HEATING COST ALLOCATION IN CENTRALLY HEATED RENTAL HOUSING: ENERGY CONSERVATION POTENTIAL AND STANDARDS ISSUES

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ABSTRACT

PRISM analysis of nine Minnesota buildings in which heating cost allocation was implemented showed an average savings of 16% of normalized annual gas consumption (NAC). Economic analysis showed that the owners could achieve a one year payback while increasing tenants' total average costs by only five dollars per month. Owners reported generally positive tenant reactions and no long term increase in turnover or vacancy.

These findings suggest a role for heat metering in energy conservation, but regulation may be needed to protect tenants and the public interest. No U.S. jurisdiction currently has a comprehensive policy on heating cost allocation, but litigation is beginning to emerge. The Minneapolis Energy Office has been working to develop a draft policy. Combining our own experience with an in-depth review of standards from European countries where heat metering is widespread, we have identified five key areas that must be addressed. The first is to require that the buildings meet an energy code, since otherwise allocation may decrease owners' incentive to make conservation improvements. Any policy must also regulate the metering equipment itself. European standards offer valuable guidance in this area, covering types of equipment allowed for various applications, required accuracy of measurements, procedures for conversion from the measurement value to estimated heat consumption, tamperproofing, and a host of other issues. Since uses not monitored by the allocation equipment often comprise up to 60% of the total fuel bill, standards for the equitable distribution of non-metered costs are a third critical issue recognized by European countries (and some U.S. monitoring firms). In our test buildings, such standards reduce the maximum annual variation between units within a building from 40 to 1 for metered hours, clearly an unrealistic spread, to 4 to 1 for billed energy charges. The policy should also require owners to disclose past bills to prospective tenants and to provide clear information on how the allocation system works and how they can reduce their energy expenses. Finally, billing provisions should prohibit profit from resale and should require owners to offer budget billing. January bills in the test buildings were typically 7 to 10 times summer bills and were frequently in excess of $80.

A national effort is needed to develop standards using centralized resources, so that individual jurisdictions do not have to face litigation and policy questions unassisted. In the meantime, standards which address the above five issues, even if somewhat bare of technical details, can provide a framework for interaction among governments, landlords, tenants and monitoring companies.

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BACKGROUND

Heating cost allocation systems are combinations of monitoring devices and accounting procedures designed to allow the energy costs in centrally heated multifamily buildings to be divided among the individual apartments on the basis of use. The systems discussed here deal only with central heating and domestic hot water; the concerns would be somewhat different for systems dealing with centrally cooled buildings or district heating systems.

From a policy perspective, heating cost allocation (HCA) has several potential benefits. First, it places the financial responsibility for energy consumption on the user of energy. Occupants' energy use habits are a major factor in building energy consumption. Studies at Princeton University have documented two to one variations in energy use in identical residences due to variations in energy lifestyle (Sonderegger, 1978). By billing the tenant directly for energy used, HCA gives the residents of multifamily buildings a motivation to use energy more efficiently, keeping thermostat settings reasonable and keeping windows closed in cold weather. A number of studies have cited the division of responsibility between owners (who pay the bills) and residents (who control much of the day to day operation of the building) as one of the major institutional barriers to energy conservation in multifamily buildings (e.g., Bleviss and Gravitz, 1984). It is estimated that the 9 million U.S. rental households in buildings with owner-paid space and/or water heating consume 0.8 quadrillion Btu's of natural gas and oil annually (U.S. DOE, 1981, cited in McClelland, 1983, p. 4). Allocation may be the only effective way to realize behavior-related savings in this sector; tenant education and RUBS billing have been found to be far less effective (McClelland, 1980, p. 45 and McClelland, 1983, p. E-4). Second, allocation is probably preferable to installing individual heating systems in each unit. In recent years a major shift toward electric heating in new multifamily buildings has occurred (U.S. D.O.E., 1985, pg. 9) motivated largely by owners' desire to make tenants directly responsible for heating costs. At the same time, retrofit installation of individual heating systems in existing centrally heated buildings has begun to occur in a number of cities. Often the heating systems chosen are electric resistance units with high operating costs; in Chicago such systems have made some buildings unrentable (Basler, 1983). Even if fuel-fired systems were installed, they probably would not be as efficient or as well maintained as a large central system. Finally, a good allocation system divides energy costs in a way more truly reflective of actual consumption than dividing costs based on apartment size, which is the method implicit in including energy costs in the rent.

There are, however, at least two public policy concerns relating to heating cost allocation. The first is the possibility that in transferring the energy bills to the tenant, heating cost allocation removes the building owner's incentive to make his/her building energy efficient. The second is the equitability with which these systems allocate energy costs on the basis of use. This turns out to be a rather complex issue that goes far beyond the question of equipment accuracy, as will be discussed later.

In Europe over 40 million energy monitors are in use (McClelland, 1983). The guidelines of the European Community council demand means to allow the allocation of energy costs according to use and many governments view individual allocation favorably (Goettling and Zaworski, 1983). The Federal Republic of Germany actually requires it (Goettling and Kuppler, 1981).

In the U.S., we estimate based on contacts with manufacturers that perhaps at most a quarter million allocation devices are in use (see also Goettling and Zaworski, 1983). The greatest concentration by far is in Colorado, where one manufacturer estimates that 50% of Denver apartments are "individually metered". In 1983, McClelland identified 24 companies selling allocation devices; 12 of these and 5 others responded to telephone inquiries made by the authors in 1984. Nearly all of these companies are rather small, the large metering and heating systems control companies not having entered the market. Virtually no U.S. states or cities currently have legislation or regulations dealing specifically with heating cost allocation, though some may consider it to fall under regulations prohibiting submetering (McClelland, 1983, p. 82, 83, McClelland, 1980, Vol. II, pgs. 5-7). One exception is a brief statement of no objection by the Colorado Public Utilities Commission (Decision No. C80-1828, Case No. 5321). There is also a dearth of case law. As of this writing, however, an HCA distributor is suing the City of Seattle, which issued stop orders to prevent him from selling HCA devices or using the ones already in place for allocation, claiming that they were "commercial measurement devices" and had to meet utility meter accuracy standards. A distributor in Michigan is seeking a declaratory ruling from the Michigan Public Utilities Commission.

It is likely that heating cost allocation will become more prevalent in the U.S. as energy costs and rental property operating costs increase, and it is also likely that litigation over the issue will increase. It appears that a national standards-setting effort, coordinated by the various national standards, heating, and energy institutions (e.g., NBS, ASHRAE, DOE) would be preferable to establishing practices through litigation. This paper suggests some areas to be addressed by such standards.

ENERGY SAVINGS AND ECONOMICS

In 1983, McClelland documented median savings of 14% of total annual gas use in 50 buildings in San Diego, Colorado, and a scattering of other locations converted from owner-paid to tenant-paid space and water heating (p. E-4, 30). In order to find out more about the energy savings and economics of heating cost allocation in cold climates, the Minneapolis Energy Office initiated a study funded by Minnegasco, the local gas utility. The office made contact with owners of 41 buildings in Minnesota converted to HCA which were identified by local HCA distributors. (This probably represents most of the HCA buildings in Minnesota at that time). Fifteen owners representing 39 buildings were surveyed to determine whether they had made other conservation improvements that might interfere with analysis as well as to explore their level of satisfaction and other issues. Twenty five of the buildings had enough pre and post retrofit data for immediate analysis, and nine of these had made no other significant improvements during the analysis period. All nine were low rise buildings with hot water multizone heating systems. The change in energy use was determined using the Princeton Scorekeeping Method (PRISM) (Fels, 1985). These buildings showed a mean reduction in total weather normalized gas consumption (NAC) of 16% the first year after HCA installation (table 1), and an additional 5.5% the second year (total=20.6%), although the date of our survey was such that we are not sure that all of these buildings did <u>no</u> other retrofits in the second year after implementation of HCA.

