RESEARCH REPORT

SURVEY OF IN-SUITE SPACE AND DOMESTIC HOT WATER HEATING SYSTEMS IN MULTI-RESIDENTIAL BUILDINGS

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Survey of In-Suite Space and Domestic Hot Water Heating Systems in Multi-residential Buildings

Final Report

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Abstract

This report documents the findings of a study of 9 multiresidential buildings selected for their use of both in-suite heating and air-conditioning systems and in-suite domestic hot water systems. In particular the authors were commissioned to compare stakeholders' evaluations of the performance of in-suite, or decentralized HVAC and DHW systems with buildings equipped with the common 2-pipe fan coil central system. The study is largely based on structured interviews with developers, architects, design engineers, property managers and residents of the buildings.

Key Words:

Multi-unit residential buildings, heating, air conditioning, ventilation, in-suite

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This study of in-suite systems in multi-residential buildings would not have been possible without the generous cooperation and assistance from a number of individuals and companies.

First of all, we owe our thanks to the 29 residents and families who participated in the study in a formal interview. They patiently responded to an hour or more of questions relating to their levels of comfort and satisfaction living with in-suite water heating and HVAC systems. Their input gave us valuable insights on these systems from the ultimate point of view - that of the end user. As promised, we're not publishing residents' names. You know who you are, and we thank you very much.

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- *Space Conditioning and Service Water Heating Options in High-rise Condominium Buildings,* July 2000
- *Vertical Subdivisions – Issues and Challenges, June 1999*

We tried to keep track of every conversation in the course of this study, but we've likely missed some individuals or firms who helped us out. If so, we apologize for omitting direct reference to your contribution and we appreciate your interest and assistance.

Table of Contents

Appendix E - Photographs

Appendix F - Utilities Costs

Appendix G – Data and Information for Buildings in the Sample

Executive Summary

In 1991, CMHC published a research report on building systems. *"HVAC Systems in Multi-unit High-rise Residential Buildings"* was a response to the sense that the heating, ventilating and air-conditioning (HVAC) systems of the day were not living up to performance expectations. The report catalogued the results of a nation-wide field survey of system equipment, identified problem areas and made recommendations relating to technology transfer, demonstration projects and research and development activities.

Since that report was produced, the high-rise multiresidential market has seen an increase in the use of HVAC and domestic hot water (DHW) systems that constitute a marked departure from the traditional central systems (like the 2-pipe fancoil and central water heating) and decentralized systems (like electric baseboards and electric water heater storage tanks).

The newer breed of in-suite systems are:

- stand-alone – in most cases completely independent of any central equipment;
- gas-fired, for both space heating and DHW; and
- almost always individually metered, for both gas and electricity.

This study is based on interviews with developers, design engineers, architects and property managers who are involved in the construction and operation of multi-residential high rise buildings using gas-fired in-suite systems for both DHW and space conditioning. It also draws on the experience of residents living with these systems.

The study's objective was to learn more about these systems - their cost and comfort performance characteristics from a resident's point of view and the advantages and disadvantages of the system from the point of view of the construction and building operations communities. The basis for comparison is the widely-used 2-pipe fancoil HVAC system and central water heating.

Based on a small survey of 9 buildings in Ontario, the study's key conclusions are:

1. High-rise residents of units with in-suite systems generally find they provide a high level of comfort conditions at a reasonable operating cost. They particularly like independent control of conditions in their suite. Two-thirds of occupants say type of system will play a role in the residents' next high-rise move, with in-suite as the system of preference.
2. Architects (who generally don't like *any* mechanical systems) are critical of the design challenge posed by mechanical space consumption in suite, and the aesthetic compromises to the building's exterior caused by various venting arrangements. They agree with residents – the comfort control and operating economics of in-suite systems are a plus.
3. Design engineers are generally indifferent to type of system – central or in-suite. They argue in-suite metering drives more conservative behaviour than what occurs in buildings with central systems, where utility cost is bundled in rent or condominium fees. But, they counter, the rate structures of individually metered accounts result in a higher cost per unit of energy.

4. Property Managers are strong supporters of in-suite systems. Since the occupant owns the equipment or rents it from the gas utility complaints to the manager relating to space conditioning or water heating virtually disappear. There are no central systems to look after, apart from the rooftop packaged ventilating units for the common areas of the building.
5. Developers install in-suite systems in response to market demand for the lowest possible rents and condo fees, and improved control over comfort and occupancy costs. Compared to bulk metered buildings with central systems, individually metered suites reduce gas and electricity bills for the common areas by at least half. Most importantly, gas utility equipment rental programs significantly reduce the capital cost of construction. In spite of this, some major developers are moving back to 2-pipe fancoil systems. Others are going with an in-suite gas-fired furnace but central water heating. The water loop heat pump system (a hybrid HVAC system using individual and central system components) was not part of the scope of this study, but was frequently cited as a system attracting more attention in the developer community.

This report makes the following recommendations:

- Operation and maintenance guides for in-suite systems, aimed at renters and condominium owners should be developed.
- Research should be conducted on the market penetration of in-suite systems in Canadian high-rise construction, and the reasons for any change in popularity trends.
- The life-cycle cost of gas-fired in-suite systems should be more thoroughly explored.
- Gas utilities should be consulted to gather insight on the value of in-suite equipment rental programs and the likelihood of continued support by the utilities.

Résumé

En 1991, la SCHL publiait un rapport de recherche sur les installations mécaniques des bâtiments intitulé « *HVAC Systems in Multi-unit High-rise Residential Buildings* ». Elle réagissait ainsi au sentiment généralisé à l'effet que les systèmes de chauffage, de ventilation et de climatisation (CVC) de l'époque n'offraient pas une performance à la hauteur des attentes. Ce rapport présentait les résultats d'une enquête nationale menée sur le terrain au sujet des composants des installations mécaniques, signalait les problèmes et formulait des recommandations en matière de transfert technologique, de projets de démonstration et d'activités de recherche et de développement.

Depuis la parution de ce rapport, le marché des tours d'habitation a vu apparaître un nombre croissant d'installations CVC et de chauffe-eau qui se démarquent nettement des traditionnelles installations centrales (comme les ventilo-convecteurs bitubes avec chauffage central de l'eau) et des systèmes décentralisés (comme les plinthes électriques et les chauffe-eau électriques).

Pour les appartements, il existe désormais un nouveau genre d'installation individuelle :

- elles sont autonomes – dans la plupart des cas, elles sont complètement indépendantes de tout équipement central;
- elles fonctionnent au gaz pour le chauffage de l'eau et des locaux;
- elles sont presque toujours associées à un compteur individuel, tant pour le gaz que pour l'électricité.

L'étude dont il est ici question repose sur des entrevues menées auprès de promoteurs, d'ingénieurs d'études, d'architectes et de gestionnaires immobiliers participant à la construction et à la gestion de tours d'habitation faisant usage d'installations individuelles au gaz tant pour le chauffage des locaux que pour la production d'eau chaude. Elle met aussi à contribution l'expérience acquise par les résidents utilisant ces systèmes.

L'étude avait pour objectif de jeter davantage de lumière sur ces systèmes afin d'en savoir plus sur leur coût et leur performance au chapitre du confort, et ce, du point de vue des résidents. Elle devait en outre faire ressortir les avantages et inconvénients de ces installations dans l'optique des responsables de la gestion de la construction et des bâtiments. Les auteurs ont utilisé, comme base de comparaison, l'installation CVC très courante à ventilo-convecteur bitube et à chauffe-eau central.

Voici donc les principales conclusions de l'enquête qui reposent sur un petit échantillon de neuf bâtiments situés en Ontario :

1. Les occupants de grands immeubles d’appartements dotés d’installations individuelles estiment généralement qu'elles procurent un haut niveau de confort à un coût d’utilisation raisonnable. Ils apprécient particulièrement la régulation autonome des conditions ambiantes de leur logement. Les deux tiers des occupants affirment que le genre d’installation mécanique aura une incidence s’ils ont à déménager dans une nouvelle tour d’habitation, et ils accorderont la préférence à des immeubles offrant des installations individuelles.

2. Les architectes (qui, en général, n'aiment pas beaucoup les systèmes mécaniques, *quels qu'ils soient*) se montrent critiques à l'égard des défis conceptuels créés par l'espace qui doit être prévu pour l'équipement individuel et à l'égard des compromis d'ordre esthétique touchant l'extérieur des immeubles et rendus nécessaires à cause des mesures que l'on doit prendre pour ventiler les appareils. Ils sont d'accord avec les résidents sur l'avantage que représentent les économies d'utilisation et la possibilité de régler soi-même les conditions de confort au foyer.
3. Les ingénieurs d'études n'ont généralement pas d'opinion tranchée quant au type d'installation à privilégier (centrale ou individuelle). Ils prétendent que la facturation individuelle incite les occupants à se soucier davantage de la conservation que dans les immeubles équipés d'installations centrales où les coûts relatifs aux services publics font partie intégrante du loyer ou des charges de copropriété. Ils font toutefois remarquer que la structure tarifaire des services publics pour les comptes individuels entraîne des coûts plus élevés par unité d'énergie.
4. Les gestionnaires immobiliers sont très en faveur des installations individuelles. Comme l'occupant est propriétaire de l'équipement ou le loue au fournisseur de gaz, les plaintes adressées au gestionnaire relativement à des problèmes d'eau chaude ou de conditionnement d'air sont pratiquement chose du passé. On n'a plus à s'occuper d'un système central, sauf les groupes de ventilation autonomes placés sur le toit pour conditionner les aires communes du bâtiment.
5. Les promoteurs optent pour des installations individuelles afin de répondre à la demande d'une clientèle qui exige les loyers et les charges de copropriété les plus bas possible et qui souhaite pouvoir mieux maîtriser les éléments de confort intérieur de même que les frais d'occupation. Comparativement aux bâtiments à système central dont la consommation d'énergie est mesurée pour l'ensemble des occupants, les immeubles munis de compteurs individuels affichent une facture de gaz et d'électricité réduite au moins de moitié pour les aires communes. Qui plus est, les programmes de location d'équipement offerts par les compagnies de gaz abaissent énormément les coûts en immobilisations de la construction. Malgré tout, certains grands promoteurs reviennent aux systèmes à ventilo-convecteur bitube. D'autres choisissent d'installer des générateurs de chaleur individuels au gaz, mais conservent le chauffage de l'eau centralisé. La pompe à chaleur pour le chauffage de l'eau sanitaire raccordée à une boucle de circulation d'eau (un système CVC hybride faisant appel à des composants individuels et centraux) n'a pas été considérée par la présente étude, mais a souvent été mentionnée parmi les systèmes recevant la faveur d'un grand nombre de promoteurs.

Les auteurs formulent les recommandations suivantes :

- Élaborer des guides d'utilisation et d'entretien pour les installations individuelles à l'intention des locataires et des copropriétaires.
- Mener des recherches sur les percées réalisées sur le marché par les installations individuelles dans le secteur canadien des tours d'habitation, et faire état des raisons qui motivent tout changement de tendance en regard de leur popularité.

- Le coût global d'une installation individuelle fonctionnant au gaz devrait être examiné plus à fond.
- Les compagnies de gaz devraient être consultées afin de réunir de l'information sur la valeur des programmes de location d'équipement et sur la probabilité que les entreprises de service public maintiennent cet appui.

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Introduction

Multi-residential high-rise construction has seen two common approaches evolve over the last few decades to providing space heating, air-conditioning (optionally) and Domestic Hot Water. Of course there are variations on these themes, but generally they were:

1. **Decentralized, in-suite systems.** Electric baseboard heating, with either in-suite electric water heaters or a central water heating system. If they wanted air-conditioning, residents had the option of installing their own window-mount units;
2. **Central systems.** 2-pipe fan-coil hydronic system or hydronic baseboard using gas-fired boilers, a chiller if air-conditioning is required, with a central gas-fired DHW system.

