The Great White Whale in Weatherization: A Large Multifamily Building Program

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ABSTRACT

In mid-2009, the State of Wisconsin, like a number of states with large federal ARRA Stimulus grants, initiated a low-income weatherization program specifically targeting larger multifamily buildings. Wisconsin's program specifically focused on the sizable proportion of eligible applicants residing in larger (>20 units) multifamily buildings (MFBs.) Implementation is ongoing for Wisconsin's ambitious (6,000 units, $20 million) effort, with all work due to be completed by early 2012. Given the likelihood that some MFB weatherization efforts will be the subject of future evaluation work, we present data that could inform those evaluations.

This study describes the program design, and assesses program implementation. We present background regarding energy use in Wisconsin MFBs, the operation of the MFB housing sector and the implications for energy efficiency program design, savings, implementation costs and cost-effectiveness. We present preliminary information on the energy savings impact of comprehensive weatherization in MFBs.

In the 40 projects for which we have bids and hard cost figures (average project size is 66 units and $231,000 total costs per building weatherized), per-unit total costs averaging $3,500 per unit ($2,500 per unit in "hard" construction costs) are sufficient to allow comprehensive weatherization in cold-climate MFBs. Program administration and non-ECM repair/"health & safety" construction costs are significantly lower than in Wisconsin's "conventional" (single-family oriented) weatherization program. Data from seven projects completed before December 2010 show space heating savings of 25.8 percent and reduced overall electric consumption (common area and in-unit) of 14.5 percent.

Introduction

Numerous energy efficiency actors are attempting to step up efforts in MFBs, to respond to the fact that they represent a significant source for energy efficiency gains. Nationwide, 25 percent of all households live in multifamily buildings (Stone 2009, 3). Seventy percent of those households are income-eligible for weatherization services (US DOE 2011, WPN 11-04). While energy use per household is lower in multifamily buildings than in single-family (SF) homes, the smaller size of units in multifamily homes (2,720 Ft^2 in SF vs. 872 Ft^2 in MFBs) means that energy use per square foot (EIA 2005) in MFBs is 56 percent higher than in SF units (62.91 kBtu/ft^2 in rented MFBs vs. 40.3 kBtu/Ft^2 in owned SF).[1]

In the past, weatherization programs' approach to multifamily housing (except in a few large urban areas) has been haphazard at best. Energy efficiency program implementers generally lack information on multifamily housing such as effectiveness of various measures, best practices and program design elements to overcome the very sizable barriers to completion of weatherization in complex projects.

This study offers information about the design and implementation of a low income weatherization program to improve larger (20+ unit) apartment buildings in Wisconsin. We present preliminary energy

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[1] Actually, it appears that the imbalance may be more extreme. RECS collects energy use data only for living units in MFBs, missing the 15 to 20 of added floor space in MFB that is common area. Since MFB common areas are conditioned the same as living spaces, but are usually lit 24/7, the electric consumption for common space may well be higher (per Ft^2) than in units. Statistically representative primary data is simply not available.

savings analysis of a sample of participating buildings. Seventy buildings comprising over 4,000 units were in progress and more than 15 buildings (approximately 1,200 units) had been completed by the end of our study period (May 2011). We also present general information on the MFB housing stock in Wisconsin, with energy use baselines, pre-program building benchmarks, and other characteristics of typical buildings compared to buildings treated in this program.

Effective program design in this arena is complex, and above all requires a commitment to longer-term (multiple years) involvement in this market. There are substantial economies of scale to be gained from committing to a sizable and persistent program effort. Compared to weatherization in SF homes, federal funding rules require a more "engineered" approach to comprehensive implementation in MFBs. Measure design and implementation expertise is largely non-existent, but we were able to develop these assets fairly rapidly, once all stakeholders become convinced that the program volume would justify the investment. Since multifamily building ownership patterns and participant incentives are diverse, program staff must start with a very clear vision of program goals, but be willing to demonstrate great flexibility in tactics in order to achieve the sizable energy savings available.

Questions we address include: What most characterizes multifamily housing (especially low-income buildings)? What characteristics of multifamily housing need to be considered by program designers and implementers? What energy efficiency measures are most often appropriate and cost effective for retrofitting existing (cold-climate) multifamily housing? What unanticipated program challenges arose? And, most importantly, what data and information should the evaluation community develop and deliver, to support and expand energy efficiency efforts in multifamily housing?