The particular systems installed were relatively inexpensive ones, with an average cost of about $90 per apartment (table 1). The dollar savings can be looked at two ways. From the owner's point of view, the savings are potentially the <u>entire</u> pre-retrofit gas bill, which s/he no longer pays. This gives very dramatic paybacks on the order of two to four months. From an energy conservation perspective, the savings are equal to the <u>change</u> in the gas bill. This gives an average payback of 1 1/2 years, which is very attractive when compared with many other conservation retrofits, although some, like outdoor resets (Hewett and Peterson, 1984) or low flow showerheads probably perform as well or better. If the owner were in fact to transfer the entire energy bill to the tenant without a concomitant rent reduction, the increase in the tenant's total housing cost would be substantial: for the nine buildings analyzed, the post-retrofit energy cost per apartment averaged $420/year or $35 per month (table 1). This is not comparable to recent rent increases in Minneapolis, which have typically been less than $15 per year, so most owners in this area reduced the rent at least somewhat before passing on the heating costs. In some other urban areas, though, a $35 total rent increase would be feasible.

An alternative economic analysis was made to determine the impact on total average tenant costs if the building owner adjusted rents with the goal of retaining for him/herself a one year payback. For this group of 9 buildings we estimated that a 24.7% reduction in pre-retrofit energy costs would give the owner a 95% confidence of achieving a one year payback, or stated another way, the owner could reduce rents by an amount equal to 75.3% of the pre-retrofit gas bill at the time that HCA commences and still have a 95% confidence of a one year payback. The cost of the billing service, estimated at $1.50 per apartment per month, must be subtracted from this rent reduction. For this group of buildings with this type of metering equipment, the owner could secure a one year payback while only increasing total tenant costs by an average of about $5 per month, which would be comparable to recent rent increases within the City of Minneapolis.

Reasons owners gave for installing HCA systems ranged from the general desire to cut energy bills or get them out of the rent to the specific intention of stopping what they saw as tenant abuses of open windows, neglect or waste. Eight of the fifteen owners felt their bills for the buildings were unusually high before HCA was installed. Only five owners reported some modest turnover when the system was first installed and none reported any long term increase in turnover. Two reported some increase in the length or number of vacancies, although one of these felt it was due to the concurrent change from month-to-month rental to year leases. One other owner noted that some people who inquire about his apartments are not interested once they find they have to pay for heat. Of the fifteen owners surveyed, nine were very satisfied, five were fairly satisifed, and one had not had the system long enough to be sure. Two other owners interviewed briefly had had the systems installed but had never used them, and a third we were told about by a distributor installed the equipment in a low income building and discontinued using it when he was unable to collect the bills. Twelve owners said they would implement HCA in another building and would recommend it to others, although one cited the need for more tenant public relations and another the importance of the base charge (discussed later) for equitable billing. Among the other three owners, one said it would depend on the building, one said he would not do it in a building with an established clientele and one did not yet have an opinion at that time.

Tenants' response was not as favorable. Five owners said tenant reaction was good or very good and four said they were agreeable to it or went along with it. Two of the latter mentioned that they had lowered rents or significantly delayed rent increases. One reported "varied" reaction and five said that there was some apprehension or opposition at first. Tenants were not surveyed directly both for logistical reasons and because the most dissatisfied would already have left, skewing the results.

STANDARDS

The Minneapolis Energy Office initially began investigating heating cost allocation systems in response to a request by a local distributor to finance such systems through various energy conservation loan and grant programs. A proposed interim policy was developed in 1984 but not implemented due to the limited interest in the measure among local property owners.

Since virtually no U.S. legislation, regulations or case law could be found, and since the European countries have a great deal more experience in this area, the Office has sought to collect European standards in an effort to refine the draft policy. Standards or draft standards have been obtained from Germany, France, Switzerland, Austria and Greece, and at this date the first three of these have been translated. Sweden, Norway, the United Kingdom, the Netherlands and Denmark have informed us that they do not have national standards for HCA.

Our review of existing standards and our own work indicate that five distinct areas must be addressed in developing standards that protect tenants and the public interest. These are:

1. Building energy codes.
2. Equipment and installation.
3. Allocation of non-metered uses.
4. Disclosure and tenant education.
5. Billing and meter reading.

While there may be a natural tendency to focus on equipment accuracy, we hope to demonstrate that all five issues are important.

BUILDING ENERGY CODES

It has been documented (McClelland, 1983) that owners of tenant metered buildings make fewer energy conservation improvements than owners of master metered buildings, although they still make some (pg. 48, 49). McClelland concluded on the basis of sensitivity analyses that tenant metered buildings were nevertheless likely to remain more energy efficient than master metered buildings over 10 and 20 year time horizons (p. 81). Metering companies say that tenants complain vociferously about energy inefficiencies they observe once they are paying the bill, thus keeping pressure on owners to make improvements. In fact, some metering companies stress their opinion that buildings that are inefficient or in poor condition are poor candidates for HCA. This may not be an area that governments want to leave to the mechanics of the marketplace, since some of the possible outcomes are high total housing costs and/or abandonment of housing that is unrentable due to high costs. The German HCA standards (DIN 4713 Part 1:2) explicitly require the heating and water heating plant to satisfy the requirements of their energy saving law prior to implementation of HCA. The other countries do not include energy efficiency in their allocation regulations, but at this writing we do not know if such standards are present in separate laws or regulations. In Minneapolis the Rental Energy Standards (Housing Maintenance Code Sec. 244.680) provide some leverage over rental housing efficiency. Inspections normally occur only upon tenant complaint, but could be automatically triggered whenever a permit for installation of an HCA system is applied for.

EQUIPMENT AND INSTALLATION STANDARDS

This part of the standards deals primarily with hardware issues, while the last three portions deal with accounting and billing procedures.

General Provisions

Certain general provisions seem obvious, such as:

1. that allocation devices must be installed in all apartments and all apartments must pay for energy use on the same basis (see JOE Art 10,JOA Art 12),

2. that allocation devices must be installed on all heating elements and all allocation devices must be of the same model, and

3. that they may be installed only in apartments in which the tenant has control of the heat by means of a functional thermostat or valve (see DIN 4713 Part 3:1).

Yet all three issues have arisen in the Seattle case (letter of Walter Tank, Seattle Department of Licenses and Consumer Affairs, to Richard Oberhausen, Monetech, September 9, 1985, and form letter from Licenses and Consumer Affairs to apartment owners), and energy auditing experience clearly demonstrates that non-functional controls are a common problem. Thus these provisions should be made explicit.