Since CMHC's research report on apartment building systems *"HVAC Systems in Multi-unit High-rise Residential Buildings"* was published in 1991, a number of drivers have come into play creating a need for more information on in-suite, *gas-fired* systems.

- The upward trend in energy cost, and the volatility of electricity and natural gas in deregulated jurisdictions, has generated more owner interest in assigning utility cost to the occupant;
- Energy price trends have created a market perception that natural gas offers a higher value proposition; gas has become a "fuel of choice" for many developers;
- Changes in local and national building codes and municipal regulations are enabling greater flexibility in the distribution of gas lines throughout a multi-residential building;
- Gas utilities have been promoting leasing arrangements for gas-fired water heaters, furnaces, clothes dryers, and fireplaces.
- A range of combinations of gas-fired mechanical equipment for providing heating, air-conditioning and domestic hot water is emerging giving the design team more flexibility.
- The huge growth in popularity of the high-rise condominium has created a market demanding low common area fees, greater individual control over their space comfort conditions and independence of their neighbours' needs and behaviour.

The benefits of decentralized in-suite systems that provide gas-fired heating and domestic hot water seem fairly predictable:

- The metering of consumption of both gas and electricity enables allocating the cost of monthly bills to the occupant and lowering their rent or condominium fees;
- Developers have a gas-fired alternative to electric in-suite systems, responding to the market perception that gas is the cheapest way to heat space and water;

- With gas utilities offering appliance rental programs, including those for water heaters, the developer's first cost for heating and DHW systems is sharply reduced.
- The maintenance, and the need for "seasonal changeover" from boiler to chiller associated with 2-pipe central systems disappear;
- Occupants have control over their comfort conditions independent of a central system;
- Occupants have greater control over their bills – conservative users who would be subsidizing their neighbours in a building with central systems pay lower utility bills.

But what are the costs and space requirements associated with in-suite system? Do they deliver the operating and maintenance savings anticipated by developers, owners and property managers? To what extent are residents satisfied with their comfort conditions? Do they understand what they've purchased and how it operates? Do they find ownership and maintenance of equipment a burden? What are the trades and construction implications for pipe routing, combustion air and exhaust ducting? Are fire or liability insurance premiums affected?

There's lots of evidence gas-fired HVAC and DHW systems are a viable alternative to electric baseboards and conventional central systems – at least in some markets. But CMHC believes the shortage of information on the current status of these systems in Canada curtails a meaningful and enlightening debate.

This study is based on interviews with developers, design engineers, architects and property managers who are involved in the construction and operation of multi-residential high-rise buildings using in-suite systems for DHW and space conditioning. It also draws on the experience of residents living with these systems. As end-users, they know any differences between promise and delivery.

CMHC's objective is to draw some conclusions about in-suite systems from both major stakeholders - the construction community and the building occupants – specifically in comparison to similar buildings using central systems. If there's a clear "winner" here, which is it, and why has only a small portion of the market gone the in-suite route? And if it's not clear across the board which system best serves the needs of builder and resident, then what are the determining factors in selecting one over the other for both stakeholders?

Organization of this Report

The body of this report defines the various in-suite systems under consideration, and the base case against which we'll make performance comparisons. We describe our methodology, a summary by stakeholder of our findings through interviews and building visits, and make general conclusions.

There are a number of questions we haven't been able to answer absolutely. A few of these were part of our original scope of work: we simply couldn't reach a definitive conclusion on some issues, or couldn't get supporting data. Some new questions have come out of discussions in the many interviews we've conducted. And, there were clearly divided opinions on some topics. These are also explored.

The report's appendices contains information on the sources of information for the study, desired building characteristics, heating system schematics, capital costs, photographs of the systems and buildings reviewed, utility costs and detailed profiles for each building in the survey. We've kept the specific identity of a building, its address and the names of all participants confidential.

Purpose of this Study

This study compares the features, advantages and disadvantages of gas-fired in-suite HVAC and DHW systems in high-rise multi-residential buildings compared to similar buildings using central systems – specifically the popular 2-pipe fancoil system, with central DHW. The target readership is the construction and design communities who may benefit from the experiences of some of their colleagues in relation to in-suite systems and reactions from residents in the high-rise condo and rental market. Tenants' groups, and associations representing condominium corporations interested in the operation, maintenance and economics of in-suite systems will also find valuable information in this report.

Methodology

This study is based on collections of data, long engineering experience with multi-residential systems, and studies conducted by other organizations. The cornerstone to a report we feel is well grounded in reality, however, is interviews (some formal, some not) with scores of individuals in the construction communities and in the target market for multi-residential living – residents.

Finn Projects' original project design to conduct a study comparing in-suite systems to central comprised these steps:

Step 1:

Clearly define and describe the gas-fired, in-suite space and Domestic Hot Water (DHW) systems under consideration. Where there was potential for ambiguity, define those systems *not* under consideration. Define and describe the comparison base case.

Step 2:

Develop a comprehensive wish list of what we want to know. "Hard" data requirements included:

- Annual (by month) energy use and costs by suite and total building, gas and electricity.
- Developers' capital costs (installed) compared to the base system.
- Operating and Maintenance costs.
- System components and specifications.

"Soft" or anecdotal information we required included:

- Developers' reasons for specifying in-suite systems in their projects; their conclusions on this approach as a means of building a cost-competitive product; their experience marketing in-suite high-rises versus central system buildings.
- Operating and Maintenance considerations from the perspectives of condominium corporations and property management companies.

- Mechanical design considerations – envelope penetration, handling of combustion air and exhaust, trades implications, commissioning requirements, and any incremental design work compared with a central system in the same building.
- Architectural considerations – space use and layout, requirement for bulkheads, dropped ceiling and valences to conceal ductwork, multiple envelope penetrations, building aesthetics, etc.
- Metering approaches (bulk and individual suite metering) and accountability for payment, reaction from tenants, condominium corporations.
- Levels of satisfaction of building owners, property managers.
- Occupants' assessment of their *comfort conditions* – space heating, cooling and water heating and their sense of the extent to which their systems deliver value (service calls, utility bills).
- Occupants' understanding of their HVAC and DHW systems and how they operate.
- CO, CO2 monitoring, general safety considerations.
- Insurance implications.
- Financing vehicles – from manufacturer, utility, leasing companies. Their impact on system selection for the developer, and what effects this has on the residents.

Step 3:

Write a clear specification for the buildings that qualify for the study (**Appendix A**). Obtain a list of candidate buildings for the study group, and solicit owners' cooperation.

Sources of information on buildings include:

- Manufacturers
- High-rise developers
- Gas utilities

Step 4:

Design interview questionnaires to accurately capture input from stakeholders: occupants, property managers, developers, architects and mechanical engineers.

Step 5:

Conduct the information gathering. Obtain billing histories from utilities and occupants.

Step 6:

Consolidate the information gathered in a report containing a section of data for each building in the study group, plus a section on our general conclusions.

Our next issue was getting people to talk to us. It was far more difficult than we had anticipated getting developers and property managers, in particular, to give us an hour of their time. Occupants – particularly in Toronto – were not readily willing to open their doors to a stranger who wanted to ask questions about their space and water heaters. In

the end, however, this situation may have helped us: the individuals we were able to meet with – from the construction communities to condo corps to residents - were truly interested in the in-suite concept and were very generous with their information.

Scope

Building Search

Our plan was to shop the specification in the table below in centres across the country to get a regionally diversified group of buildings that met our criteria, shown in the table below.

Size	3 floors minimum, the larger the better
Type	Rental or condominium units
Age	Minimum 3 years, to get billing history and usage experience
Occupant profile	Families and couples, typically (avoid special needs like retirement or nursing homes)
Space Heating	In-suite space heating system, gas-fired, individually metered
Air-conditioning system	In-suite
DHW system	In-suite DHW system, gas-fired
Energy Metering	Each residential unit individually metered for gas and electricity Single bulk meters for common area gas and electricity
In-suite systems *excluded* from the study	Water-loop heat pump systems

We set up engineering partnerships in Halifax, Ottawa, Winnipeg, Calgary and Vancouver to complement our team in Toronto. Our first difficulty was encountered in trying to locate qualified buildings across the country.

In Eastern Canada, oil and electricity are the energies of choice, and in-suite systems, if they exist in any multi-residential buildings at all, are rare. Several high-rise buildings in Ontario meet our specification for gas-fired in-suite heating and air-conditioning, but the addition of in-suite water heating narrowed our choices considerably. The few buildings in Manitoba and Alberta we short-listed turned out to have central hot water systems. We were able to locate one mid-rise in Vancouver that met spec. After agreeing to participate, the condo corporation withdrew from the study due to a dispute with the property management company (unrelated to HVAC and DHW systems, but it made the timing inappropriate).

On the one hand, we were disappointed we failed to get more regional diversity in our sample. On the other, it was revealing that many large urban centres in Canada don't have, for whatever reasons, a situation that encourages consideration of in-suite systems – at least as we defined it.

In the end, we settled on 9 buildings in Ontario that met our search criteria with these characteristics:

Building ID	Type	Age	Number of floors	Number of residential units
1	Condo	8	11	105
2	Condo	4	12	156
3	Condo	4	4	46
4	Condo	1	4	87
5	Condo	6	6	150
6	Condo	7	4	216
7	Rental	6	3	15
8	Rental	7	4	84
9	Condo	5	26	203

The HVAC Base Case – "2-Pipe Fancoil"

We don't know the exact extent to which the central system known as 2-Pipe Fancoil dominates Canadian high-rise multi-residential construction. But its popularity in a wide range of buildings in a diversity of markets ranging from public housing to luxury condominiums justifies its selection as the basis of comparison for this study. Readers of this report will be familiar with this HVAC system.

Here are the system's main characteristics:

1. The 2-pipe fancoil is a *central* hydronic system, comprising boiler (usually natural gas-fired when this fuel is available), electric chiller, and a closed loop of pipe filled with water that serves as heat source when connected to a boiler, and heat sink when connected to a chiller. A centrifugal pump constantly circulates the water in the loop.
2. The two pipes referred to in the system's name are the supply and return lines in the water circuit. The loop is distributed throughout the building in vertical risers in a layout designed to lower first cost, optimize economy of operation and balance flow to every suite in the building. (A third pipe provides drainage for condensed water vapour on the cooling coil.)
3. A vertical fan-coil unit is the distribution terminal in the suite. This is a sheet-steel box containing a fan to draw return air through a filter and push it across a copper or aluminum-finned coil tapped into the supply and return risers. Heat is conducted to or from the air moving through the coil depending on the temperature of the water flowing through the coil. The temperature of the water in the coil is controlled by a 3-way valve that mixes more or less supply (hot or cold) and return water (less hot or less cold) through the coil.
4. Temperature control in the suite is achieved through a wall mounted, low voltage thermostat. The thermostat sends two signals – one for position change in the 3-

way valve across the heating/cooling coil, and one to select the appropriate fan speed.