This program was designed to use federal ARRA Stimulus funding to fulfill multiple goals, with energy efficiency being only one goal. (The primary goal of the ARRA program as a whole was to stimulate employment.) The program operates under the rules of the federal low income weatherization program, but utilizes both ARRA Weatherization funds allocated by the federal Department of Energy (DOE) and State of Wisconsin systems benefit charge (Public Benefits) funding. In order to use slack construction market capacity, program managers forged new partnerships with private architecture-engineering (A/E) firms, rather than local weatherization agencies, to act as general contractors and implement weatherization measure design and installation. Existing A/E firms with extensive experience in commercial construction design and project management were selected[2] to estimate costs, prepare bid documents and working drawings, and manage the sizable construction projects implemented. Contractors selected through a sealed bid process generally had extensive experience in managing large, complex construction projects, but only limited experience in MFBs. Risk-averse building owners found significant value in the in-depth energy audits and engineering analysis that were completed on all buildings in the program.

Typical measures included insulation and air sealing, heating system and water heater replacement, and electric baseload and in-unit electric measures.

"How the Money Works" in Multifamily Housing

Our fundamental principal of rental housing is that "whether or not the tenant has a utility bill, the tenant pays the utilities." In many cases, this is not in question; in Wisconsin, 85 percent of tenants in 20+ unit buildings pay their own electric bill, 49 percent of tenants pay directly for space heating, and 31 percent pay directly for water heating (Pigg & Price 2005, 30-31). Low-income tenants paying these costs benefit directly when aggressive weatherization work reduces energy consumption and utility costs.

More commonly, however, the owner/operator pays some or most utility bills. In a market rate apartment building all those operating costs are then loaded into the rent. The operator may assume some

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[2] Four A/E firms were originally selected from a sealed-bid process to manage all projects in each of four regions in the state. One firm was later dropped from the program.

pricing risks in the short run (sheltered somewhat by the fact that utility costs are a deductible business expense), but the tenants end up footing all the bill in the long run. Simply put, as long as the building has adequate cash flow and has rents low enough to keep vacancy to a minimum, operators are essentially indifferent to utility costs. Granted, this may seem like an extreme assertion. However, it is important to recognize that, in the business of rental housing, sensitivity to utility costs is never an issue in and of itself, but solely a contingent concern, as long as the building has sufficient operating cash flow.

Even in the most extreme case, in public housing, where the actual utility bill is paid almost entirely by HUD, tenants "pay" the utilities when high energy costs crowd out ongoing building maintenance or any but the most fundamental amenities. Thus it furthers significant social goals to provide safe, decent, affordable housing, to provide fully-funded weatherization services even to buildings where the tenant *appears* to have no energy burden at all.

Another driving force of the multifamily housing market is that of economies of scale at all levels. Larger, taller residential buildings are cheaper to build, per unit and per square foot. This lower cost is the primary driver for MFB development. These construction cost efficiencies are attained partly because larger projects justify the use of cost-saving and labor saving technologies that are unsuited for smaller buildings. And, as we shall see below, other powerful economic dysfunctions assure that even the best-designed MFB project is forced to lowest first-cost technologies and construction practices.

However, one of the deepest and most pernicious market defects affecting multifamily housing is the "split incentive" problem. Put simply, in every (non-condo) multifamily building, the tenant pays the utility bills (directly or indirectly) but has no control over capital investments that affect energy consumption or energy conservation. Those few changes that a tenant might make that could impact their utility bill tend not to be completed, as the tenant will be unable to take the improvement with them when they move.

This problem manifests itself in many ways, most of which assure that MFBs will be built to lowest first cost, and to the lowest level of energy efficiency allowed by Code. Table 1 summarizes some characteristics of Wisconsin residential buildings, to illustrate the problems that result from split incentives. The data on the difference between SF owned homes and SF rented homes provides an illustrative look at the split-incentive problem, in buildings that are essentially identical except for the difference in ownership.

Electric space heat (inexpensive to install, expensive to operate) is virtually unknown in SF housing in Wisconsin, but found in more than 1/3 of MFB units. Single pane windows are virtually never found in owned SF homes, but are still found in 1/8 of MFB units (and in a similar proportion of rented SF homes.)

A special case of this general problem is that MFBs are *always* designed and built by actors that will not live in them. They are designed to low budget and built through a low bid process. When the inevitable construction contingencies and cost over-runs erupt, energy-efficient and innovative systems are usually the first sacrifices made to keep the building under budget. Thus it is that multifamily housing is almost universally *designed and built* to be less energy-efficient than comparable owner-occupied housing, making it an excellent target for weatherization[3].