Allowable Types of Heating Cost Allocation Equipment, Measurement Accuracy, and Related Issues

Types of monitoring equipment are discussed by Goettling and Zaworski (1983) and IREM (1981). Only 5 common types are described here. Four of these are the actual types of equipment being sold by manufacturers we contacted. The fifth is a type commonly included in the European standards.

Time Meters. Time meters are probably the most common type of HCA equipment currently being sold in the U.S. These do not actually measure the amount of heat delivered, but rather provide an estimate by recording the number of hours the thermostat calls for heat or the number of hours the zone valve is open. Time metering systems cost \$80 to \$150 per apartment, installed. The heat given off by finned tube radiation is very strongly dependent on the water temperature, and less so on flow rate (figure 1). Figure 2 illustrates the percent difference in heat received (Btu output per lineal foot) by two apartments with zone valves open for the same amount of time, if there is a 10°F or a 20°F difference in the inlet water temperatures to the two apartments. For example, if an apartment near the boiler is receiving water at an average temperature of 170°F, and an apartment further away is receiving it at 160°, the difference in heat delivered per unit time is about 12%. The error increases the lower the supply water temperature. With outdoor reset control the supply water temperature may be as low as 100°F, and the relative errors quite large, although on a seasonal basis the proportion of heat delivered at these low temperatures is small. The differences in actual heat delivery caused by supply water temperature differences will not be detected by a time metering system. Unfortunately we have been unable to locate data on typical differences in inlet water temperature from one apartment to another within a building, so we cannot say how significant this problem really is. It should be noted that with reset systems water temperature also varies from time to time, so that households that have their thermostat set up more often in the evening, for instance, would receive a higher average water temperature than those who set them up during the day, other things being equal. Thus, although a time based system may measure time with very high precision, it is clearly false to imply that it "measures" heat flow with comparable accuracy.

The European standards we have obtained do not discuss time based systems. As yet we have not determined whether they are not allowed in these countries or perhaps are not sold due to a limited number of heating systems with electric zone valves or thermostats.

If U.S. jurisdictions decide that errors due to variations in water supply temperature and flow are not serious, there are still other issues to address to insure reasonable usage estimates. The amount of heat represented by an hour of time on the meter is strongly dependent on the length of the finned tube radiation in each apartment (as well as the type, if this varies within a building), and it is imperative that the billing system correct for this. A further consideration is that the thermostat may be calling for heat but the zone valve may be stuck closed, in which case no heat is actually being delivered. Systems which record time only when the thermostat is calling and a temperature sensor verifies flow of hot water are available and eliminate this problem.

<u>Btu Meters</u>. Btu meters (or thermal meters) are much more expensive than time meters ($350 to $500 per apartment), but actually determine the amount of <u>heat</u> delivered to each apartment by measuring mass flow and inlet and outlet temperatures. In terms of engineering principles, they are potentially more accurate than time meters. Many Btu metering companies we contacted did not supply accuracy data for their meters; figure 3 shows accuracy data for the three that did. They all indicate the general trend of decreasing accuracy for decreasing temperature drop. According to an individual at the Institute for Boiler Research, the typical temperature drop around an individual apartment loop is on the order of 5°F. Two of the metering companies do not even give accuracies for this low of a temperature difference, and the third shows the error increasing very rapidly in this range of temperature differences. A study by Guinn and Hummer (1982) found errors ranging from 1 to 30% with temperature differences from 10° to 100°F in a sample of 35 Btu meters due to problems with temperature and flow sensors and poor quality control. They concluded that Btu meters should be tested for operation and reasonable accuracy before installation, something that the typical multifamily building owner is unable to do. In practice, then, many Btu meters have relatively poor accuracies at the small temperature differences common across a baseboard loop, so they may not be significantly more accurate than time meters. Btu meters generally are too expensive for most apartment owners to consider in any case.

Thermal meters are discussed in the German, Swiss and OIML standards. OIML sets standards for permissible errors in several different temperature-difference ranges for three classes of meters (OIML 2: 3.2, 3.3). The Swiss standards make clear that thermal meters used to divide a central bill into shares must have a maximum error of 8% at ΔT less than 10°C, while meters used for billing heat directly (e.g., in district heating), must have a maximum error of 5%, although both standards are relaxed by 2% for low flow rates. (Article 4). The German standards state explicitly that heat meters must be selected based on data on expected flow rates and temperature drops (DIN 4713 Part 4:3.2), so that conditions lie within the accurate operating range of the meter, and this is implied in the Swiss and OIML standards. The Swiss standards (4.1.7) also state that the instrument must be incapable of recording heat energy when there is no heating liquid flow.

<u>Time Plus Temperature Systems</u>. Electronic systems that estimate heat use based on measurements of temperature but not flow have recently been developed energetically in Europe and are also being manufactured by a few U.S. companies. Some of these measure the radiator supply and return temperature to calculate mean radiator temperature, and combine this with the ambient room temperature to estimate heat flow rates, while some attempt to place a single sensor so that the approximate mean radiator temperature is measured directly (Goettling and Kuppler, 1981). Others are simplified even further by assuming the room temperature rather than measuring it. At least two U.S. companies are making the latter type, while a third is making one which measures the difference in air temperature above and below the fin tubing. These systems improve on the accuracy of time meters but cost less than Btu meters ($200 to 400 per apartment). They take the water temperature into account, which time meters cannot, without requiring the measurement of a small temperature difference as

Btu meters do. In this paper these are referred to as time-plus-temperature systems.

For this type of equipment, Germany requires the standard deviation of measurement values measured on 100 sensor elements or sensor pairs under the same temperature conditions to be not more than 2% (DIN 4714 Part 3:3.1.1). France requires that the overall integrating factor (counts per unit of energy) for each monitor not deviate from its nominal value by more than 8% over the operating range.

The fact that temperature is measured with precision does not guarantee an accurate estimate of heat delivered. The method of converting the measurement to a consumption estimate, whether electronically within the instrument or externally, is critical. Germany requires a calculation factor for the size of the radiator (heating element) (DIN 4713 Part 3:4.1), to be determined from tabulated values, and for the type of radiator (DIN 4713 Part 3:4.2), to be determined by empirical measurement of the HCA device's electrical output on the radiator being evaluated compared to that on the standard radiator. If the HCA device does not measure ambient temperature, a calculation factor must also be introduced for those rooms with design temperature different from 20°C (DIN 4713 Part 3:4.3). Further corrections must also be made for unusual types of connection (DIN 4713 Part 3:4.4). France also incorporates corrections for the size and type of radiator, by requiring that the monitored temperature difference be converted to a calculated thermal output starting from tabulated laboratory values for the output of each specific size and type of radiator at $\Delta T = 60°C$ (JOS Art 2).

Both countries also specify certain types of systems on which these particular HCA devices may not be used. For example, France allows them only on heating elements with fixed geometry and no forced convection of ambient air (JOS Art 10). They also specify the placement of the sensor on the heating element (DIN 4713 Part 3:3.2, 4714 Part 3:7, JOS Art 11). Major variations in sensor location have been an issue in the Seattle case. It is clear that regulations that set high standards for sensor or processor accuracy without addressing such issues as corrections for radiator size, allowable applications, and sensor location are missing the mark.