5. The conditioned air is discharged horizontally into the space near the ceiling, typically into a living room on one side of a partition and a bedroom on the other. The fancoil unit is located in a closet on an exterior wall to offset the heat loss of the suite through the building envelope. Short runs of ductwork may be included in a valance or dropped ceiling to reach rooms in larger suites or in non-standard floor plans.
6. The 2-pipe fan-coil system is in one of 2 modes at any given time of year: heating or cooling. The boiler is connected to the loop in the fall – typically October 15th and disconnected in mid-April to accommodate the connection of the chiller. This "seasonal changeover" means residents have no heating before and after certain dates in the fall and spring, when there are large fluctuations in temperatures throughout the day. Most fan-coil units are equipped with electric resistance heaters to provide supplemental heat during the changeover. There is no provision for supplemental air-conditioning.
7. The only energy sources brought to the fan-coil in the suite are electricity (for fans and controls) and the heat (or "cool") in the water loop. There is no in-suite combustion.
8. Natural gas is brought from the main gas line to the building, metered at the point of entry, and piped to the various burners, including heating boilers, DHW boilers, and Make-Up Air (MUA) units. All combustion takes place in the mechanical room, usually located in a penthouse on the roof or in the MUA units.
9. Residents in buildings using 2-pipe fan-coil and central DHW systems may or may not pay their own electricity bills, depending on whether individual suite meters are installed. They do not pay their own gas bill. The building is bulk-metered for electricity and natural gas. Any consumption costs not captured by suite meters, if they exist, are recovered through monthly condominium fees or rent.

The DHW Base Case

Domestic Hot Water in a multi-residential building using a 2-pipe fan-coil system is almost always provided by one or more central boilers connected to insulated storage tanks. The storage tanks are connected to a supply/return distribution loop routed to all suites. A centrifugal pump provides constant circulation of the hot water in the insulated loop. Circulation is a requirement of central hot water systems; otherwise residents would experience long delays in getting hot water from heater to the tap, depending on the distance from the suite to the HW storage tank. The DHW boilers and circulation pumps are often located in the penthouse, but could also be in the basement or a ground floor service room. with the central HVAC equipment.

Central DHW is the system against which we compare decentralized in-suite systems in our study.

In-suite Systems Description – Heating, Air-conditioning and DHW

Our direction from CMHC was to confine our investigation to buildings using *in-suite* mechanical systems for *both* space conditioning (heating, and optionally, cooling) and Domestic Hot Water. Our operational definition of "in-suite systems" in this report never contemplates a central hot water scheme, and includes only natural gas-fired equipment.

Gas-fired in-suite systems in multi-residential applications have a variety of equipment, manufacturers and setup arrangements, but they have these characteristics in common:

1. They're forced-air systems, using an Air-Handling Unit (AHU) containing at a minimum a return-air side with a filter, a fan, and heat exchange surface(s).
2. Domestic hot water is provided by means of a storage tank heater or an on-demand "instantaneous" heater. Both types of equipment are usually power vented, and sometimes use sealed combustion.
3. Natural gas is piped directly to a mechanical closet *in the suite.* The gas meter is located in the same closet. Depending on the equipment characteristics, the mechanical closet may be located against an exterior wall or within the suite. If space allows for this, interior mechanical rooms are often combined with household storage and/or laundry facilities.
4. Gas is burned in the equipment, in-suite, to create heat for space conditioning and Domestic Hot Water (DHW) for the kitchen and bathrooms.
5. There is provision for the intake of combustion air and the venting of combustion gases laterally or vertically .
6. Space is heated by fan-driven warm air distributed in the apartment through ducts terminating in diffusers.
7. Space is cooled (optionally) by means of a cooling coil in the air-handling unit. The cooling coil can be the evaporator component of a mechanical cooling system. In this case it absorbs heat from the air in the AHU and rejects it through a compressor/condenser component located on a balcony, on the roof or in a niche in an exterior wall. The cooling coil could also be a part of chilled water loop connected to a heat rejection scheme that could include chiller and cooling tower. In any case, cool air is distributed using the same system of ducts and diffusers used by the heating system.
8. A return air plenum and louvre ensures a dedicated route for air in the suite to get back to the air-handling unit, and provides for insertion of an air filter in the return air path.
9. While cooling mode extracts moisture from the air and reduces relative humidity, there is no provision in the system to add humidity.
10. A low-voltage thermostat, mounted on an interior wall in the suite provides for setting of the desired space temperature, and selection of cooling mode, heating mode, or "off". It is not normally programmable.
11. Electricity consumption within the suite is metered in a closet in the corridor. Several meters are grouped in one meter closet, which typically serves 2 or 3

floors. Residents of buildings using in-suite heating, cooling and DHW systems almost invariably pay their own electricity and gas bills.

12. A drain in the floor of the mechanical closet provides egress for condensate from the cooling coil and combustion chamber, or any leaks in the heating or DHW systems due to joint or valve failure or pressure relief through a PRV.

To facilitate the discussion of systems with various combinations of equipment, we've sorted them into 3 categories of in-suite system arrangement. The categories describe the types of systems encountered in the survey of 9 buildings: there are other configurations – see footnote to Type 2. Our categories are indifferent to manufacturer, although certain makes of equipment invariably show up in a specific category. Category numbers denote nothing more than differentiation – no value or popularity of system is implied.

Type 1

Heating: Return air fan-driven through *hot water coil* in AHU.

Cooling (optional): Return air fan-driven through cooling coil (evaporator) in AHU.

DHW: Heater/storage tank, *shared* with space heating. (Known as the "combo" system.)

Type 2

Heating: Return air fan-driven over a steel heat exchanger that separates the burner and exhaust gases from the heated air going to the space. The heating configuration is very similar to a residential forced-air gas furnace. The packages encountered in the survey also included the air conditioner - compressor, condenser and evaporator.

Cooling: Return air fan-driven through cooling coil (evaporator).

DHW: Heater/storage tank, *separate* from space heating.[1]

Type 3

Heating: Return air fan-driven through hot water coil supplied by on-demand water heater (no storage) *dedicated* to space heating, and separate from DW heating

Cooling (optional): Return air fan-driven through cooling coil (evaporator)

DHW: Separate from space heating, supplied by on-demand water heater (no storage). The on-demand water heaters for both space heating and DW heating are in the same packaged unit, with controls to select space DHW heating, or DHW heating AND space heating.

[1] There are also packages that integrate heating, cooling *and* DHW in the same cabinet, such as Lennox's Complete Heat™ product.

The table below shows the characteristics of the buildings in the sample:

Building ID	Hot water heating coil in AHU	Direct fired SS heat exchanger in AHU	Heating and DHW share same source	Heating and DHW have separate sources	Tank type Water Heater/ storage for space heating	Tank type Water Heater/storage for DHW	On-demand water heater for space heating	On-demand water heater for DHW	Cooling coil in AHU	Split system cooling	Compressor/condenser/evaporator in AHU	Low velocity air	Hi velocity air delivery	Equipment leased from gas Utility	Type
1		✓		✓		✓			✓		✓	✓		✓	2
2	✓		✓		✓	✓			✓		✓	✓		✓	1
3	✓			✓			✓	✓	✓	✓		✓		✓	3
4		✓		✓		✓			✓		✓	✓		✓	2
5	✓		✓		✓	✓			✓	✓		✓		✓	1
6		✓		✓		✓			✓		✓	✓		✓	2
7	✓		✓		✓	✓						✓		✓	1
8	✓		✓		✓	✓						✓		✓	1
9	✓		✓		✓	✓			✓	✓			✓	✓	1

Findings

Information-gathering: Questionnaires and Billing Data Requests

Finn Projects designed separate questionnaires for:

- Residents
- Multi-residential developers
- Multi-residential property managers
- Architects, and
- Mechanical design engineers.

The intent of the questionnaires was to facilitate collection of the information we wanted (outlined in Step 2 of methodology above) as efficiently as practical, and collect it in a systematic, standardized manner. To minimize handwriting labour, encourage conversational discussion and provide as accurate a replication of the information as possible, most of our interviews were recorded, with the prior consent of the respondent.

We assured all respondents – particularly residents – we'll ensure the confidentiality of their information; the names and addresses of individuals, or the specific location of their building is not divulged to third parties other than employees of Finn Projects and CMHC.

In order to obtain 2 years' billing history from residents for their suite consumption and building management for the common area consumption, we prepared release letters that when signed by the appropriate individual, authorized the utilities' billing departments to send spreadsheets of consumption and cost directly to Finn Projects' office. Some occupants felt this request was too invasive of their privacy, and refused to sign.

The table below summarizes, by building, the number of the formal interviews conducted. Our target number of interviews for each building was one each of developer, architect, design engineer and property manager, and 6 occupants. Finn Projects encountered resistance to participating in a formal interview from some members of all stakeholder groups, and we fell short of our target number of interviews. We believe, however, we obtained a great deal of very valuable information from the individuals who did participate. In addition the shortfall in numbers of formal interviews was offset by the many informal conversations we had with mechanical suppliers and other members of the multi-residential design and construction network.

Building ID	Developer	Architect	Design Engineer	Property Manager	Resident
1	1	1	1	0	1
2	1	1	1	1	4
3	1	0	0	1	5
4	1	0	1	1	1
5	1	1	1	1	5
6	0	1	1	0	3
7	1	0	0	1	1
8	0	1	1	1	5
9	0	1	1	0	4
Totals	**6**	**6**	**7**	**6**	**29**

Notes:

1. Buildings 4 and 5 were built by same developer.
2. Building 1's developer and architect was the same individual.
3. The same mechanical engineer designed Building 6 and Building No 1.

There are two rental buildings in the audited sample. One is owned by a cooperative, the other by a developer. The remaining 7 buildings are condominiums. In both cases – tenants and condo owners - residents rent in-suite equipment from the gas utility – water heaters, and in one case a furnace - and pay rent on their monthly gas bills.

In order to provide the reader with some quantitative context for stakeholders' view of in-suite systems, we've summarized the findings from our interviews in a few key questions for each stakeholder group. The key questions and the response summary appears at the end of each stakeholder section.

Occupants

General

Renters and condominium buyers do not – at least not yet, anyway – typically ask a lot of direct questions about the HVAC and DHW system in their prospective living units. Particularly among condo buyers, however, there's a marked interest in monthly fees: how much and what's covered. Some members in the multi-residential market still like the idea of the "utilities included" concept. But it's our feeling a growing majority – especially among residents with living experience in more than one high-rise – value individual control over their bills and space comfort, and include these as part of their selection criteria for a living unit.

In 29 formal interviews, 22 residents said type of HVAC and water heating system would play a role in their next move to a multi-residential building. All other things being equal, they expressed a preference for in-suite systems for the controllability of the conditions in their suite, independence of a central plant, and accountability for their own utility bills.

The majority of residents we spoke to are generally satisfied with the comfort conditions their in-suite systems provided. They're very aware of the benefits, and articulated them clearly and repeatedly during interviews:

- They get control of conditions in their suite independent of their neighbours' requirements.
- They can heat or cool at any time in all seasons. (Residents who had lived in central-system high-rises all recalled the discomfort of "seasonal changeover".)
- They get as much hot water as they need, whenever they need it.
- They're rewarded for conservative behaviour because they're paying for the consumption inside their living space.
- They believe the electricity and gas utilities give good service for a reasonable price.
- Residents' maintenance obligations amount to periodically changing a filter, and are not seen as a burden.
- They do not see the routing of gas lines throughout their building as posing any incremental risk of fire, explosion, CO or CO_2 poisoning.
- Noise, from condenser/compressor units, AHU fans and pumps or air moving through diffusers was generally not a concern to our residential respondents.

On the basis of our interviews, we conclude in-suite HVAC and DHW systems are effectively serving the basic comfort needs of residents and deliver clear additional benefits the market values. Under today's conditions, we predict in-suite systems – in particular heating and air-conditioning - will increase their share of the multi-residential market.

This having been said, let's get closer to the ground and examine some of the issues around living with in-suite systems.

Residents' training on the use of their systems

We conclude occupants of suites using in-suite HVAC and DHW are generally left to their own devices in determining how their systems work, and how to keep them in good operating condition.