Furthermore, the financial imperatives of operating low-income multifamily housing assure that buildings will rarely be improved without a concerted public program. Virtually every large residential building is, above all, systematically under-capitalized for its intended purpose. Managing a financially viable apartment building requires maintaining full occupancy, above all else. As a result, those capital expenditures that do occur are, first of all, oriented to cosmetic improvements that will increase the likelihood that prospective renters will select the owner's building as their new home. Since energy improvements impact only deductible costs, owners/operators almost always "under-invest" in them,

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[3] In one project, our program invested a quarter million dollars ($2,500/unit) in a 100-unit building built just 12 years before. The package of measures implemented is projected to save $1.20 for every dollar invested, using technologies and devices generally available at the time of design. The developer could clearly have made all the same decisions we did (at less cost) during the original construction and constructed a more profitable building, but chose not to do so.

preferring improvements with less perceived risk and more immediate returns. In the battle of new carpeting versus new boilers, the carpeting wins every time.

Curiously enough, the one exception is that of in-unit refrigerators. These are the only energy sink in MFBs that prospective tenants are fully qualified to evaluate when making a leasing decision, and MFB operators appear to replace refrigerators earlier in their life cycle than is the case in SF housing (PA Government Services 2002). Still, we found cost-effective refrigerator replacement opportunities in most of the buildings in this program.

This systematic under-capitalization has operating implications as well. In most MFBs, non-cosmetic maintenance is typically completed only upon failure. This is a barrier to multifamily energy efficiency programs of all types; most successful programs seek especially to engage owners at the crucial instant that a key system has failed and must be replaced. For weatherization, this "replace on failure" (ROF) imperative means that weatherization in MFBs must deal with a backlog of deferred maintenance issues.

Again, the one exception is refrigerator replacement. We found in many buildings that there were two or three "families" of refrigerators, with each family being of identical model and age. This indicated clearly that several different waves of refrigerator replacement had been undertaken, rather than a constant trickle of ROF replacements. Refrigerators are seen by operators as a cosmetic/marketing tool, not an energy issue.

All these fundamental principles apply regardless of the owner type. Private (non-investor owned) buildings are most frequently owned and managed to support maximum current income, not to reduce current (deductible) operating costs. Investor-owned buildings are frequently stripped of equity to leverage that investment and fund other property investments, so as to maximize investor profit. Buildings operated by housing authorities compete with a panoply of other worthy public goals for scarce capital funding.

Thus it is that low-income weatherization programs are uniquely suited to improving multifamily housing energy performance, because every other incentive in the development and operation of these buildings incents the improvement of every aspect of the building *except* the energy efficiency of the building and the lowest possible utility costs for the residents.

The result is that a program designed to fulfill public goals by investing in operations improvements can find ready participants, all of whom are eager to use the program. Rental residential programs that provide only marginal funding are notoriously difficult to implement. (Equity-stripping by owners severely limits the ability of many building managers to invest matching funds.) Owners of all stripes eagerly participate in programs (like low-income weatherization) that fund most of the cost of measures. Program design must be carefully thought out, or owners will use it to achieve primarily non-energy goals.

Characteristics of Wisconsin Multifamily Housing

Designing an effective program to improve the energy performance of MFBs requires, first of all, a detailed knowledge of the target buildings. We had the advantage of starting with the comprehensive characterization study of Wisconsin's rental housing stock completed by the Energy Center of Wisconsin (Pigg & Price 2005)[4].

In Wisconsin, the 3,100 residential buildings larger than 20 units (our target population) comprise less than two percent of the rental buildings in the state, but provide almost 20% (123,000 units) of all rental housing (US Census 2000). The vast majority were built after 1960. The typical wood-frame low-rise[5] MFB benchmarks at approximately 5 Btu/Ft^2/HDD, and uses approximately 7,900 kWh/unit/year for all purposes

[4] Unless otherwise noted, all characterization data in this section is from the Energy Center of Wisconsin study.
[5] Note that, throughout our work, a "low-rise" building is one of any size that has wood-frame walls and a pitched roof with an accessible cavity attic. A "mid-rise" building is one of any height (but generally three stories or higher) with masonry walls and a flat (solid, built-up) roof.

but space heating. The small amount of definitive data on high-rise buildings (over three stories) suggests that they have somewhat higher space heating usage and lower in-unit electric use, compared to low-rise MFBs. However, high-rise buildings have higher overall electric consumption, because of elevator usage, larger common areas inside and outside that are lit 24/7, and the fan power load of whole-building ventilation systems.