Ambient Temperature Monitors. An entirely different allocation approach is to monitor the ambient temperature or comfort level of the apartment. This approach is based on "equal cost for equal comfort" rather than "equal cost for equal energy use", and gets around some of the difficult measurement problems as well as reducing some of the problems (discussed later) caused by variations in energy use due to exposure of the unit to wind or sun, proximity to and therefore unpaid heat gain from the boiler room, etc. Some such monitoring systems measure the apartment space temperature at a representative location and integrate it over time, while others measure the thermostat setting, not the actual space temperature (Goettling and Kuppler, 1981). Germany does not allow ambient temperature based systems (Goettling and Kuppler, 1981), but France does (see JOA). There the temperature measurement is converted to an energy consumption estimate using the volume of the room and a volumetric heat loss coefficient (JOA Art 2), the latter factor serving to make the measurement somewhat more an approximation of energy use level than pure comfort level. The only U.S. system we are currently aware of measures the setpoint temperature, not the space temperature. In a well maintained system these will be the same, but there are a number of situations that could cause this not to be the case.

Evaporative Monitors. The final type of monitoring device is based on evaporation of liquid from a vial attached to the radiator. Since this system is not in widespread use in the U.S., it will not be discussed, except to note that both Germany (DIN 4713 Part 3, 4714 Part 2) and France (JOE) have developed detailed standards to help insure that heat usage is approximated equitably.

Accuracy in the Seattle Case. Accuracy has been a major issue in the Seattle court case (Monetech, Inc., et. al. vs The City of Seattle, et. al., King County Cause No. 85-2-15555-6). The City of Seattle initially asserted that "the use of a metering system to establish a billing is a function of the Weights and Measures Section of the Department of Licenses and Consumer Affairs", and further that a "device...used in commercial trade is accurate in the range of one-tenth of one percent (.1%) or better" (letter from Regina Tyner, Seattle Department of Construction and Land Use, to Richard Oberhausen, Monetech, April 25, 1985). Later they set an interim standard of 2%, since this is a common accuracy requirement for utility meters (letter from Katy Chaney and Tyner to Oberhausen, June 10, 1985). These accuracy standards are clearly much stricter than the international (OIML) standards for heat meters or the European standards for various allocation devices. It is not clear that such strict standards would be in the public interest, since they tend to obviate against allocation systems that could almost certainly be more equitable than the existing flat rate charges and in favor of eventual movement toward individual heating systems (or building abandonment). In the absence of case law, a number of metering manufacturers and developers have asserted that tenant allocation practices will be governed not by utility law, but by landlord-tenant law. While the former requires high standards of accuracy, the latter requires only that the landlord be reasonable in what he does and that he explain to the tenant in advance how his costs will be determined. It remains to be seen whether future litigation will bear out this claim.

Indirect Heat Delivery. Another consideration bears on the issue of "accurate" allocation. The problem is not simply a matter of accurately measuring heat delivered by the heating elements. In apartment buildings, a certain amount of heat will always be delivered by indirect transfer paths other than the distribution system, for example, heat transferred through the wall from the boiler room to adjacent apartments, and warm air rising from lower apartments to higher ones. These heat flows cannot be measured readily, so accurately measuring the heat delivered by the distribution system alone does not guarantee a perfect allocation. The metered energy used by each apartment will also vary depending on exposure to wind, sun and stack effects, sheltering by the earth in garden level apartments, etc. There is a philosophical question of whether there should be equal cost for equal comfort or equal cost for equal energy use. A somewhat analogous situation arises in duplexes with separate meters and heating plants. Here each household quite commonly pays for energy used by its furnace or boiler, even though it is clear that with infiltration predominating at lower levels and exfiltration at upper levels, a significant amount of heat transfer from the lower to upper apartment occurs. Nevertheless, in multifamily buildings metering companies have tended to make qualitatively determined adjustments in bills based on obvious spatial patterns of use. (Much can be learned about this by monitoring for a few months before beginning billing). France evidently agrees with this approach, allowing up to a 30% correction for unfavorable situations or configurations (JOE Art 13, JOS Art 12). In this context a 2% measurement accuracy seems incongruous. While accuracy standards are a valuable part of overall HCA regulation, it is necessary to consider them within the framework of a concept of "equitability" which covers a host of other issues discussed later.

Other Equipment Issues. A variety of other provisions related to equipment are needed. A key one is tamperproofing. In the buildings involved in the Seattle case, many tenants simply disconnected the temperature sensors or cut the wires. The German and French standards both require secure sensor attachment (e.g. DIN 4713 Part 3:3.1) and require seals or other protection on the equipment so that any interventions can be detected. For this to be effective, it must be that tenants who do tamper with the equipment pay some significant penalty, or else the savings in energy costs would encourage tampering, but we currently have no details on this.

Other provisions in the European standards cover susceptibility to fluctuations in power supply voltage or frequency, electromagnetic fields, ambient humidity and temperature, etc. Construction quality and maintenance schedules are also regulated. A list of key provisions with citations to the European standards is given in table II.

ALLOCATION OF NON-METERED USES

A significant fraction of the total fuel energy delivered to a building ends up somewhere other than in the heating distribution systems of individual apartments. In Minneapolis buildings, for example, about 25 to 30% of the total natural gas consumed on an annual basis is used for domestic hot water, and another 5% for stoves. Of the remaining 60 to 65% which is used by the boiler, about two fifths is lost up the flue or from the jacket, so that the useful heat produced by the space heating system is somewhere around 40% of the total gas bill. And of this perhaps as much as a tenth to a fifth goes to heat common areas. Thus it is certainly not justifiable to divide the total gas bill or even the total space heating bill based on metered hours, yet some billing systems provided by HCA firms do just this. As an example of the problems this can cause, consider a mild fall month in which the heating system is on, but only two or three of the tenants call for a few hours of heat. These tenants will receive the total gas bill under such a system.

A fair and reasonable billing system should probably divide the bill into three components:

1. Domestic hot water use. If this use is not actually measured separately for each apartment, it should be allocated on a per occupant basis, or as a second choice, on a per square foot basis. While per occupant allocation is more realistic, fluctuations in tenant population make it more difficult.

2. Base use (for boiler losses, common area heating and miscellaneous uses). This should be allocated on a per square foot basis.

3. Apartment heating use. This should include the actual heat delivered to the apartments.

Figure 4 demonstrates the problem and shows how a reasonable billing system creates more equitable allocation. Consider for example building TEN. Over a one year period, the median number of meter hours registered by the 16 apartments in this building was 998. However, the apartment with the most metered hours experienced 2259, while the one with the least experienced only 59. It is unlikely that this 39 to 1 spread reflects the true difference in use of these two tenants. This metering company uses the following simple billing system: half of each winter gas bill and all of each summer bill is considered to be base use (including both components 1 and 2 from the list above) and is divided among the apartments on a per square foot basis. The other half is the heating charge and is divided based on metered hours. Using this billing system, the total spread in billed use is from \$568 to \$218 per year, a 2.6 to 1 variation. This is a reasonable range of variation in energy use to expect for various units within a building. The other examples shown in figure 4 are not as dramatic, but illustrate the same point.