The thermostat is simple enough: a "Heat", "Cool" and "Off" switch, and a slider to set the temperature control point. (Only one building in the survey used programmable thermostats to control in-suite systems. Installation literature from the natural gas utility recommends that programmable thermostats not be used for "combo" type systems)

Residents know there's an air filter, and that it needs periodic replacing, but have a wide range of notions about how often. Estimates ranged from once a month to once every 3 years. In one building in which filter changes were made difficult due to limited access space, we observed in 2 instances the filter taped over the return air grille, leaving all kinds of other paths for unfiltered return air to go through the AHU. These residents complained the system was "dirty". Our auditors observed significant dust build-up in the diffusers of these systems. The same residents commented their suites were cold, or unevenly heated during the winter months.

In combo systems using a storage type water heater, residents invariably change the thermostat setting on the base of the tank when they want to change the temperature of the water at the tap. They believe this has the desired effect on hot water temperature. We know turning this control *down* lowers the rate of heat delivery to the AHU and effects a corresponding decrease in power in the heating system. It will have little or no effect at the tap. The control that's designed to regulate water temperature in the kitchen or bath is a 3-way tempering valve, installed to prevent scalding[2]. .

While all Type 1 (combo) buildings in the survey had this control valve installed, not one occupant we interviewed understood its function); most had never noticed it before. In one luxury 3-bedroom suite, the owner had never been able to draw a full bath before running out of hot water. We estimate the temperature at the tap (after running 3 minutes) at around 105°F. Our guess is the tempering valve was either defective or set too low.

The system residents seemed to understand most clearly is the Type 2 system, in which heating and air-conditioning are performed in one box, and water heating in another separate device. We can suggest 2 possible reasons for this. One, the system is similar in design and operation to those common in single-family houses and townhouses. Two, (at least in the two Type 2 buildings we audited) the maintenance was easy and accessible. As for the other types of in-suite systems, both of which utilize rental equipment, we

[2] The anti-scald valve (Sparco™) provides a buffer between the hot water in the storage tank (140 – 150 degrees F for optimum space heating power) and the hot water that goes to the taps. Clearly marked and fully adjustable, it tempers tap water to a safer range of 120 degrees and lower by mixing outgoing hot with incoming cold water.

wonder if the unlimited service provided by the gas utility tends to reduce the need for a lot of occupant knowledge about their system.

We recommend tenants and owners be provided with a booklet on system components and basic operating and maintenance procedures for various types of in-suite systems. The booklet should include simple graphics, step-by-step procedures, possible component replacement alternatives, and reference to other resources to find regional parts and service.

Preventative maintenance and servicing

In all system types, we observed a wide range of care in installation and design consideration given to maintenance and servicing. In the worst cases, changing the filter was either impossible or required a determined contortionist. (One return air plenum was marked "no filter installed", and it was clear no filter *could* be installed).

Our auditors were mystified in some instances as to how a pump or fan in an AHU could be reached for service. We concluded the system was installed and the closet built around it. This was a characteristic of one particular building in the survey, as indicated through discussions with management and occupants, and by our auditors' observations. Four of five suite visits revealed difficult access for maintenance in this building.

In mid-rise buildings of up to 6 stories, the compressor/condenser unit for air-conditioning is located on the roof or on wall brackets in the parking garage. (This design intentionally gets the condenser off balconies for noise and space considerations.) Roof access is by hatch and ladder.

In higher buildings the A/C unit was built into a niche on an outside wall, with access from the inside through a panel in a bedroom closet. The advantage is quiet operation, but the unit is so completely out of sight and mind owners aren't aware of its existence.

Residents with air-conditioning who we spoke to had never seen their air-conditioning unit. They had no instruction or maintenance manuals.

One high-rise in our sample includes compressor, condenser and evaporator – *all* in the air-handling unit. Heat is rejected to a water loop connected to a cooling tower on the roof. This *not* a water loop heat pump system (although it borrows from that system's design): heat movement is unidirectional from suite space to loop. This gave every appearance of being a Cadillac system: it was clearly laid out with easy maintenance in mind. Occupants of this building, like others in the survey, are generally unaware of how it works and what servicing is required. They rely on property management staff for service advice.

Some Condominium Corporations are encouraging their members to subscribe to a preventive maintenance program from mechanical contractors, and shop for a group purchase. One building in our sample uses a contractor that charges $85 for 2 annual visits to inspect each system, perform small maintenance tasks, and replace filters. Other corporations see the systems as the owner's responsibility and stay clear of any issue that might increase the common element fees.

Where residents use their mechanical closet to store sports equipment, tools, cleaning agents, pet paraphernalia and household appliances (most do), there's a risk of knocking

the condensate and other drain lines from the AHU out of alignment with the drain. In one building where this had happened, several units experienced flooding because the drains were slightly higher than the floor level. (This is probably the only risk, it's fair to say. All components are zero clearance; combustion is sealed, and combustion air and exhaust are handled by rigid PVC pipes, so where residents can possibly stow their gear, there's no risk of blockage of combustion air or exhaust.)

In the small sample of buildings we visited, we sensed a correspondence between high quality installations, consideration in the layout given to maintenance, and the level of satisfaction in the systems on the part of residents.

Rental contracts with gas utilities

All systems we looked at in the 9 buildings in the survey use equipment owned by the gas utility and rented to the occupant. Combo units (Type 1 - domestic water heater and space heater share the same heat source) in our sample use a high-efficiency storage water heater. Type 3 systems use a wall-mounted packaged unit that combines *separate* on-demand heating for DHW and space heating. In one of the Type 2 buildings we surveyed, the gas company owns the furnace *and* the (separate) water heater. Apart from their monthly rental figure, when asked about the *terms* of their rental contract, residents universally drew a blank. We asked…

- What's the term of your agreement?
- How many service calls will you have to place before the gas company replaces your heater?
- What's the gas company's customer service standard (how long do you have to wait for attention)? (Occupants were generally complimentary about the high level of service they received, but did not know if there was a contracted standard.)
- What are the physical boundaries of the agreement – i.e. what's covered, what's excluded?
- What comfort conditions – space heating temperature or DHW temperature at the tap - are specified?
- How much notice are you given if the gas company wants to get out of this program for any reason?

We have no doubt the answers to these questions are clearly specified in a contract; the point is our respondents to a person had little idea what the terms of the agreement are.

No resident, or member of the Condo Board in the Type 1 or 3 buildings in our sample has contemplated replacement alternatives for the water heaters they're renting from their gas utility. This would be an issue in 2 scenarios – the gas company drops the rental program, or the owner takes advantage of a buy-out option offered by the utility. In both cases ownership of the equipment one way or another goes to the residents or the building owner. Residents in single-family homes take it for granted there's a wide range of competitive makes of heating, air-conditioning and water heating equipment. Replacement is expensive, but not a technical or market problem. The vertical fan-coil

unit in buildings using central systems has multiple sources for parts, and the whole unit is easily replaced if need be.

Owners of suites with in-suite systems have less choice in their repair/replacement alternatives – for both the shared (combo) water-heater, and the type 3 on-demand water heater. This is not an issue for occupants renting their equipment, but what happens if the gas company wants to terminate the program?

Over half of the respondents could recall an offer from the gas company of a buy-out of the storage heater unit. Some felt the price was high, others ignored the offer as a decision they just didn't have the time to make. Residents who had made trouble calls felt the tank was a high maintenance item, and wanted the gas company to retain ownership.

The point we're making is that utility rental programs driving in-suite systems offer the occupant significant benefits. But they create a situation in which occupants need little practical knowledge about the system's operation, how to maintain it, and where to source replacement parts if they need to. If system ownership were to transfer from the gas company to the occupants without a clear transition plan including maintenance training and sources of service and parts, the occupants of some buildings will be at a loss when their system needs attention.

We stress almost all respondents are satisfied with their in-suite system, both for heating, air-conditioning and DHW and felt they received good value from their gas utility.

Water Heater Service from the Gas Utility

In at least 2 instances residents had made repeated trouble calls to the gas company relating to the water heater. Customers always got a prompt response and were always treated courteously, but were left with the impression the service technicians had little training on these systems. One trouble report for no hot water advised the occupant to draw a bath "very, very slowly". This was the fifth of five calls in the last 12 months.

None of the 29 occupants interviewed received instruction from either the property manager or gas company service technicians on the function of the tempering valve separating the heating water loop from kitchen and bath hot water taps.

A part on the storage tank water heater that seems to need frequent replacement is the igniter. The parts appear to be in good supply and quickly replaced.

One storage tank heater in our survey was replaced after a number of "no space heating " calls with an upgrade to a larger unit.

One building in our sample seems particularly prone to ice build-up in the vent pipe, leading to back pressure that shuts off the heater. The utility technician diagnosed the problem, but claimed it was not part of his service obligations. At another building, the engineer anticipated this problem – both technical and jurisdictional - and had a contractor retrofit all exhaust vents to ensure positive condensate drainage.

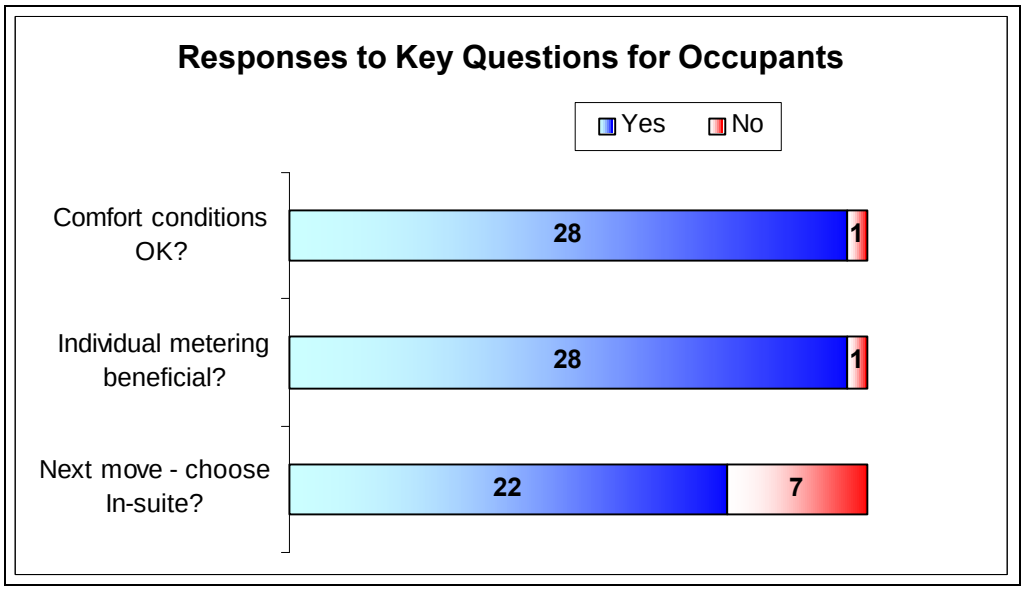
Utility Bills

Four residents in the sample pointed out their gas bills are dominated by customer and rental charges, that the commodity component was a small portion of the bill. They felt this was somehow unfair and unreasonable. We're not convinced this is a valid complaint. They seem to forget they're renting an expensive piece of high-efficiency equipment with a full service contract, and it just happens this line item shows up on their gas bill.

In two buildings in our sample, the electricity is bulk-billed (total building) and the suites submetered. A licensed meter data management company administers the bulk bill payment (they get readings directly from the Local Distribution Company) and issues individual bills to residents quarterly. This arrangement has advantages for the residents and the LDC. Residents take advantage of a commercial rate and a bill with only one customer charge. The LDC has lower billing costs. Of course there's a charge for the service, but this is offset by the savings. The residents we spoke to are comfortable with the arrangement, and feel they get good value for their energy dollar.