Table 1: Selected Characteristics of Wisconsin Housing

		20+ Unit MF Building	Rented SF Detached Home	Owned SF Detached Home
Vintage	Built post-1960 (%)	92	14	60
	Built post-1980 (%)	52	9	9
Building Size	Dwelling Unit Size (Ft^2)	730	1,310	1,630
	Dwelling Unit Size including Common Space (Ft^2)	910		2,640 (w/basement)
Fuel	Heating Energy Index ($BTU/Ft^2/HDD$)	4.9	10.3	7.5
	Tenant-Paid Electric Use per Unit (no electric heat) (kWh/yr)	5,600	9,500	
	Owner-Paid Electric Use per Unit (no electric heat) (kWh/yr)	2,300		9,330
	Electric Consumption ($kWh/Ft^2/yr$)	8.68	7.25	5.72
	NG as space heat fuel (%)	59	85	64
	Electricity as space heat fuel (%)	38	0	4
	Natural Gas as DHW Fuel (%)	59	67	62
	Electric as DHW Fuel (%)	40	33	28
Equipment and Structure	Incandescent lighting present (%)	5 (common area) 93 (in-unit)	81	----
	Low-flow showers* (%)	7	51	98
	Double-pane windows (%)	88	90	99+
	Shell insulation opportunities (%)	8	16	22

* "Low flow" in this case is 2.5 GPM for MFB and Rental SF, 3.5 GPM for Owned SF.

Living units in these larger MFBs are typically 30 percent smaller than those in duplexes, and half the size of the average SF home (Pigg & Nevius 2000, 6). Sixty percent of larger MFBs have hydronic space heating fueled by natural gas boilers (usually owner paid) of standard (nominally 80 percent) fuel efficiency, with almost all of the rest heated by (tenant paid) electric baseboard units. DHW heating follows similar patterns. In those buildings with NG-fired central DHW, fossil fuel consumption for DHW averages ¼ of total fossil fuel use. These buildings almost always have a DHW recirculating loop, with the recirc pump operating 24/7. Common area lighting is almost universally fairly energy-efficient (typically the best-available technology of 1990s vintage) while tenant lighting is virtually 100 percent incandescent. DHW devices (3.5 GPM showerheads and 2.5 to 2.2 GPM faucet aerators) of 1990s vintage are almost always installed where the building has central DHW. Refrigerators are typically smaller, newer and more efficient

(PA Government Services 2002) than in SF homes, generally dating from the early to mid-90s. Windows are typically double-hung wood or vinyl units in low-rise buildings, with double-pane metal slider units being common in high-rise buildings. While many SF homes of similar vintage are moderately air-tight, we have found that air sealing opportunities abound in MFBs, especially in low-rise buildings.

The resident profile for MFBs is different than for smaller buildings. The average low-income single-family house in Wisconsin has 3.4 occupants (Pigg & Nevius 2000, 6), while the average MFB has only 1.7 occupants per unit. In fact, 64 percent of units in MFBs are single-occupant households. The residents of MFBs are four times more likely to be seniors (23 percent of households in MFBs, compared to 5 percent in 2-4 unit rental units). There are also fewer children resident in MFBs; 44 percent of households in 2-4 unit buildings have children, as opposed to 11 percent in 20+ unit buildings.

The Wisconsin Program Model

Weatherizing a large apartment building is a complex and time-consuming process, demanding careful analysis, detailed planning, and coordination of many specialized participants. We made a strategic decision at the very beginning to *not* work through conventional low-income weatherization grantees. Those agencies also received very substantial ARRA grants, requiring them to expand their conventional weatherization work by 50 percent or more. None of them had slack capacity to support this effort. Instead, the model chosen was to solicit competitive bids and select private contractors for all work completed.

No paid marketing was feasible, so program staff recruited participants informally but broadly through many channels, especially using a HUD-generated list of all HUD-funded buildings in the state. We contacted public housing authorities, private owners with HUD Section 8 contracts, the state's Housing Finance Authority (WHEDA/WHPC), and area and state Apartment Associations. Staff with Wisconsin's "Focus On Energy" statewide energy efficiency program identified a number of target buildings. Over the course of a year, we received reasonably complete applications for 368 buildings. Given the substantial fixed cost for auditing and energy analysis, program staff employed several tools to identify 120 buildings most likely to benefit from weatherization. A desktop benchmarking tool (HUD 2007) was used to identify those applications most likely to be good candidates for further investigation. Prospect buildings were deemed to be good candidates if they demonstrated one or more of the following characteristics:

- Above-average Heating Energy Index (exceeding 5 to 6 $Btu/Ft^2/HDD$)
- HUD Benchmark rating less than 70
- Utility costs exceeding $1,000/unit/year
- Central heating system (almost always NG-fired boiler system)

Staff then visited each building to complete a building assessment, educating the owner or manager about the program and taking 2-4 hours to inventory the building shell and systems. This assessment focused on gauging the owner's interest in participating in the program, identifying likely weatherization measures, and identifying potential hazards (including moisture problems and possible asbestos-bearing elements), and other technical barriers to weatherization.

DOE rules require 66 percent of households in a building to be income-qualified for weatherization of systems that serve the entire building. We knew that conventional weatherization grantees frequently avoid MFB projects precisely because of the very substantial effort needed to qualify dozens of households, and the substantial sunk/wasted program cost of getting a building qualified to only 55 or 60 percent. We dedicated a concerted effort in this arena, and eventually managed to qualify almost all targeted buildings.