Three levels of determining the division of the bill into the three components could be considered. The first would be to simply require billing systems to make a reasonable and fair estimate of the three components. The second would be to require some centralized metering of the three components. For example, all systems could be required to separately meter the total gas use for domestic hot water, either with an hour meter, a gas meter, or in the case of domestic hot water heated by the main boiler, a Btu meter. One reason for requiring metering of domestic hot water use in Minneapolis is that this use is highly seasonal, owing to the wide swing in water supply temperature over the year (figure 5). Thus estimating domestic use year round based on summer use is inaccurate. Btu based or time-and-temperature based systems determine the approximate apartment heating use directly, and could calculate base use as equal to total use minus DHW use minus apartment heating use. Systems based on time only would have to estimate the division between base use and apartment heating use, but guidelines for doing this could be established. The third, most extreme, level of accuracy would be to require Btu's for both space heating and domestic hot water to be metered at the apartment level. Since most existing U.S. apartment buildings are plumbed with several domestic hot water supply lines into each apartment, this system would be prohibitively expensive with current monitoring equipment costs.

The German standards address procedures for allocation of nonmetered uses. For combined central heating and water heating plants, the cost for water heating must be separated (DIN 4713 Part 5, 2.5). The energy use can be estimated based on the volume of water heated and the type of fuel, using a table in the regulations, or if the volume cannot be measured, by assuming 18% of fuel use is for domestic hot water. It is not clear how this water heating bill is then divided among the tenants. The standards also require that part of the heating costs be divided according to area, but they do not specify the fraction (DIN 4713 Part 5:3). The French standards do not discuss this issue, but their HCA systems are clearly set up to estimate heat use, not merely subdivide a central bill. Thus the measurements from all devices should presumably total to much less than the entire fuel bill, with the rest to be charged to tenants in some other way. In Austria, the most commonly used regulation is "...a key which distributes 40% of the costs with respect to the housing area percentage and 60% with respect to the measured heat consumation (sic)..." (letter from Dr. B. Ziuwa, Bundesministerium Sekton V (Energie) to Helen Emslander, Minneapolis Energy Office).

DISCLOSURE AND TENANT EDUCATION

If owners or monitoring companies are not allowed or do not choose to make adjustments in the bills based on variations in heating load from apartment to apartment, then there may be some significant variations in tenants' energy costs. In these circumstances in particular, a provision that requires the owner to disclose the energy costs for a particular apartment at the time of rental gives tenants some very desirable protection. This would probably encourage some variations in the base rent to offset the variations in energy cost. The required disclosure could include the previous 12 months' energy expense for the apartment, the highest single month's energy expense for the apartment out of the last 12 (especially if budget billing is not required) and the highest and lowest total energy expense for the previous 12 months for apartments of comparable size in the building.

Prior to the availability of 12 months of data the owner could be required to provide a reasonable estimate of the above items based on the total bill for the building and the metering company's experience regarding variations in use depending on apartment size, location and orientation. These estimates should also be provided to the existing tenants at the time of implementation.

The owner should also be required to provide to all tenants at the time of implementation and to all new tenants information on how the HCA system works, how to reduce their energy expenses, and how to identify system problems that might cause them to be overbilled.

METER READING AND BILLING

A common provision of state utility regulations requires that when electricity or gas is submetered, the building owner may not make a profit on its resale, which should also be the case for HCA.

A further issue to consider is whether owners should be required to offer tenants budget billing, or should be allowed to pass each month's bill directly on to the tenant. Figure 6 shows the range in monthly bills for our sample of buildings if budget billing were not used. The typical midwinter bill is in the $50 to $100 range, but some are as high as $140. Summer bills are about $5 to $15. While some billing companies feel that budget billing is too complicated due to tenant turnover, others find that it is not a problem or even recommend that it be used. At least in Minnesota, multifamily building owners can receive budget billing themselves from the gas company so they would not have to tolerate an irregular cashflow to provide tenants with budget billing. It should be noted that the typical renter has an annual income about half as large as the typical homeowner (U.S. DOE, 1985, p. 12), so that budget billing would seem to be a desireable policy requirement.

Provisions for the frequency of readings (including readings when tenants move out and in) and required contents of the bill should also be included.

CONCLUSIONS

Heating cost allocation can result in significant energy savings in the multifamily housing sector by making building occupants financially responsible for their energy lifestyle. HCA systems can play a role in containing building owners' costs and protecting the housing supply while mitigating against mass conversion to individual heating systems. Standards are needed to protect tenants from owners' lack of motivation to maintain energy efficiency after implementation and from the many possibilities for inequitable allocation of costs. These standards should address: 1) building energy codes, 2) equipment and installation, 3) allocation of non-metered uses, 4) disclosure and tenant education and 5) meter reading and billing. All five components are necessary to assure an equitable system. All except (2) are reasonably straightforward to draft; equipment and installation standards are conceptually straightforward but practically speaking nontrivial to establish and to develop testing procedures for.

A national effort is needed to develop such standards using centralized resources so that individual jurisdictions do not have to struggle with the issue one by one. In the meantime standards which address the above five issues, even if somewhat bare of technical details, can provide a framework for interaction between governments and businesses which sell HCA equipment.

ACKNOWLEDGEMENTS

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STANDARDS AND DRAFT STANDARDS CITED

Abbreviation	Standard
DIN:	Federal Republic of Germany, Deutsches Institut fur Normung e.V, December 1980.
JOA:	France, Journal Officiel de la Republique Francaise: Dispositions relatives aux repartiteurs de frais de chauffage utilisant la mesure de la temperature ambient des locaux. June 10, 1983.
JOE:	France, Journal Officiel de la Republique Francaise: Evaporateurs-repartiteurs de frais de chauffage. March 16, 1982.
JOS:	France, Journal Officiel de la Republique Francaise: Dispositions relatives aux repartiteurs de frais de chauffage utilisant la mesure de la temperature de surface des emetteurs de chaleur. June 10, 1983.
Mpls:	"Proposed interim policy on financing of tenant metering systems through City of Minneapolis energy conservation financing programs", Minneapolis Energy Office, November 15, 1985.
OIML2:	Organisation Internationale de Metrologie Legale, 2nd Draft International Recommendation on Heat Meters, July 1984. OIML Reporting Secretariat SP 12- Sr8.
S:	Switzerland, Ordonnance sur les appareils measureurs de l'energie thermique (Ordonnance sur les compteurs de chaleur (draft).
SA:	Ordonnance sur les compteurs de chaleur, appendix for Art 3, line l of the main ordinance (draft).

Notes:

1. References S and SA have subparts some of which are labelled "Article" and some are not, and the subparts are not in numerical sequence.

2. Copies of the foreign language originals or English translations can be obtained from the authors for the cost of reproduction.

Table I. Energy data for nine Minnesota buildings in which tenant metering systems were installed.

a. Energy use, savings, costs and payback.