Key Questions for Occupants:

1. Do your in-suite systems provide you with desired comfort conditions in your suite? Are you generally satisfied with performance of the heating/cooling and hot water systems in your suite?
2. Do you see individual gas and electricity metering as a benefit? Do you like being accountable for your own gas and electricity costs, compared to paying for them in your rent or condominium fees?
3. All other considerations being equal, would you choose in-suite systems over central in your next move?



Developer

The five developers of high-rise multi-residential buildings we interviewed see themselves in an extremely competitive business. They see their market – even first-time buyers - getting increasingly knowledgeable about what they want in the areas of space comfort and physical and financial control.

Buyers may be less knowledgeable, however, about the features that deliver the benefits they're looking for. So while they want the benefit of lowest possible condominium fees, they may not be aware that individual suite metering of electricity and gas takes the burden of in-suite consumption off the monthly condo fees. Buyers with experience in buildings with central systems may look for buildings in which they endure no seasonal changeovers, but they won't necessarily make the connection with in-suite space conditioning systems and independence from a central system.

The residents we interviewed in our building sample were almost unanimous that in-suite systems would be their preference in the event they were looking for new high-rise accommodation. So our research indicates there are some signals from the condo-buyers to developers that in-suite systems deliver benefits they're looking for.

Notwithstanding *market* drivers, we're convinced the gas utilities have had a significant influence in putting in-suite systems on the map. More than one developer told us the utility's provision of a water heater and tank, suitable for use in a configuration that provided both hot water *and* space heating, convinced them to go with an in-suite design. Add to this the utility paying the cost of the gas lines from the street to the meter *in the suite* and the developer realizes a huge capital cost avoidance. The builder's only expense is the capital cost of the air-handling unit the air-conditioner and the installation of the system. In Ontario, the utility provides rental units for both the storage-type combo system (Type 1 as defined above) and the on-demand or "instantaneous" water-heating package that independently provides space heating and DHW (Type 3). In one building we sampled the gas utility also provided the AHU; we suspect this was an experiment in the early development of the program.

One of the objections we heard from developers (and architects) regarding in-suite systems is they tie up space in two specific areas of the suite: floor space for the equipment, and exterior wall space that could otherwise be used for balconies and windows. (The residents we interviewed are aware the equipment takes up space, but no one indicated much concern about it; they saw it as a necessary but minor inconvenience.)

Developers don't like tying up balcony space with compressor/condenser units. And in spite of the much lower noise levels afforded by scroll-type compressors, they can't really be described as "quiet". Both these features are a sales liability. None of the buildings in our sample used balcony space for air-conditioners. They were located on the roof, wall-mounted in the garage, or placed in a louvred niche in an exterior wall away from the balcony. One innovative design put all the refrigeration components - the compressor, condenser and evaporator - in the AHU, and cooled the condenser by means of a water loop that ran throughout the building to a cooling tower on the roof.

We heard from developers the louvres used in the exterior walls to cover equipment (direct-fired systems and compressor/condenser units) are an eyesore, and that the various configurations of combustion air intake and venting pipes – especially in the winter where ice build-up can be seen adhering to the brickwork – are uniformly ugly. One developer spent a significant amount of money to route combustion/exhaust treatment to the rear of the building, to improve the project's streetscape.

The developers we interviewed are generally comfortable with in-suite systems – both for space conditioning and Domestic Hot Water. They all had past experience with the construction of buildings using in-suite systems, and they will continue to build them. (Although we wonder to what extent if the gas utility gets out of the equipment rental business.) In-suite systems (with utility involvement) reduce their first cost. They take utility costs out of the monthly condominium fees. They provide as good or better comfort and control conditions to the residents.

While probably about as energy-efficient as central systems, the in-suite's facility for individual metering motivates more conservative behaviour on the part of residents, resulting in lower consumption within the living units.

We have not completely resolved to our own satisfaction why some developers are convinced in-suite is the *only* HVAC and DHW approach going forward, and others are staying the course with a central system strategy – even developers competing in the same locales. We induce the critical factors are:

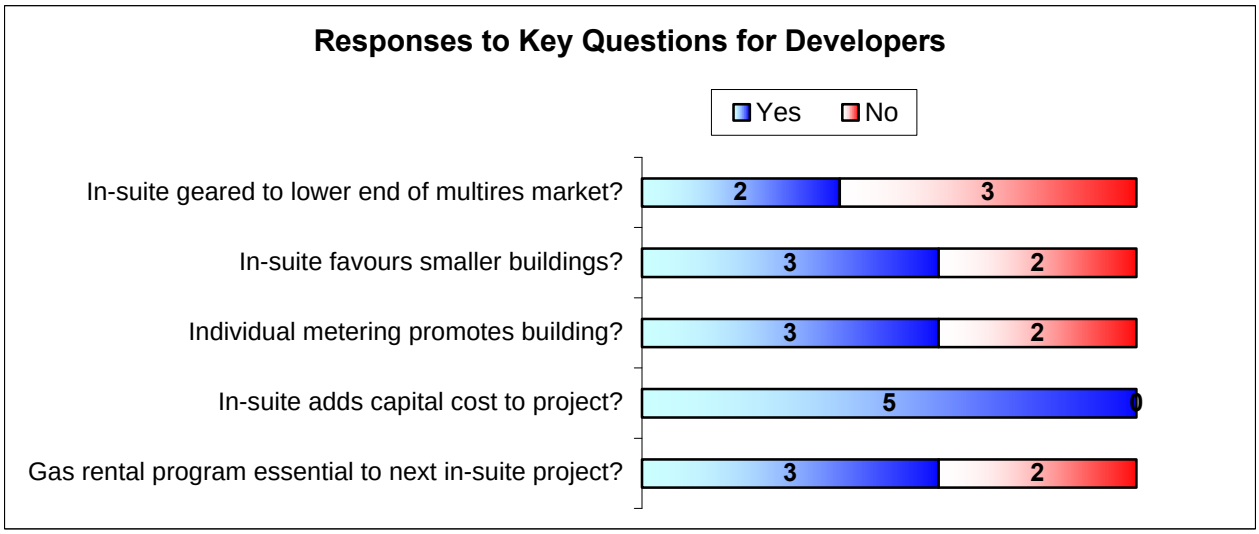
- education, awareness
- architect and engineer preferences
- experience (none, or negative)
- cost
- energy price
- local market sophistication
- availability of gas utility rental programs

One major high-rise developer has standardized on an in-suite system (Type 2) for all their buildings – but for space conditioning *only.* For DHW they use a central system. The suite metering sees all electricity and gas consumption within the suite. The bulk building meters capture consumption for water heating and transport. One architect we interviewed has designed several in-suite buildings (HVAC and DHW) but has 3 projects on the books with in-suite HVAC and central DHW.

Key Questions for Developers

1. Do in-suite systems favour buildings at the lower end of the market?
2. Do in-suite systems (HVAC and DHW) favour smaller buildings compared to central systems?
3. Does individual suite metering of gas and electricity assist in marketing your building?

4. If you have to buy all equipment (no rentals) do in-suite systems add capital cost to a new building compared to a central systems for the same building?
5. Without rental equipment from the gas utility, will you install in-suite systems in your next project, for both HVAC and DHW?



Mechanical Engineer

Regardless of what mechanical systems are to be put in a multi-residential building, the designer's objectives within the walls of the suite are to provide high quality, maintainable and reliable systems that:

1. Provide controllable space comfort conditions (temperature, humidity and air quality) that serve the needs of the occupants throughout the day, and throughout all seasons of the year;
2. Provide hot water to the bath, laundry room and kitchen in sufficient quantities and at the correct temperature.

The engineer's clients want these outcomes too, but at the lowest possible cost (the developer), occupying zero floor and head room (the architect) and in no way compromising the aesthetics of the building (the architect and the developer).

The challenge for the engineer in switching from a central system to in-suite is not *technical*; it's the art of trading off these competing objectives and coming up with a reasonable compromise.

In the following table we compare design considerations – central versus in-suite combo systems – for the same building:

Requirements	2-Pipe Fancoil Central System, Central DHW	In-suite Heating, A/C, and DHW
Space for equipment	24" X 24" typically located on exterior wall.	36" X 36" minimum; can be located anywhere in suite.
Space for air ducts	Valences, dropped ceiling	Valences, dropped ceiling
Exterior wall penetrations	None.	Combustion air intake, combustion gas exhaust; fan forced.
Service access	Remove one panel to expose filter and gain access to fan and heating/cooling coil. Generally easy, convenient working levels. Occupants' effects around closet easily moved.	AHU suspended above the storage water heater; overhead access. In the best case, access to filter and mechanics not as convenient. Equipment located in interior closet often combined with personal storage space and/or laundry machines. Usually crowded with occupants' effects.
Drains	The "third pipe" in a 2-pipe system, to drain cooling coil condensate. No floor drain.	Combustion condensation, cooling coil condensation, tank leaks and PRV release – all are routed to a floor drain that has to be plumbed prior to pouring the floor slab and routed horizontally to a vertical drain (riser).

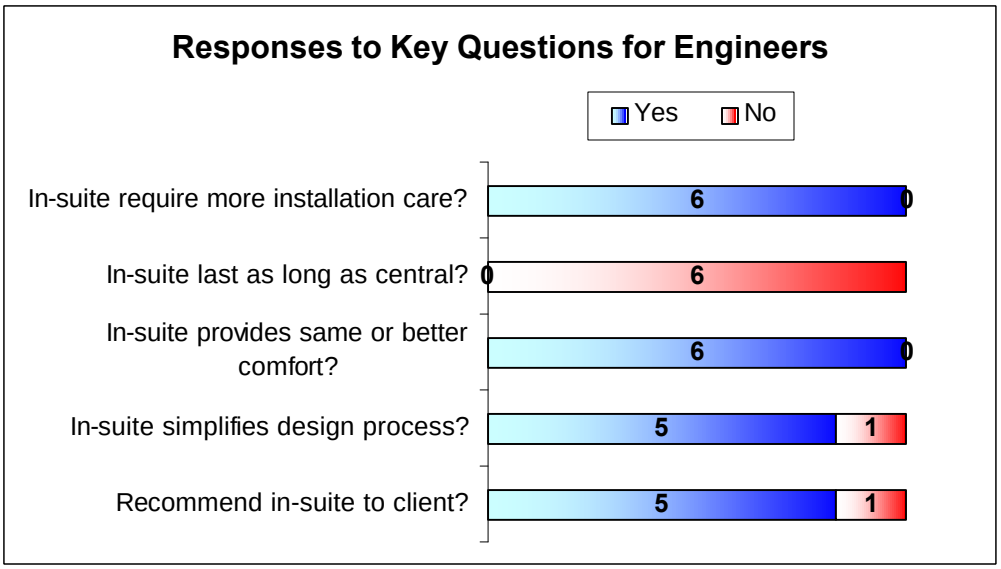
Requirements	2-Pipe Fancoil Central System, Central DHW	In-suite Heating, A/C, and DHW
Circulating pump	None (not in suite).	Yes, within or outside AHU enclosure.
Combustion condensate neutralizer	None.	Included to neutralize the pH of the combustion condensate going to the city system.
Exterior wall space	2 feet.	None.
Air-conditioning placement	None. Common coil for heating and cooling. Chiller in central mechanical room.	Compressor/condenser location: roof, garage, balcony, louvered recess in exterior wall.

Regardless of the HVAC system, engineers have to calculate the heat loss and cooling load for each suite in the building, and size the heat/cool delivery mechanics accordingly. We came to no definitive conclusion that engineering fees were any higher or lower for the in-suite system. (One engineer told us he submits a fee *before* he knows what system is going in the building.)