After the initial building assessment, 90 buildings judged to have the best weatherization potential were referred to our energy engineering firm for a detailed audit and energy modeling with TREAT analysis software. [6] The company winning the bid to complete building audits was an engineering firm with broad MFB experience implementing Wisconsin's "Focus On Energy" public benefits program. We found substantial advantage in the fact that this company had also previously participated in a small-scale MFB weatherization pilot program. They were already generally familiar with DOE-approved weatherization measures and materials, and needed only moderate coaching to adapt to the methods and policies required of a DOE-funded weatherization program.

The auditors developed a Measures List and general scopes of work for measures that appeared to have potential to be cost-effective in each building. The Measures List was then submitted to the A/E firm that would manage the project, and they developed cost estimates for each prospective measure.

DOE program rules require meeting Savings-to-Investment Ratio targets (SIR) for every measure and for entire buildings/projects. (The SIR is a ratio of net present value of life cycle energy savings, compared to the first cost of installing a given measure.) With the measure cost estimates by the A/E firm, provisional SIRs were calculated (by the energy audit firm, using their TREAT model) for each measure and for the building/project as a whole.

Program (State of Wisconsin) staff then reviewed all measures estimated, both for package cost-effectiveness and for general feasibility. Those measures that could be funded (that indicated sufficient energy savings to meet the SIR test or were required to correct health/safety defects) were then submitted to the A/E staff for design, bidding, and implementation.

A/E firm staff developed detailed bid specifications and drawings (reviewed by program staff to assure conformance with DOE program standards). The project package was then offered for sealed bid by State of Wisconsin construction procurement staff, and the bid costs used to repeat the cost-effectiveness tests. Small (under 25 percent) owner co-payments were required to proceed with about 10 percent of the projects, and program staff negotiated those agreements. Based on the bid results and negotiations, the winning construction team was then contracted to implement all measures that could be funded.

During construction, A/E staff managed coordination between the building owner, the general contractor and subs, and program staff. They managed change orders and all measure modifications required. The A/E staff completed the project inspections required by DOE and supervised the process of providing building staff with suitable training and documentation to operate new systems. Program staff perform monitoring inspections of most buildings completed, inspecting most of the individual units as well.

This complex program model offers many advantages, and a few challenges as well. As we plan a continuing program for weatherizing large MFBs, we will likely retain most of the elements of this model.

The previous experience of our energy engineering firm was invaluable in ramping up this program. The TREAT modeling software can be comprehensive in analyzing most energy end uses in a building, but requires considerable expertise. As the audit firm involved acquired greater experience using this software, they evolved exceptional expertise in devising energy retrofit measures that could conform to DOE weatherization rules. We benefited greatly from having three engineers modeling at least one building per month, acquiring great familiarity with the process. [7] Since the program volume supported multiple engineers working on this task, they derived great benefit from regularly consulting amongst themselves to model unusual building features. We are now convinced that some significant ongoing volume of work (at least 10-20 buildings per year) would be necessary to develop and maintain a similar level of expertise.

By the same token, everyone involved (especially A/E staff and contractors) made a considerable effort to adapt their existing design and construction expertise to the peculiar goals and analytical methods of our weatherization program. There is little doubt that this was motivated by the fact that program had

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[6] DOE has approved only two software tools to analyze weatherization measures in buildings larger than 24 units; TREAT (Targeted Retrofit Energy Analysis Tool, by Performance Systems Development, Inc.) and EA-QUIP (Energy Audit using the Queens Information Package, by Association for Energy Affordability, Inc.)

[7] In general, the audit/modeling process averaged 4-5 days per building, depending on the building's size and complexity.

more than $20 million of committed budget, leading all contractors to dedicate specific staff and resources to attaining the necessary experience and expertise.

One unexpected benefit derived from the fact that TREAT includes a tool to evaluate its energy model against known utility bills. When this is done carefully, one variable that drops out of the model is a good proxy for the infiltration behavior of the building. Since blower door testing of large buildings is an art still in its infancy, this proved to be very useful. We were originally skeptical of this data, but observed early on that the results of the TREAT-modeled infiltration tracked reasonably with visual evaluation of leakage paths. In those areas where specific infiltration features (garbage chutes in particular) could be evaluated by independent engineering calculations, the results obtained from modeled data appeared to be of reasonable accuracy. This analysis indicated that every building in the program could benefit from air sealing. In most buildings, air sealing was the single most cost-effective measure employed.