BLDG ID	PRE NAC[1] CCF	STD ERR	POST NAC CCF	STD ERR	CHANGE IN NAC	%CHANGE IN NAC	BUILDING AREA SQ. FT.	PRE BTU PER SQ. FT.	POST BTU PER SQ. FT.	CHANGE BTU PER SQ. FT.	METER SYSTEM COST	ACTUAL[2] FYS,$	ACTUAL[2] PAYBACK	COMPARATIVE[3] FYS,$	COMPARATIVE[3] PAYBACK	NUMBER OF APTS.	COST PER APT,$	DATE BUILT	ENERGY COST/APT PRE,$	ENERGY COST/APT POST,$
BLR	3520.5	30.7	2761.9	111.1	758.6	21.55	5184	67911	53277	14633	500.00	2063.01	0.24	444.54	1.12	4	125.00	1964	515.75	404.62
TEN	12186.9	415.8	10563.7	259.2	1623.2	13.32	10080	120902	104799	16103	1281.50	7141.52	0.18	951.20	1.35	16	80.09	1957	446.35	386.90
ALD	4876.2	46.3	3859.9	106.5	1016.3	20.84	7200	67725	53610	14115	360.00	2857.45	0.13	595.55	0.60	4	90.00	1927	714.36	565.48
ROC1	16863.7	738.0	13566.0	371.0	3297.7	19.56	26037	64768	52103	12665	2744.30	9882.13	0.28	1932.45	1.42	30	91.48	1975	329.40	264.99
ROC2	13238.7	565.5	11518.6	319.6	1720.1	12.99	25854	51206	44552	6653	2294.30	7757.88	0.30	1007.98	2.28	30	76.48	1978	258.60	225.00
ROC3	13972.3	582.6	12505.3	368.9	1467.0	10.50	25854	54043	48369	5674	2294.30	8187.77	0.28	859.66	2.67	30	76.48	1978	272.93	244.27
SK1	18410.8	521.9	16675.3	256.2	1735.5	9.43	18846	97691	88482	9209	1748.00	10788.73	0.16	1017.00	1.72	19	92.00	1966	567.83	514.30
SK2	6451.9	154.8	5099.8	272.5	1352.1	20.96	7650	84339	66664	17675	460.00	3780.81	0.12	792.33	0.58	5	92.00	1966	756.16	597.70
SK3	5946.7	224.9	4981.1	202.4	965.6	16.24	7650	77735	65112	12622	460.00	3484.77	0.13	565.84	0.81	5	92.00	1966	696.95	583.78
MEAN	10607.5		9059.1		1548.5	16.15		76258	64108	12150	1349.16	6216.01	0.20	907.39	1.39		90.61		506.48	420.78
STD.DEV.	5509.5		4968.7		743.5	4.76		22123	20184	4145	947.19	3228.57	0.07	435.67	0.73		14.58		192.57	151.13

b. PRISM data.[4]

BLDG ID	ALPHA PRE	STD ERR	ALPHA POST	STD ERR	CHANGE IN ALPHA	%CHANGE IN ALPHA	BETA PRE	STD ERR	BETA POST	STD ERR	CHANGE IN BETA	%CHANGE IN BETA	TAU PRE	STD ERR	TAU POST	STD ERR	CHANGE IN TAU	%CHANGE IN TAU	R2 PRE	R2 POST	CV PRE	CV POST
BLR	2.5566	0.2567	1.6405	0.7099	-0.9161	-35.83	0.3424	0.0082	0.2687	0.0306	-0.0737	-21.52	63.13	1.39	65.00	5.20	1.87	2.96	0.9993	0.9741	0.87	4.02
TEN	4.7935	4.0269	4.8012	1.5353	0.0077	0.16	1.0491	0.0653	1.0092	0.0637	-0.0399	-3.80	71.47	5.22	67.43	2.92	-4.04	-5.65	0.9788	0.9891	3.41	2.45
ALD	4.1637	0.5225	2.8053	0.4614	-1.3584	-32.62	0.4129	0.0091	0.4409	0.0351	0.0280	6.78	65.27	1.96	58.59	2.57	-6.68	-10.23	0.9998	0.9914	0.95	2.76
ROC1	12.9000	5.7835	13.3059	2.2165	0.4059	3.15	1.3343	0.1277	1.0844	0.1040	-0.2499	-18.73	68.72	7.02	64.92	3.99	-3.80	-5.53	0.9780	0.9708	4.38	2.73
ROC2	10.6240	3.7107	9.6303	1.8030	-0.9937	-9.35	1.0552	0.1049	1.0927	0.0941	0.0375	3.55	67.91	6.70	62.23	3.32	-5.68	-8.36	0.9853	0.9768	4.27	2.77
ROC3	11.5760	4.3246	12.6403	2.0632	1.0643	9.19	1.0827	0.1058	1.1144	0.1149	0.0317	2.93	68.36	7.16	61.26	3.91	-7.10	-10.39	0.9853	0.9697	4.17	2.95
SK1	9.7895	4.3053	11.4260	1.6652	1.6365	16.72	1.5902	0.0856	1.5386	0.0600	-0.0516	-3.24	69.46	3.86	65.27	1.93	-4.19	-6.03	0.9846	0.9942	2.83	1.54
SK2	4.8164	1.2765	4.5369	1.4249	-0.2795	-5.80	0.5106	0.0254	0.5834	0.0813	0.0728	14.26	69.00	3.55	56.28	4.69	-12.72	-18.43	0.9868	0.9572	2.40	5.34
SK3	5.4055	1.6446	4.3241	1.2354	-1.0814	-20.01	0.4690	0.0391	0.4232	0.0483	-0.0458	-9.77	66.51	5.32	64.96	5.37	-1.55	-2.33	0.9661	0.9533	3.78	4.06
MEAN	7.4028		7.2345		-0.1683	-8.27	0.8718		0.8395		-0.0323	-3.28	67.76		62.88		-4.88	-7.11			3.01	3.18
STD.DEV.	3.7943		4.4996		1.0392	18.13	0.4504		0.4244		0.0957	11.77	2.47		3.61		4.02	5.92			1.36	1.12

Notes:

1. NAC is the total weather-normalized annual gas consumption in therms, determined by applying the Princeton Scorekeeping Method (PRISM) (Fels, 1984) to monthly gas data. 1 therm = 1 CCF = 100,000 Btu.
2. "Actual" first year savings were calculated assuming that the owner passes the entire gas bill on to the tenant without a rent reduction, so that the owner's savings are the entire pre-retrofit gas bill.
3. "Comparative" first year savings were calculated as the change in NAC multiplied by the cost of gas ($.585/therm). This calculation was made to allow comparison with typical energy retrofits, where the owner pays the utility bills both before and after.
4. The parameters in the PRISM analysis are discussed in Fels (1984). Alpha is the base load use. Beta is the heating response factor (energy use per degree day to reference temperature Tau) and Tau is the reference or balance point temperature.

Table II. Existing or proposed regulations dealing with heating cost allocation equipment.