Engineers we asked were divided equally on the subject of commissioning of the in-suite systems. Half felt in-suite was more work than a central system, but only through sheer numbers of components.

Key Questions for Design Engineers

1. Would you agree that in-suite systems require more attention paid to installation and service access than central?
2. Will in-suite systems last as long as a central system, all other things being equal?
3. Compared with a central 2-pipe fan-coil system, and central hot water system do in-suite systems provide at least the same comfort conditions?
4. Do in-suite systems simplify the design process?
5. Would you recommend in-suite systems to a client?


Responses to Key Questions for Engineers
Yes
No
In-suite require more installation care?
6
0
In-suite last as long as central?
0
6
In-suite provides same or better comfort?
6
0
In-suite simplifies design process?
5
1
Recommend in-suite to client?
5
1

Architect

The 5 architects we interviewed were careful not to say this in as many words, but we suspect they prefer to work around *central* systems, as opposed to in-suite. Mechanical systems are a necessary evil to the architect, who sees floor space tied up with heating and cooling equipment as a waste, and wall penetrations as cluttering up the building's elevation. The engineers' most frequent complaint about in-suite systems was how little space the architect left them in which to cram in a serviceable mechanical system providing both space conditioning *and* domestic hot water.

Architects don't like the look of bulkheads and valences to conceal ductwork. While some concealment is necessary for a 2-pipe vertical fancoil system, there's more of this work required for the in-suite system – especially when the mechanical room is located in the interior of the suite. Not only are there longer air duct runs, the combustion air and exhaust conduits have to be boxed in to the exterior wall.

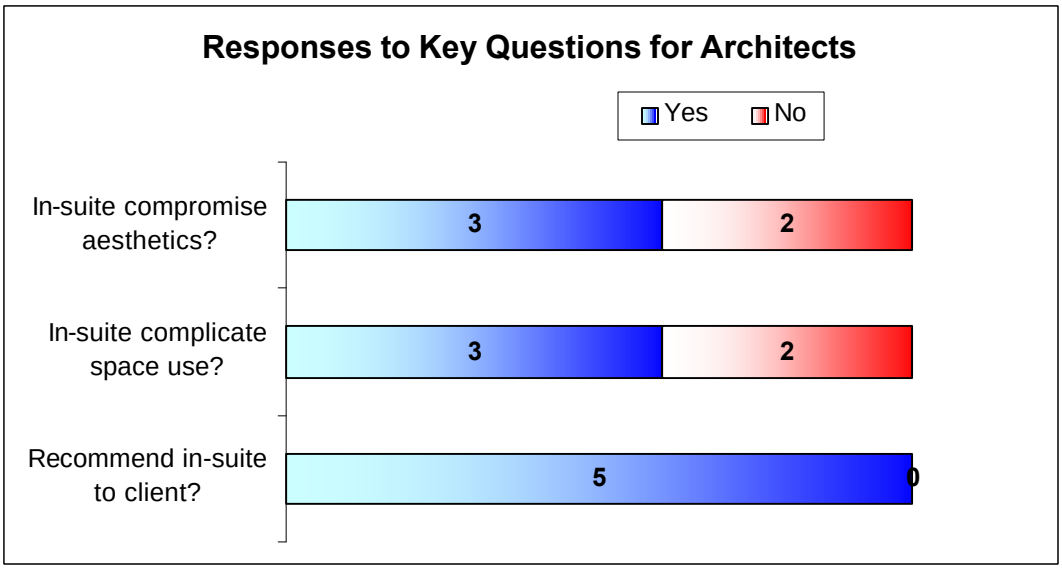
In one of our sample buildings the designer resolved this by allowing a full 10 feet between floor slabs, and dropping a ceiling over the *entire* floor plan of the suite. All ducts, diffusers and conduit run in the one-foot space between the slab and the finished ceiling. Not only is this design pleasing to the eye, giving the sense of unbroken space, it allows routing of flex duct uncompromised by any consideration of the location of concealment. The ceiling-mounted diffusers can be put anywhere, probably providing better air distribution and balance in the suite.

More than one architect in our survey lamented the lack of a more aesthetically pleasing louvre design to cover indirect-fired furnaces in the Type 2. One 16-year-old building we know of uses perforations in the brickwork to allow the system to breathe. From the outside an observer would never know it concealed an in-suite design using gas-fired furnaces. We suspect this is an expensive way to avoid using louvres.

Architects seem to care about resources and the environment; they were in general agreement the individually metered in-suite design offers reduced consumption and environmental impact.

Key Questions for Architects

1. Do the wall penetrations (vents, louvres) that characterize in-suite systems compromise the building aesthetics?
2. Compared to central systems, do in-suite systems compromise your goals with respect to space function?
3. Would you recommend in-suite systems to a client?


Responses to Key Questions for Architects
Yes
No
In-suite compromise aesthetics?
3
2
In-suite complicate space use?
3
2
Recommend in-suite to client?
5
0

Property Manager

Residents of buildings served by central HVAC and DHW systems invariably call the Property Manager (PM) when they're too hot, too cold or can't get hot water from the tap. The PM, or the Building Superintendent, may have the training or experience to run through some basic checks in the mechanical penthouse to identify the problem, and in some instances may even have the technical skills to fix it. Beyond the basics, however, the PM calls a mechanical or electrical contractor (who's usually on retainer) and ensures corrective action takes place. In most cases the problem is minor, but occasionally a major breakdown sets up an emergency situation that has to be fixed immediately. In either case, the PM is accountable for maintaining the building systems in good shape in order to keep the residents satisfied.

The Property Managers we interviewed endorse in-suite HVAC and DHW systems. Apart from minor courtesy calls, perhaps to explain the operation of a thermostat or how to change a filter, the PM has no obligation (or authority) to act on resident complaints relating to in-suite conditions – space temperature or hot water temperature.

Accountability for the maintenance and problems relating to the in-suite system rests with the condominiums suite owner, or the rental-building owner, or the gas company in the case of systems using rental equipment. This means PMs in buildings with in-suite systems have significantly reduced workload compared to what they'd have in the same building with central systems. In addition, they don't have to deal with the swell of "seasonal changeover" complaints that characterize the twice-annual switch from boiler to chiller and back again.

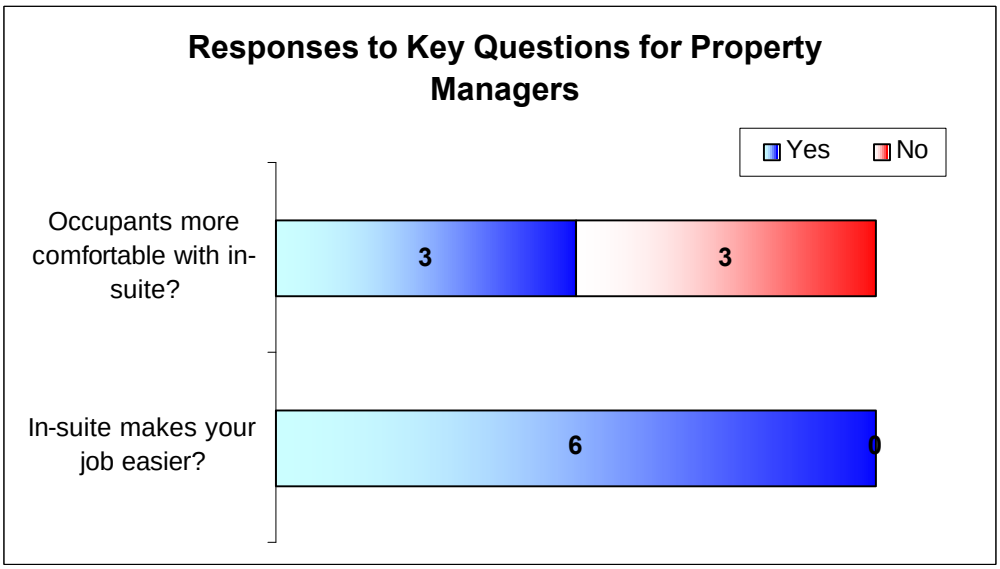
In the case of the 2 rental buildings in our survey, the Property Manager and the owner are the same – one an individual, the other a Cooperative Board. The gas company owns and maintains the water heaters, but the owner/PM is responsible for the upkeep of the air-handling unit. Neither one of these buildings is air-conditioned, but if they were, the compressor/condenser and cooling coil would be the owners' responsibility as well.

Of the 5 PMs we interviewed, 4 had past experience in buildings with central systems. Apart from resident complaints that seem to accompany every seasonal changeover in these buildings, they reported no significant difference in resident comfort, comparing in-suite systems against central. Individual metering keeps utilities out of the condo fees, and eliminates residents' concerns over subsidizing their wasteful neighbours. All PMs agreed individual metering of gas and electricity reduced overall consumption, but they didn't know by how much. In addition they were all aware the cost per unit of fuel increases with individual metering because of the residential rate structure, so that while overall energy savings were likely, cost savings are more doubtful, when comparing in-suite system buildings with central.

Key Questions for Property Managers

1. Compared to Buildings you have managed (are managing) do you believe occupants of buildings with in-suite systems are more comfortable? Have fewer system-related complaints?

2. Compared to central 2-pipe fancoil system and central DHW, do in-suite systems in a building you are managing make your job easier?



Conclusions

Gas-fired in-suite systems in high-rise multi-residential buildings evolved in the early 1990s. Our findings indicate in Ontario, at least, the foundations for the "vertical subdivision" were laid by the two gas distribution companies. The Ontario Governments SHERP (Social Housing Energy Retrofit Program also generated interest through the provision of funds to convert public housing from electric baseboards and hot water systems. As a result, many apartments were provided with in-suite combo systems.

We believe a major marketing and lobbying effort on the part of Enbridge Gas Distribution and Union Gas gave rise to a viable alternative to electric baseboards.

We say this for two reasons. Without building code changes the distribution piping that carries the gas from the point of supply from the street to the living units throughout the building would be illegal. Secondly, the gas utilities' marketing programs have enabled considerable capital savings for the developer. Rental equipment, supplied at no cost to the developer, includes high-efficiency storage tanks, on-demand water heating packages and occasionally, air handling units. In addition, the utility pays for the gas distribution line from street to suite, reducing the builders' cost even further.

Our survey of 9 buildings indicates residents are generally satisfied with the comfort conditions the in-suite system provides, whether it's a combo or a indirect-fired heating/cooling package with separate DHW. They like being accountable for their own gas and electricity bills, and independence from a central system. System type – central versus in-suite - will play a role in the selection of their next high-rise move, with in-suite being the preferred way to go.

We have some reservations.

It's our opinion the long-term effectiveness of the in-suite system is highly sensitive to design consideration given to maintenance. In one building in the survey, we saw installations that simply could not be serviced without the removal of interior partitions, and that made changing the filter a major chore. This was the exception, however. The other 8 buildings in the survey had in-suite installations clearly laid out to facilitate all service tasks – routine and complex. We saw a direct correlation between clean well-maintained components and the occupants' ease of access.

In all but one combo (Type 1) installations, the compressor/condenser unit was out of sight and out of mind. Some residents had to think before they could recall where their unit was located in the building. We speculate the resulting neglect will shorten the useful life of the equipment.

We have some concern about the lack of knowledge on the part of all occupants in the survey regarding the operation and maintenance of their in-suite system. Our strong impression is they get little instruction from property management, the developer or the gas utility on regular maintenance tips that would contribute to better performance and longer service life of the equipment. We suggest a booklet on the operation and maintenance of the various types of in-suite systems would be welcomed by landlords, cooperatives and condominium corporations.