The integration of A/E firms into the program design was originally intended primarily to meet stimulus goals of the original funding. We did expect their design expertise to be useful in preventing problems experienced in previous large-building weatherization projects. Especially, failure in previous efforts to have a precise, engineered design of a measure (especially large, multi-boiler heating systems) had led to imprecise contractor bids, expensive change orders, and generally difficult implementation. The A/E firms' design blueprints and detailed specifications for these very expensive measures assured that bidders were all offering largely identical products/services, at directly comparable prices.

The involvement of A/E staff was useful in another surprisingly common problem; that of correcting operators' misguided efforts to reduce operating costs by disabling supply ventilation systems. In about 15 percent of buildings, we found building supply ventilation disabled or abandoned. In a few cases, failed systems were simply not repaired, but in most cases it was clear that the systems had been shut down years before, to reduce utility costs. In most of these buildings, the ventilation cost burden was exacerbated by the fact that the supply air heating fuel was (expensive) electricity or that the original system was grossly oversized. The disabled systems were not critical failures in the buildings as audited; natural infiltration in leaky buildings was often (but not always) sufficient to prevent moisture/mold problems and gross odor complaints. The ancillary effects of disabled supply air (uneven heating, odor migration and generally poor indoor air quality) had historically been simply accepted as unavoidable defects of an old building.

These buildings presented substantial challenges. Implementing (very cost-effective) measures to reduce infiltration in buildings with defective ventilation could compromise the health and well-being of residents and the durability of the building. Simply restoring the supply air as part of weatherization would of course restore the high energy costs; extensive engineering effort was necessary to down-size systems appropriately, convert them to less expensive fuels, or install well-balanced heat recovery systems. The goal of these projects frequently evolved to simply restoring the building to the effectiveness and comfort that the designer intended while still saving at least some space heating energy.

Further, the A/E firms' special expertise in managing large construction projects with multiple contractors proved to be useful in another unexpected manner. We experienced superb cooperation from most building owners and managers, due in large part to the A/E firm's engineering expertise, *and* the excellent client management expertise the A/E firms brought to bear.

We also found one *very* unexpected benefit; the involvement of licensed design professionals gave our program a way to rectify original design mistakes. A dozen of our projects demonstrated high energy costs because of misguided decisions during the original design. [8] We exploited the capabilities of our A/E

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[8] The most extreme example; the top-floor hallways of a 30 year old, 100-unit building were designed and built with three passive exhaust grilles, totaling 24 Ft^2 of area, through the top floor hall ceiling directly to outdoors via large cupola structures on the roof. The two hallway furnaces supplying 8,000 CFM of conditioned air to the hall served to only partially overcome the enormous heat losses, and occupants throughout the building had extreme comfort complaints. Our A/E analysis provided "official permission" to undo this very unfortunate design element. This will provide enormous energy

staff to remove furnaces from unconditioned attics, reduce the volume of over-sized ventilation systems, or adapt new lighting designs. Virtually every one of these discussions started with the assertion, "You can't change the building design without an architect's stamp on your drawings." Having architects on contract provided the "official permission" to substantially improve these buildings.

One important program design finding is that supplemental funds greatly facilitate the ability to provide comprehensive weatherization in MFBs. DOE requires that each measure individually and buildings as a whole meet a cost-effectiveness test, with an SIR of 1.0 or greater. In most buildings we assessed, it was not difficult to get a package of measures that met the DOE "building SIR" standard, even with some measures that had an SIR well below the SIR ≥ 1.0 standard. In some extreme cases, it would have been impossible to complete repairs of deferred maintenance if DOE rules were adhered to rigidly. Given the equity-poor position of many owners, a requirement to "buy down" the cost of these measures would have delayed weatherization for months or stopped the project completely. In order to leave the residents with an optimal weatherization effort, Wisconsin planners chose to subsidize our efforts with State low income "public benefits" funds in accordance with DOE program guidance (US DOE, 2010 WPN 10-17). While the subsidy required varied from building to building, we found that an aggregate subsidy of 25 percent of State funds was sufficient to do complete and effective weatherization within the confines of DOE's rules.

Preliminary Findings from the Wisconsin MFB Weatherization Program

At this point, our conclusions are preliminary. Sixty buildings are still in progress, and more data is being acquired on a monthly basis. However, given the historical neglect (from an energy efficiency standpoint) of this entire sector, we believe that even preliminary information will be useful and timely, to assist the energy efficiency community in designing new energy efficiency programs for MFBs, and to provide information to the evaluation community about this building type. We believe even our preliminary data is sufficiently representative that it can inform program design and evaluation efforts. We look forward to the opportunity to provide more comprehensive and more rigorous data as the program progresses.