PROVISION	TYPE OF METERING EQUIPMENT: THERMAL METERS	ALLOCATION BASED ON ELECTRONIC SENSING TEMP OF HEATING ELEMENT	ALLOCATION BASED ON AMBIENT TEMPERATURE	ALLOCATION BASED ON EVAPORATION	ALLOCATION BASED ON ON-TIME
1. Definition and operating principle	OIML2:1/DIN4713 Part 1:3.1, Part 4:2.1/S Art 2a, SA 1	DIN4713 Part 1:3.2.1.,3.2.1.2, Part 3:2/JOS Art 1	JOA Art 1,3,4,5	DIN4713 Part 1:3.2.1, 3.2.1.1, Part 2:3/ JOE Art 1	
2. Operating ranges	OIML2:2,3.1/S 2.5,2.6,3.1, SA 2	DIN4714 Part 3:2.3			
3. Allowable Appls. a.htg units		DIN4714 Part 3:1/JOS Art 5,10		DIN4713Part2:1/JOE Art11	
3. Allowable Appls. b.op. cond.	DIN4713 Part 4:3.3,4,4.1	DIN4713 Part 3:1	JOA Art 12	DIN4713 Part 2:1	
4. Accuracy or repeatability	OIML2:3.2, 3.3, 4.1.7/ DIN4713 Part 4:3/ SArt 4, 3.2, 4.17, SA Art 5,7	DIN4714 Part 3:3.1/ JOS Art 9	JOA Art 11	DIN4714 Part 2:2.5, 2.6, 2.7, 3.2, 3.3, 3.5/ JOE Art 6	Mpls B2
5. Susceptibility to disturbances	OIML2:4.2, 7.2/S 4.2, 7.2	DIN4713 Part 3:3.4, 3.6, 4714 Part 3:3.3/JOS Art17.4	JOA Art 19.2	DIN4714 Part 2:3.3	
6. Conversion from measurement to consumption or percentage: General		DIN4713 Part 3:4, 4.5/JOS Art 2	JOA Art 2,8/Mpls B2	DIN 4713 Part 2:2.1,2.2, 5.1, 5.6	
Size of htg elem.		DIN4713 Part 3·4.1/JOS Art 2/ Mpls B2		DIN4713 Part 2:5.2/JOE Art 13,14	Mpls B2
Type of htg elem.		DIN4713 Part 3:4.2, 4714 Part 3: 2.1, 2.2, 2.7/JOS Art 2		DIN4713 Part 2:5.3, 4714 Part 2:2.1,2.2,2.3/JOE Art 13, 14	
Diff. room temp.	NA	DIN4713 Part 3:4.3		DIN4713 Part 2:5.4	
Type of connection		DIN4713 Part 3:4.4		DIN4713 Part 2:5.5	
Volume or area			JOA Art 2, 8		
Heat loss coeff.			JOA Art 2, 8		
Cold evaporation				DIN4713 Part 2:2.3, 4.3 4714 Part 2:2.4	
7. Unfavorable conditions	Mpls 7	JOS Art 12/Mpls 7	NA	JOE Art 13/Mpls 7	Mpls 7
8. Sensor placement and attachment	DIN4713 Part 4:3.4, 4.1.1, 4.1.2	DIN4713 Part 3:3.1, 3.2, 4714 Part 3:7/JOS Art 11	JOA Art 12 (?)	DIN4713 Part 2:4.1/ JOE Art 12	
9. Readout	OIML2:4.1.4, 4.1.5, 5/ S4.1.4, 5		JOA Art 8, 9	DIN4714 Part 2:2.5, 2.6, 2.7, 3.5/JOE Art 14	
10. Construction	OIML2:4.1/S Art 3.1, 4.1.1, 4.1.3	DIN4714 Part 3:3.1.1, 3.3/ JOS Art 6		DIN4714 Part 2:3/ JOE Art 2, 4, 5	
11. Tamperproofing	DIN4713 Part 4:4.1.3/Mpls B2	DIN4713 Part 3:3.5, 4714 Part 3: 3.2/JOS Art 8, 17.5/Mpls B2	JOA Art 19.3/Mpls B2	DIN4714 Part 2:3.4/ JOE Art 7/Mpls B2	Mpls B2
12. Maintenance	DIN4713 Part 4:3.3,5/Mpls 4	DIN4713 Part 3:5/Mpls 4	Mpls 4	DIN4713 Part 2:6/Mpls 4	Mpls 4
13. Test Procedures	OIML2:7.1/S7, SA 10, 11	DIN4714 Part 3:4,5,6/ JOS Art 14, 15, 16, 17, 19	JOA Art 16, 17, 18, 19, 21	DIN4714 Part 4:4,5/JOE Art 9,16,17,18,19,20,22	
14. Certification	OIML2:7.3/DIN4713 Part 4:7, Part 6/S7, SA Art 8, 9, 12	DIN4713 Part 6/JOS Art 4, 18, 20, 21, 22, 23, 24	JOA Art 7,20,22,23, 24,25,26	DIN4713 Part 6/JOE Art 21 23,24,25,26,27	
15. Required Labelling	OIML2:6, S4.1.2, 6	JOS Art 7	JOA Art 10	JOE Art 8	

Figure 1. Baseboard heat output as a function of water temperature and flow rate.

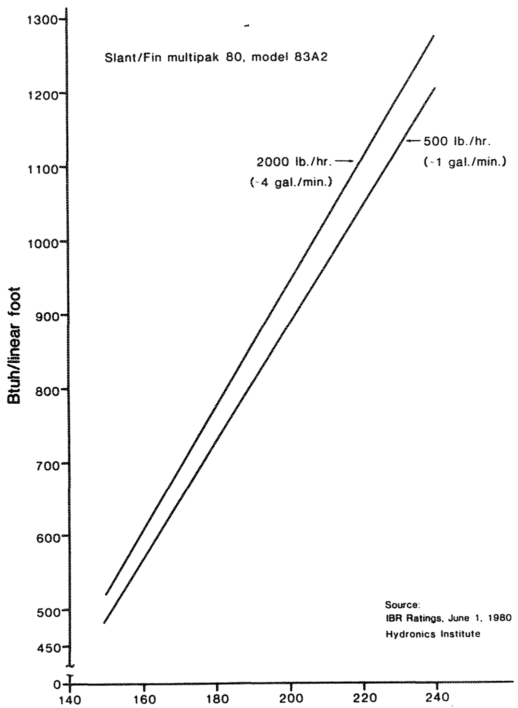


Figure 2. Percent differences in baseboard heat output. for 10 and 20 degree differences in supply temperature.

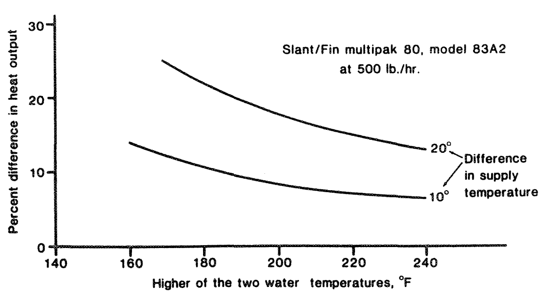
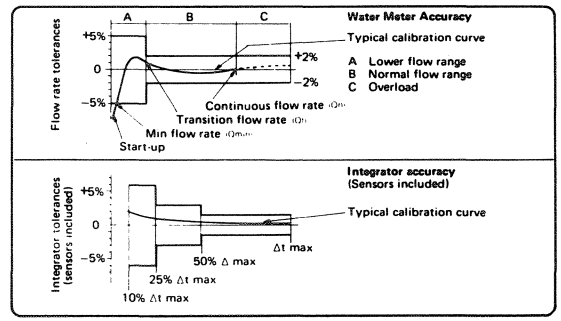


Figure 3. Accuracy data provided by Btu meter manufacturers.

1. Sonceboz Model 323 (note Δt max =180°F)



2. Brunata/USA

Meter provides accuracy of energy use in the following delta T range:

±3½%	Delta T range	8°-20° C.	(15°-36° F.)
±2%	Delta T range	20°-40° C.	(36°-72° F.)
±1%	Delta T range	40°-80° C.	(72°-144° F.)