Our interviews with residents also gave us cause to speculate on what happens if the gas utility decides to get out of the equipment rental business. Most residents are aware the utility had offered them a buy-out opportunity, but no individual we spoke to gave it a moment's thought. (Too expensive, said some; others did not want to lose the all-in lifetime service warranty the gas company includes in the rent.)

We also wonder about replacement parts – fans, pumps, storage and on-demand heaters. One engineer assured us no component of these systems is single-sourced, but admitted the choice for replacements was limited, and not typically consumer products.

Gas-fired in-suite systems offer an alternative to electric baseboards and water heaters, but they suffer from the same inflexibility of energy source. If increasing natural gas prices drive a need to consider electric systems, the switching cost will be high. Apart from changing water heaters and furnaces, suites wired for lights, appliances (including air-conditioning) and plug load would likely require an electrical service upgrade to carry the heating demand.

Recommendations

This report makes the following recommendations:

- Develop a handbook on the operation and maintenance of in-suite systems, aimed at renters and condominium owners. Include a section on what condo owners should know with respect to taking ownership of a system formerly rented by the gas utility.
- Conduct research on the market penetration of in-suite systems in Canadian high-rise construction, and the reasons for any change in popularity trends.
- From a broader sample base, generate more in-depth analysis of the life-cycle cost of gas-fired in-suite systems.
- Get more perspective from the gas utilities on the value of in-suite equipment rental programs – are they good business, and will they continue to grow?

Appendix A - Specification for the buildings in the survey

Building Characteristics:

	Must Have	Nice to Have
Size – 3 floors minimum, the larger the better	✓	
Type – rental or condominium units (client wants an even mix if possible)	✓	
Age – minimum 3 years, to get billing history and usage experience	✓	
Occupant profile – families, typically (not special needs like retirement or nursing homes)	✓	
Decentralized space heating system, gas-fired, individually metered *(- but excluding water-loop heat pump systems.)*	✓	
Decentralized DHW system, gas-fired	✓	
Each living unit individually metered for gas and electricity		✓
Single bulk meters for total building water, building common area gas and electricity	✓	

Ability to obtain information (through dialog and questionnaires) from these building stakeholders:

	Must Have	Nice to Have
Developer		✓
Architect		✓
Mechanical Engineer		✓
Property Manager		✓
Condo Corp/Strata Corp		✓
Mechanical Contractor		✓
Occupants (minimum 6 per building)		✓
System manufacturer		✓
Gas Utility		✓

Hard Data Requirements:

	Must Have	Nice to Have
For common areas, by month, for 2 years (from bills or spreadsheet from utility): energy consumption (kWh, KW, M3) energy costs		✓
**For 50% of the suites in each building, by month, for 2 years: energy consumption (kWh, M3) energy costs		✓
Capital costs for installed space heating system		✓
Capital costs for installed Domestic Hot Water system, if separate		✓
System Nameplate data – Manufacturer, model, capacity, plus auxiliary equipment, supplemental heating/cooling equipment		✓
Corridor ventilation and fresh air supply system to suites		✓
Annual O&M costs		✓
Building drawings: mechanical, electrical, architectural		✓
Equipment specifications (from mechanical schedules)		✓

Soft data requirements:

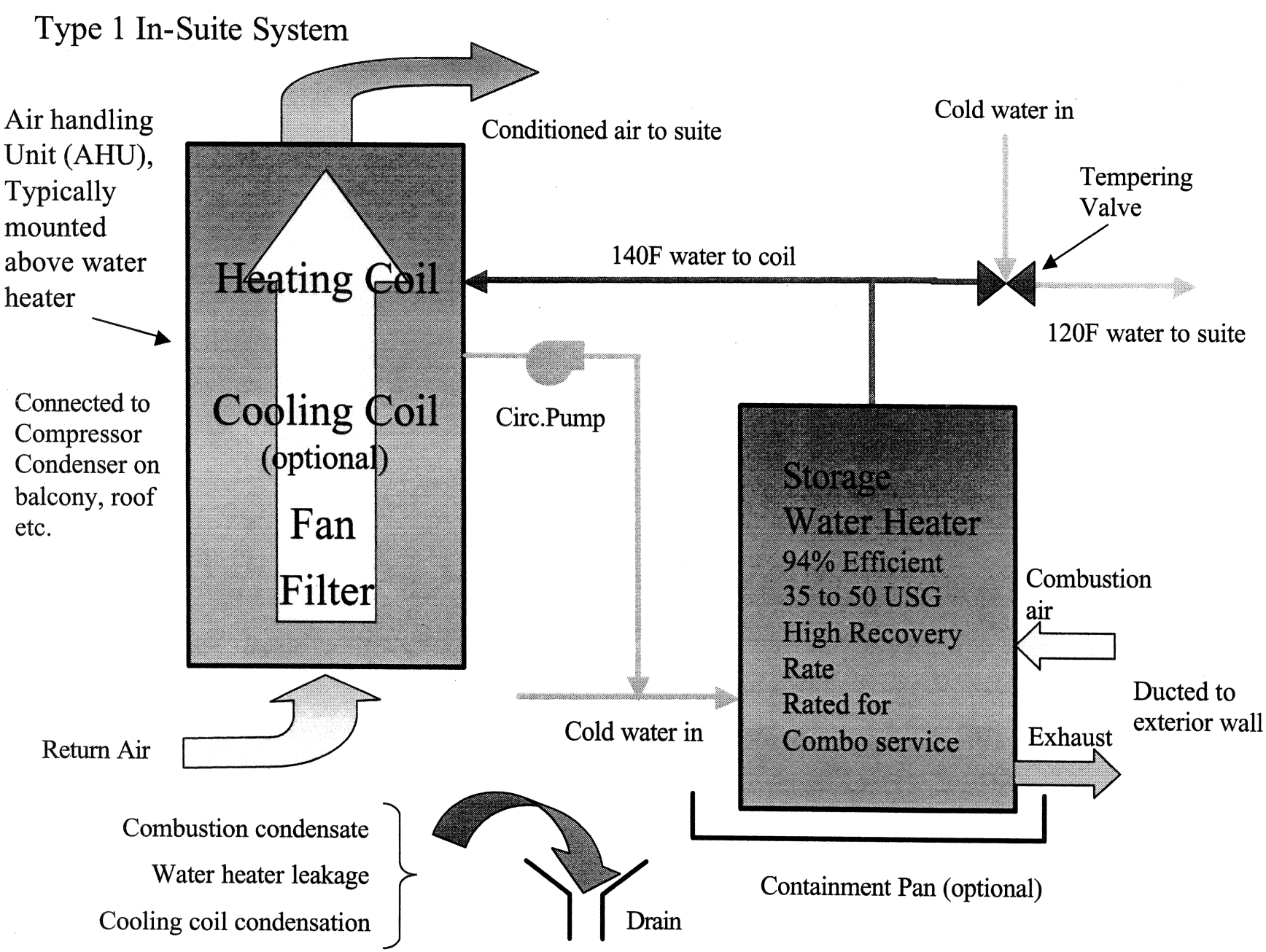
	Must Have	Nice to Have
Operations and Maintenance - general impressions of system, frequent trouble reports, parts and service availability, occupant comfort complaints, ease of control of space comfort		✓
Design and architectural considerations – space use, envelope penetration, building code constraints or anomalies, combustion air and exhaust layout, construction implications, commissioning and re-commissioning requirements		✓
Safety considerations directly relating to system, CO, CO2 monitoring, insurance implications		✓
Financing vehicles used by developer– from manufacturer, utility, leasing companies		✓
General levels of satisfaction of owners, managers and occupants		✓

Appendix B - Information Types and Sources

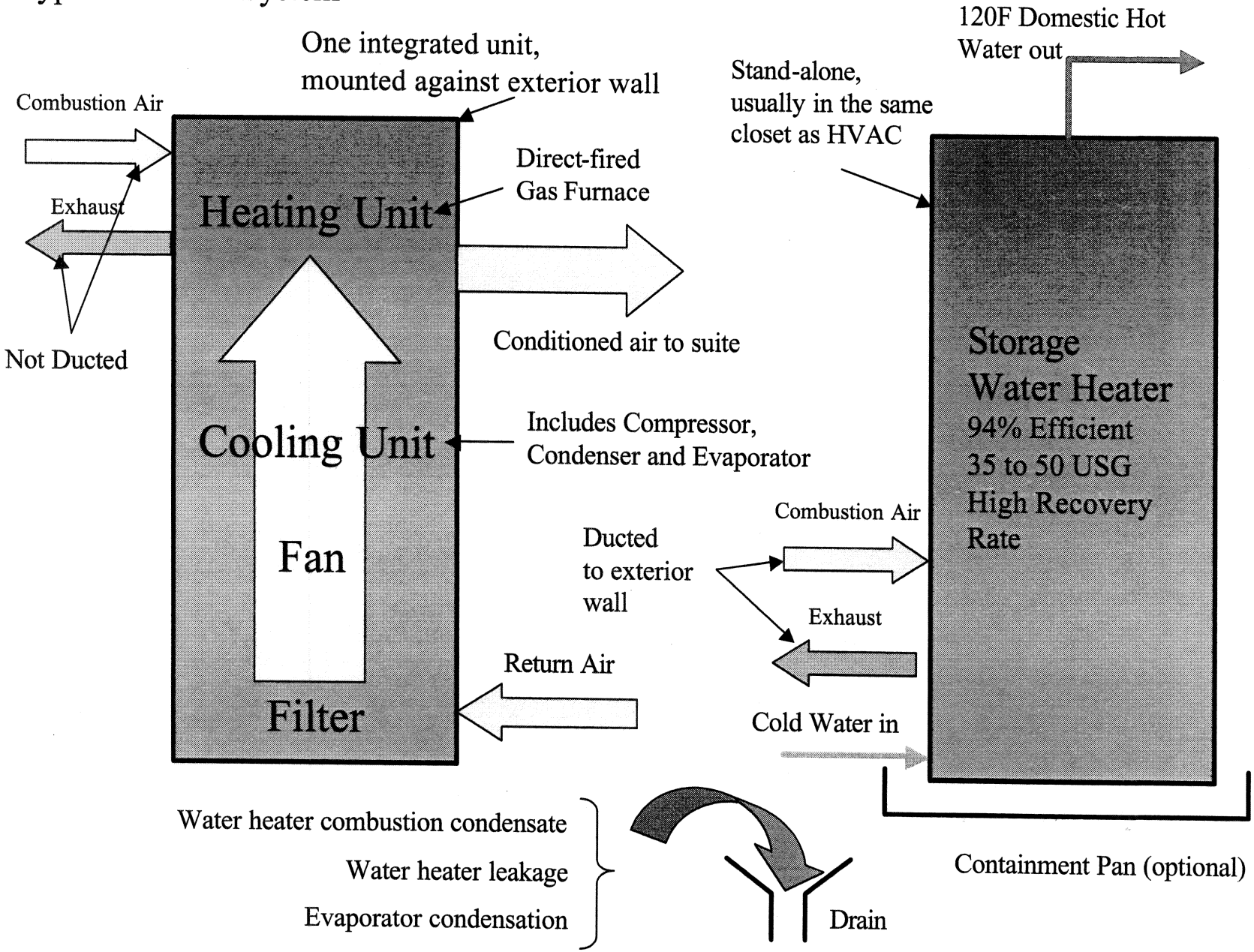
The following categories of sources were used to obtain information and data for this survey:

- Developers
- Mechanical Design Engineers
- Architects
- Equipment Manufacturers
- Gas utilities
- Distributors/Sales Agents
- Condominium Associations
- Condominium Corporations
- Residents
- Energy Management Companies

