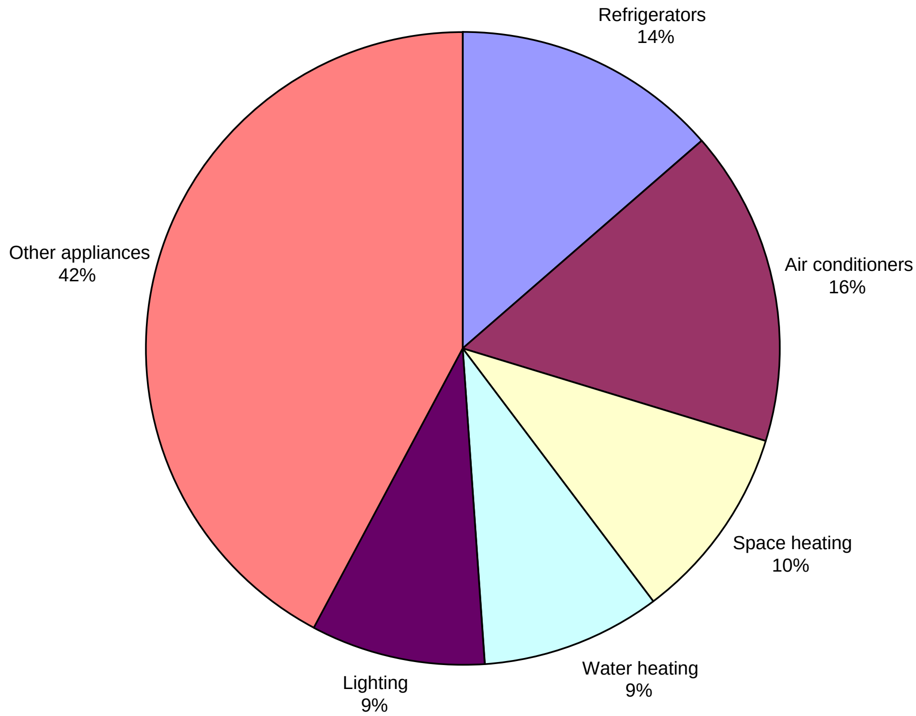
ASHRAE 90.1 Does Not Cover All Building Energy Use, Which Limits the Ability to Reach Better-than-Code Efficiency Targets

It is important to understand that not all of a building's energy use is regulated in ASHRAE 90.1. For example, lighting within dwellings is outside the scope of 90.1. Likewise, the energy use associated with water heating in an apartment is not covered. Appliance energy is also not regulated by the standard.

Figure ES2 shows the electric energy use in residential buildings as a way to illustrate where energy is used in a building. This demonstrates that even if codes and standards like 90.1 are made to be 30% or 50% better than today, the overall impact on total energy use would be substantially less in a building like an apartment. This is because 90.1 does not directly address items like appliances and refrigerators that make up a large part of a residential building's energy use.

Figure ES2 – Residential electricity by end use (2001)

Source : US. Energy Information Agency RECS data



On-Site PV Systems could Allow Buildings to Meet the 50% Goal, but are Costly and are not within 90.1's Scope

If the scope of 90.1 were broadened to capture more energy uses, it might be possible to reach the 50% goal in each city by generating electricity at the site through the use of electric photovoltaic (PV) systems or other renewable energy. Assuming that PV was recognized by ASHRAE 90.1, the costs to make up the gap between the highest levels of efficiency realized in the modeling and the 50% goal are shown below. Because there are wide ranges of costs associated with specific PV systems, a range is shown in Table ES4.

Table ES4 - PV System Cost Estimates to Supplement Other Technologies and Meet 50% Threshold

	Atlanta	Chicago	Houston
Normalized low-end cost of installed system ($/W DC)	$7.00	$7.00	$6.00
Normalized high-end cost of installed system ($/W DC)	$9.00	$9.00	$8.00
Total low-end cost of PV system ($)	$240,885	$154,778	$42,527
Total high-end cost of PV system ($)	$309,709	$199,000	$ 56,703

There may be options other than PV that can be used to make up the deficits in each location. In any case, applying them in an effort to meet better-than-code targets would require significant change to the ASHRAE 90.1 scope. If for example, lighting for dwelling units were added to the scope for the standard, then something as simple as using CFLs might provide enough savings to reach the 50% threshold in Chicago and Houston. Other improvements such as high efficiency water heaters would likely be needed in Atlanta.