At present, it appears that energy efficiency opportunities in these buildings generally track those in Wisconsin's SF low-income weatherization program. Since conversion from atmospheric to condensing boiler systems frequently entails substantial improvements in circulation plumbing, we found boiler replacements and other space heating measures are frequently not completely cost-effective unless the building could be modified to reduce flue losses and infiltration effects. We down-sized a minority of boiler systems. We might well have down-sized more systems, except for the added cost ($2,000 to $5,000 per building) of completing an engineering/heat load analysis and filing that analysis with State code officials. Water heater replacement is rarely cost effective as a stand-alone measure, especially given the (current) high cost of commercial-sized sealed combustion water heaters.

Approximately half of all refrigerators present in most program buildings meet a cost-effectiveness standard for replacement. We replaced hundreds of incandescent light bulbs (especially in units) and dozens of T-12 fluorescent light fixtures (in common areas) in virtually every building, with good cost-effectiveness.

Insulation measures are not as important or as common in our MFBs as in smaller buildings, but they still frequently offer cost-effective opportunities. We completed attic insulation in most of the low-rise buildings weatherized. In most cases, the measure was cost-effective in its own right, especially since the existing attic insulation level was frequently R-30 or less. In most other cases, attic insulation was specified after attic air sealing, in spite of measure SIRs less than 1.0, in order to repair the insulation damage caused during air sealing work. (Pitched-roof accessible attics are far less expensive to insulate than walls or flat

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savings, and further allows us to replace the inefficient, unreliable hallway furnaces with condensing units half the size of the originals.

membrane roofs.) We have not specified wall insulation on any of our 80+ projects to date. It almost never presented as a cost-effective measure. In mid-rise buildings with masonry/brick exteriors, the cost of any wall retrofit is substantially higher than for SF weatherization.

The implementation of air sealing as a measure merits its own discussion, and a good deal more research. As noted above, we derived indirect information about infiltration losses from our comprehensive TREAT energy model. (Our program building models generally showed infiltration losses at 0.6 to 0.8 ACH*n*.) We completed air sealing on every building weatherized, targeting a reduction to 0.35 ACH*n*. Air sealing was frequently the most cost-effective measure implemented. Low-rise buildings generally offer greater opportunities for air sealing than mid-rise buildings. Implementing this measure required some substantial education of designers and of contractors, but the effort seems to have been successful. As blower door testing in larger buildings continues to develop and MFB weatherization programs develop and mature, we expect to be able to take a far more rigorous approach to this important efficiency measure.

In work completed to date that could be evaluated, this MFB weatherization effort indicates energy savings of 25.8 percent of fossil fuel use and 14.5 percent of electrical savings[9]. We present comparative data from seven buildings completed by early in the 2009-10 heating season.

Table 2: Energy Savings in Seven Weatherized MFBs

	Post-Retrofit Bill Data		Baseline Data	Gas Savings	Electric Savings	TREAT Savings Estimate (MMBtu)
	Period	Duration				
26 unit low-rise	June 2010 - May 2011	12 months	1 year	21.0%	-8.9%	30.6%
54 unit mid-rise	Oct. 2010 - May 2011	8 months	2 years	19.2%	13.0%	29.6%
56 unit low-rise	Nov. 2010 - May 2011	7 months	2 years	32.1%	10.3%	32.6%
20 unit low-rise	Feb. 2011 - May 2011	4 months	2 years	38.6%	17.7%	28.3%
52 unit mid-rise	Sept. 2010 - May 2011	9 months	1 year	15.9%	24.8%	22.5%
101 unit low-rise	Nov. 2010 - May 2011**	7 months	1 year	28.1%	24.7%	29.7%
98 unit low-rise	Nov. 2010 - May 2011**	7 months	1 year	---	19.7%	32.2%
	** March 2011 data not available		**Average-All Buildings**	**25.8%**	**14.5%**	**29.4%**

We used post-retrofit energy consumption data for the longest period possible after weatherization was completed (typically an eight-month period). Given that a full year's post-retrofit data were generally not available to us, we undertook a month-by-month comparison. The energy audit provided pre-retrofit energy consumption data, over a one-year or two-year period. For the analysis above, each individual billing period was compared directly to the same billing period of the previous year. (When two years of pre-retrofit data was available, the pre-retrofit consumption data for any given billing period was averaged.)

[9] The most recent evaluation (2004) of Wisconsin's "conventional" weatherization program reported energy use reductions of 15 percent for space heating energy use and 15 percent reduction of electricity consumption. (PA Government Services 2004)

In general, it appears that the program is more cost-effective (on a per-unit basis) than Wisconsin's "conventional" weatherization program. This is not a great surprise; after all MFBs exist because there are economies of scale in producing and operating housing. It is not surprising that energy efficiency opportunities exhibit similar economies of scale.