3. Wilgood Model WHM-1

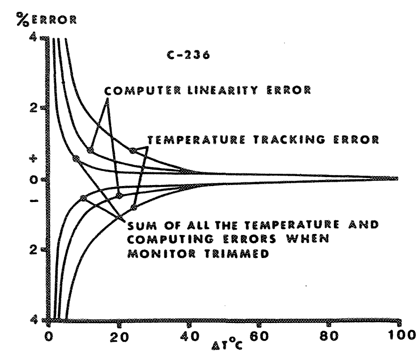


Figure 4. Range in annual meter hours and dollars billed.

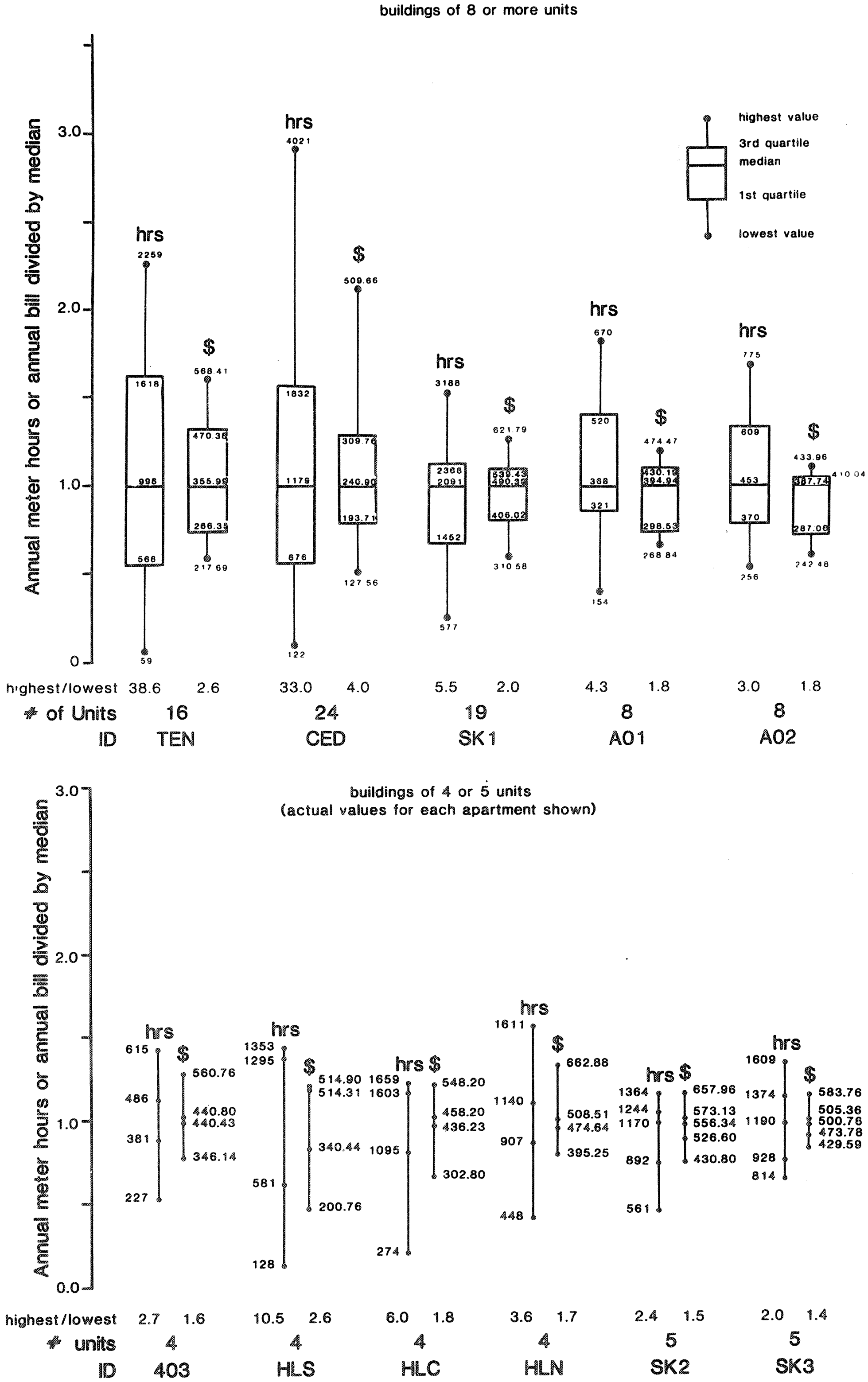
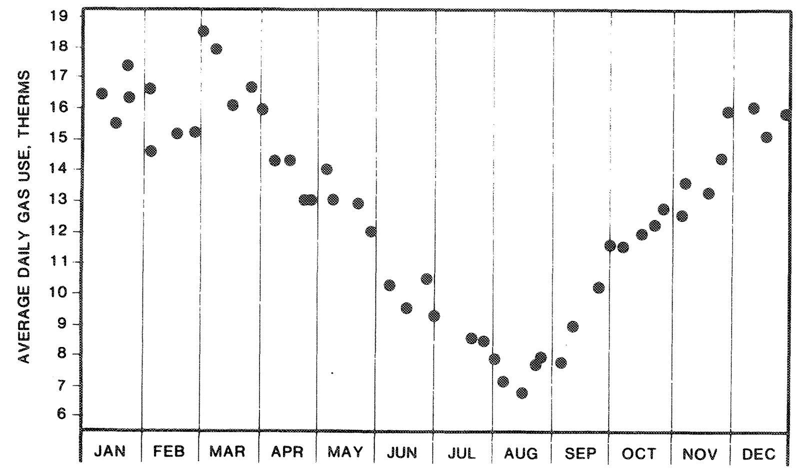


Figure 5. Seasonality of energy use for domestic hot water and of supply temperature

a. Gas use for domestic hot water heating in a Minneapolis apartment building.



b. Minneapolis water supply temperature at treatment plant.

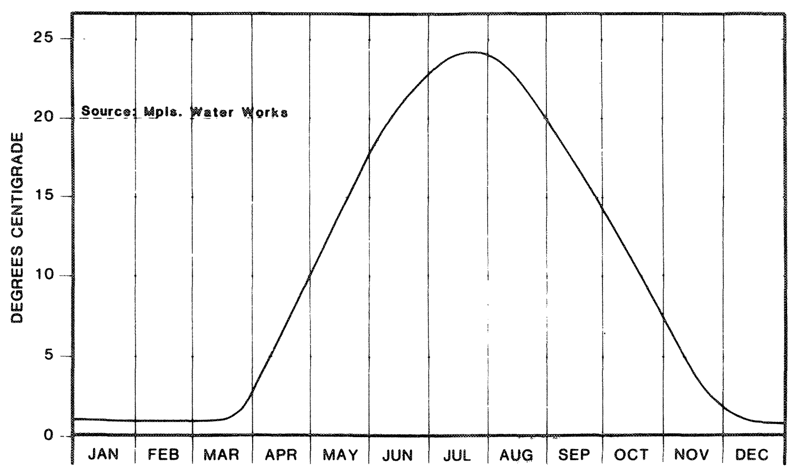


Figure 6. Range in tenant bills for coldest and warmest months.