Conclusions

Specific conclusions from this study include the following:

- The 30% and 50% “better than ASHRAE 90.1” levels will clearly present some practical and cost barriers for designers, builders and owners. In fact, it will be nearly impossible to reach the 50% level for an apartment building of the type studied in this project with today’s technology without some type of scope change to the 90.1 standard to allow credit to be taken for improvements in energy uses not currently regulated by the standard.
- Even in climates or with buildings where it may be possible to reach the 50% level, the cost to do so will be significant. Most likely, a building will need to be fitted with GSHP technology, which in many areas does not have a well developed support infrastructure at this time to support the number of buildings in question. The cost to use GSHPs in the building we simulated could be several hundred thousand dollars over conventional equipment used in today’s buildings.
- The simple payback to achieve an improvement over ASHRAE 90.1 of 30% or higher is likely to be outside of the range that would normally be accepted for this type of analysis. For example, the average payback of about 16 years for the 30% improvement level in Atlanta is somewhat excessive. Furthermore, this is only an average payback. Some buildings could be penalized with paybacks as high as 25 years depending on the local cost of items such as GSHPs, which vary greatly.
- The costs associated with reaching the 30% and 50% performance levels would be nearly impossible for a builder or owner to recapture. Increased rents would be hard to realize when renters have a choice of lower cost, older apartments – which would also tend to be less efficient. Conversely, the energy savings would accrue to the renter in a newer building where most utilities are paid by the renter. This disconnect needs to be considered in any cost benefit analysis before modifying codes and standards.
- Traditionally, energy codes and standards have targeted increased levels of insulation as the primary method for increasing a building’s performance. Additional insulation offers diminishing returns – almost all increases will improve the building by less than 1%, and most by only a fraction of a percent. Even when insulation levels in all of the major components of a building (roofs, floors, walls) are increased simultaneously, they do not begin to come close to reaching even the 15% threshold.

- Designers will need to specify high efficiency equipment to make significant gains in building performance. In most cases, this should be the starting point rather than additional insulation since the costs of additional insulation can be significant and the benefit very small.
- Changes to the 90.1 scope could help designers and builders to more easily reach the proposed increases in performance. For example, it would be easy and not very costly to use CFLs in lighting fixtures and save a significant amount of energy in an apartment. Currently, the 90.1 standard exempts the inside of dwelling units from the lighting requirements. There may be good reasons for this exemption related to enforceability, but if the standard allowed a designer to submit to the lighting requirements, it would provide an opportunity for them to move closer to the 30% or 50% levels. Appliances, water heaters, and air leakage (infiltration) are other items where similar opportunities exist.
- Onsite generation of renewable energy also could help a designer to reach the 30% or 50% performance levels. As with lighting, the 90.1 standard would need to be revised to allow for any electricity generated by PV, wind, or other systems to offset energy costs in the 90.1 energy cost budget method.
- The methods used in this study relied heavily on building simulations. Simulations are good methods to estimate the *relative* performance of changes to the same building. They should not be used to predict the actual overall energy use of a building, since there are too many factors besides design that influence energy use. Simulation tools have many limitations and require assumptions that introduce a heavy user bias. Further, use of the prescriptive methods in codes and standards is the more typical approach for designing a building. When a simulation approach is introduced, the cost and time for the simulations could be significant. Modeling results from this and similar studies could help reduce the costs by providing designers with a head start in deciding what to simulate.
- Policy makers and codes/standards developers should recognize that the market infrastructure, climate, and consumer preferences all influence the design of a building. Climates and markets can be radically different around the United States. Approaches that seem reasonable in one part of the country should not be automatically adopted elsewhere. For example, just because a high efficiency heat pump may be the best choice for a building from an energy savings perspective, in some climates it is unlikely that homeowners will be accepting of anything but a hot-air furnace system. Forcing them to accept something else could have a negative impact on energy efficiency if they are so accustomed to warmer air that they end up running their heat pump in back-up or emergency electric resistance mode as a way to provide warmer air.
- Overall, for multi-family buildings like the ones analyzed in this project, the uniform imposition of higher efficiency standards without scope changes to 90.1 could have negative, unintended consequences. Builders and owners will absorb added costs, yet the building occupants will accrue energy cost savings benefits. The required capital for engineering and constructing such buildings

will increase substantially, yet the return on this investment is uncertain at best. Ultimately these dynamics could undermine the viability of new high-performance multi-family buildings and instead push the market towards the continued use of older, far less efficient dwellings.