In fact, we experienced these economies of scale within this program. Heating system and DHW replacements seem to show economies of scale. Space heating measures often failed to meet DOE's SIR standard, except in larger buildings. DHW replacements passed the test only in the largest buildings. (We believe that one influence here is the ARRA requirement to pay "prevailing wage" rates. It is probable that some work would have been bid less expensively absent the reporting requirements, required of contractors not typically involved in publicly-funded projects, and inexperienced in such reporting.)

We were somewhat surprised to find that the economies of scale worked well in adding heat recovery ventilation to very large high-rise buildings. The hard cost for ERVs in four buildings, ranging from 10 to 24 stories, averaged approximately $1,000 per unit (less expensive than in SF homes). Given the high ventilation rates in these buildings, the very substantial energy savings yielded a average SIR of 1.5 for each dollar invested.

Electric space heating is an especially pernicious problem, and one that awaits a solution. It is specified in MFBs (generally in low-rise residential buildings) because it is very cheap to install. It also is easy to meter directly to the tenant. (Perfect for a MFB developer!) However, the cost per delivered Btu is twice to 2.5 times that of natural-gas fired space heating. And, with the tenant paying all space heating costs, they experience wide variations in utility costs over a year, which can create a substantial hardship for fixed income tenants. However, once electric space heat is built into a building, undoing it is very expensive. We evaluated several low-rise buildings that appeared to be good candidates for an electric-to-NG/hydronic conversion, and the predicted energy cost savings were substantial. Estimated hard costs in excess of $5,000 per unit generally yielded an SIR of 0.5 or so, far too low to allow consideration of such a complex measure.

Table 3: Comparison of Operational Parameters; ARRA weatherization vs. Single-family

ARRA MFB Wx Program compared to 2009 Wx Grantees	Wisconsin Wx Agencies (SF, manufactured homes and 1-4 unit rental homes)	ARRA AMP WX (10 projects closed to date)
Admin. Costs	7.6%	7.4%
Program Support Costs	26.1%	10%
Energy Savings (MMBtu)	18-22%	29%
Cost/unit	$6,734	$3,700

In the buildings analyzed so far, air sealing is generally the most cost-effective measure. Common area lighting technologies have advanced to the degree that they frequently offer very good energy efficiency opportunities, followed closely by in-unit lighting retrofits. (DOE is actively considering adding LED area lighting to their list of allowed measures, which may add another wave of lighting efficiency opportunity.) The newest DHW savings technologies (very low-flow showers and aerators) typically offer good energy savings. Refrigerator replacement is an effective measure, in spite of building management practices that would seem to indicate that it should be a less cost-effective measure.

References

PA Government Services, Inc. (Draft). An Examination of Early Results of the Apartment and Condominium Energy Services Appliance Turn-in Program. September 2002. Unpublished evaluation report prepared for State of Wisconsin, Department of Administration, Division of Energy, Madison, Wisconsin.

PA Government Services, Inc. *Low-income Public Benefits Evaluation; Year 3 Low-income Program Evaluation – Volume 1.* August 2004. Evaluation report prepared for State of Wisconsin, Department of Administration, Division of Energy, Madison, Wisconsin.

Pigg, S. and A. Price. 2005. *Energy and Rental Housing A Wisconsin Characterization Study.* ECW Report Number 232-1. Madison, Wisconsin: Energy Center of Wisconsin.

Pigg, S. and M. Nevius. 2000. *Energy and Housing in Wisconsin, A Study of Single-Family Owner-occupied Homes.* ECW Report Number 199-1. Madison, Wisconsin: Energy Center of Wisconsin.

Stone, N. 2009. *U.S. Multifamily Energy Efficiency Potential By 2020*. The Benningfield Group, Inc. (for The Energy Foundation), Folsom, CA, 2009. http://www.benningfieldgroup.com/docs/Final_MF_EE_Potential_Report_Oct_2009_v2.pdf

U.S. Census of Population and Housing, 2000 Summary Population and Housing Characteristics, Wisconsin. Washington, D.C., Government Printing Office, April 2002.

U.S. Department of Energy (DOE), 2011. Weatherization Program Notice (WPN) 11-4 http://waptac.org/data/files/website_docs/government/guidance/2011/wpn%2011-4.pdf Washington, D. C.

U.S. Department of Energy (DOE), 2010. Weatherization Program Notice (WPN) 10-17 http://waptac.org/data/files/website_docs/government/guidance/2010/wpn%2010-17.pdf Washington, D. C.

US Department of Housing and Urban Development Benchmarking Tool. 2007. http://portal.hud.gov/hudportal/HUD?src=/program_offices/public_indian_housing/programs/ph/phecc/ubenchtool

U.S. Energy Information Agency (EIA), Residential Energy Consumption Survey 2005. http://www.eia.gov/emeu/recs/recs2005/hc2005_tables/detailed_tables2005.html Washington D.C.