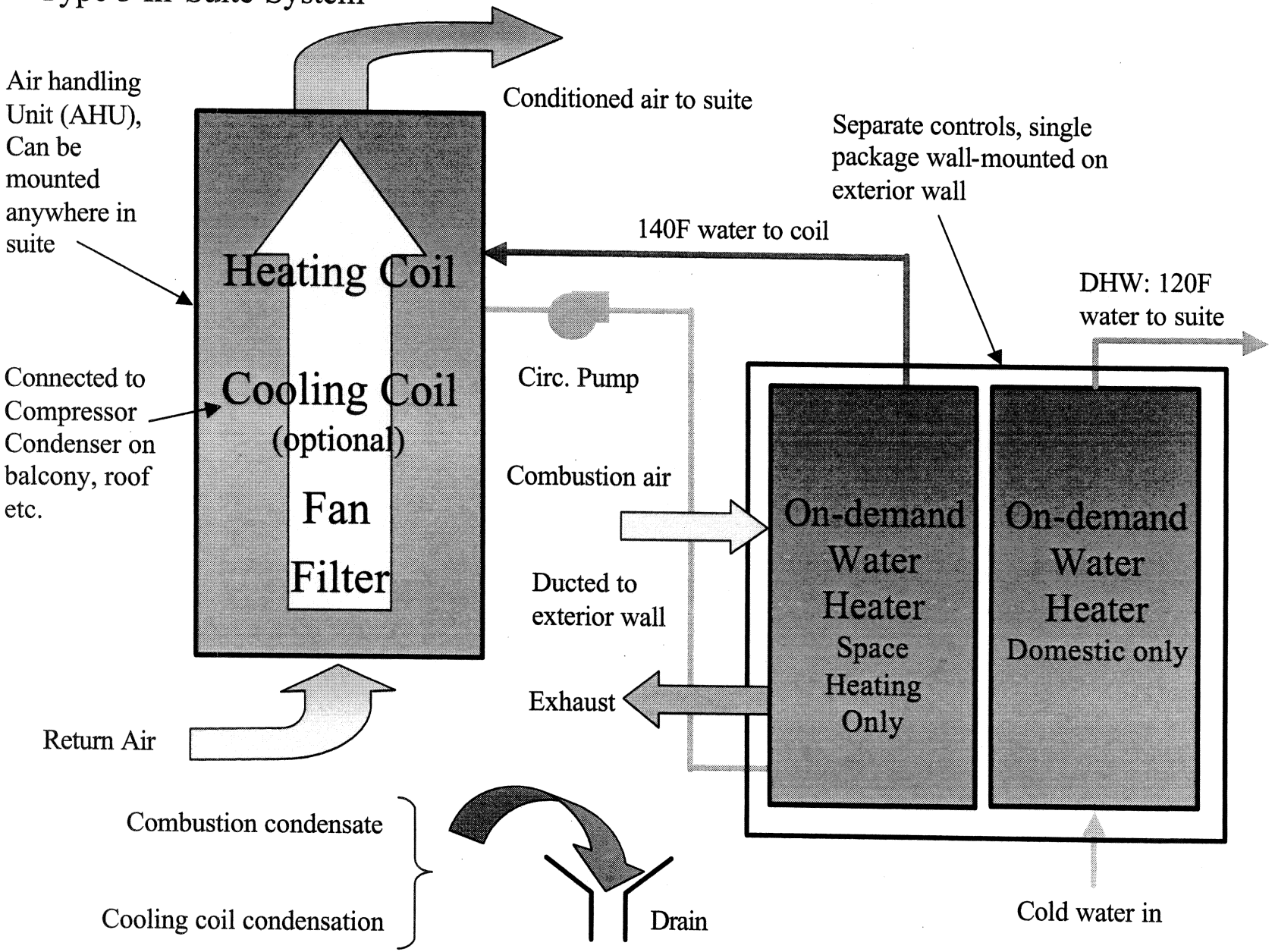
Appendix C – System Schematics


Type 1 In-Suite System
Air handling Unit (AHU), Typically mounted above water heater
Conditioned air to suite
Cold water in
Tempering Valve
140F water to coil
120F water to suite
Heating Coil
Cooling Coil (optional)
Fan
Filter
Connected to Compressor Condenser on balcony, roof etc.
Circ.Pump
Storage Water Heater
94% Efficient
35 to 50 USG
High Recovery Rate
Rated for Combo service
Combustion air
Ducted to exterior wall
Exhaust
Return Air
Cold water in
Combustion condensate
Water heater leakage
Cooling coil condensation
Drain
Containment Pan (optional)

Type 2 In-Suite System



Type 3 In-Suite System



Appendix D – Capital Costs for In-Suite Equipment

The figures in the following tables were obtained in June 2003 from various suppliers. They're indicative numbers only, and included to provide guidance on the capital costs of the gas-fired in-suite systems encountered in this study. Supply and demand dynamics can have a significant effect on the prices of this equipment from one quarter to the next and from one area to the next.

Assumptions:
One hundred 2-bedroom units, 1200 square feet each. Electric air-conditioning, gas-fired heating, and gas-fired DHW. All systems in-suite.

Type 1
Heating: Return air fan-driven through hot water coil in AHU.
Cooling: Return air fan-driven through cooling coil (evaporator) in AHU.
DHW: Heater/storage tank, ***shared*** with space heating. (Known as the "combo" system.)

Component	Purchase Cost	Installation Cost	Notes
Air handling unit, c/w heating coil, cooling coil, fan	$800		Enerzone, other fan-coil AHU manufacturers.
Pump (if separate) Hot water tempering valve	$125 $100		Pump to circ. heating water may be separately plumbed, external to AHU.
Water heater/storage unit - 34 USG	$3500		Commonly a Polaris unit made by American Water Heater (Enbridge), but could be any residential WH make, with direct/power venting and sealed combustion, rated for the combo system (providing DHW and suite heating).
Water heater/storage unit – 50 USG	$4100		Change in price for larger capacity.
Compressor/condenser unit	$800		Carrier, Trane, Lennox, Keeprite, etc.
Gas distribution piping	Base Building		Cost per suite to run gas lines from main supply to building to all suites. Enbridge bears this cost to the meter.
Gas meter			Enbridge-supplied
Drains	175.		Located next to AHU and WH tank, for condensate and leaks. Drain pan for tank incl.
Piping to drains	$40		

Combustion/exhaust piping (PVC) *internal*	$25		
Combustion/exhaust piping (PVC) *external*, if separately costed	$100		Cost to core drill exterior wall for venting
Duct work, diffusers	400		Assume 3 lengths of 6" duct, 20 feet each + main header
Valences, bulkheads, dropped ceilings to conceal ductwork.	Base Building		Metal studs and drywall.
Installation including ductwork		$3000	

Type 2

Heating: Return air fan-driven over steel heat exchange surface.
Cooling: Return air fan-driven through cooling coil (evaporator) component of DX air-conditioner.
DHW: High-efficiency heater/storage tank, *separate* from space heating.

Component	Purchase Cost	Installation Cost	Notes
Air handling unit, c/w direst-fired heat exchanger, cooling coil, fan.includes compressor	$4000.		Magic Pak (Ozz), Skypak (Skymark) Lennox, other manufacturers
Water heater/storage unit - 34 USG	$600 - $3,500		Commonly a Polaris unit rented from the gas utility, (high efficiency, high price) but could be any WH make, with direct/power venting and sealed combustion.
Water heater/storage unit – 50 USG	$700 - $4100		Change in price for larger capacity.
Drains	$175		Located next to AHU and WH tank, for condensate and leaks.
Piping to drains	$40		
Combustion/exhaust piping (PVC) *internal*	$25		
Combustion/exhaust piping (PVC)	Included in unit cost		3X4 foot grille protects furnace from weather,
external, if separately costed	Included in unit cost		otherwise open to the outdoor atmosphere.

Component	Purchase Cost	Installation Cost	Notes
Duct work, diffusers	$400		Assume 3 lengths of 4" duct, 20 feet each.
Valences, bulkheads, dropped ceilings to conceal ductwork.	Base building		Metal studs and drywall.
Combustion/exhaust piping (PVC)	$100		Cost to core drill exterior for venting
Installation labour including ductwork	3200	$3200	Increase due to 2x gas pipe and venting

Type 3

Heating: Return air fan-driven through hot water coil supplied by on-demand ("instantaneous") water heater (no storage) *dedicated* to space heating, and *separate* from DW heating.

Cooling: Return air fan-driven through cooling coil (evaporator).

DHW: Separate from space heating, supplied by on-demand water heater (no storage). The on-demand water heaters for both space heating and DW heating are in the same packaged unit, with controls to select space DHW heating, or DHW heating AND space heating.

Component	Purchase Cost	Installation Cost	Notes
Air handling unit, c/w heating coil, cooling coil, fan, pump (if included)	$800		Enerzone, ADP
Instantaneous, on-demand water heater dedicated to closed loop heating circuit, combined in same package as instantaneous on-demand water heater for DHW.	$2500 - $3000		Ocean Luna Marathon Industries Bosch
Compressor/condenser unit	$800		Carrier, Trane, Lennox, Keeprite etc.
Gas distribution piping	Base building		Cost per suite to run gas lines from main supply to building to all suites. Enbridge bears this cost to the meter.
Gas meter			Enbridge
Drains	N/A		Located next to AHU and WH tank, for condensate and leaks. (Drain pan not required)

Component	Purchase Cost	Installation Cost	Notes
Piping to drains	$40		
Combustion/exhaust piping (PVC) *internal*	$25		
Combustion/exhaust piping (PVC) *external*, if separately costed	$100.		Cost to core drill exterior for venting.
Duct work, diffusers	$400		Assume 3 lengths of 4" duct, 20 feet each.
Valences, bulkheads, dropped ceilings to conceal ductwork.	Base building		Metal studs and drywall.
Combustion/exhaust piping (PVC)	Included in unit		
Installation including ductwork		$2800.	Lower install (no tank, one vent &gas supply)

Appendix E - Photographs

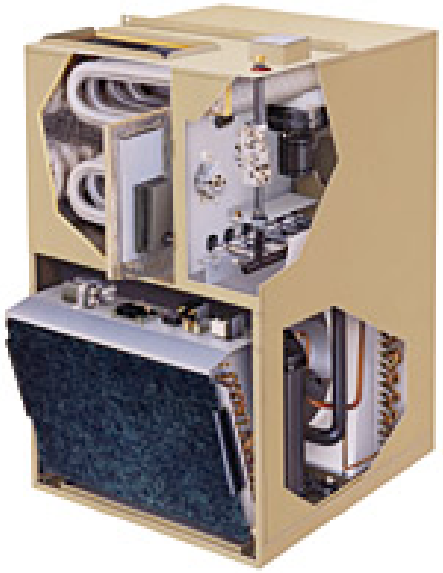
Type 1

Heating: Return air fan-driven through *hot water coil* in AHU.
Cooling: Return air fan-driven through cooling coil (evaporator) in AHU.
DHW: Heater/storage tank, *shared* with space heating. (Known as the "combo" system.)

<table>
<tr>
<td>  </td>
<td>Typical Type 1 (combo) arrangement, showing 34USG high efficiency storage providing 140°F water through (white) lines to the heating coil in the air handling unit overhead. In this case combustion air and exhaust for gas-fired water heater are in separate conduits (gray horizontal PVC pipes).

Return air enters at left side of AHU (through filter, which in this case has particularly awkward access). Supply air is fan driven through plenum (right) and then through ducts to the rooms in the suite.</td>
</tr>
<tr>
<td>The combo system uses a tempering or "anti-scald" valve that ensures water temperature to kitchen and bath is around 120°F. The water in the heating loop, at 140°F would present a scald hazard without this device. Auditors often found these valves seized. No occupants we interviewed were aware of the valve's existence or function.</td>
<td>  </td>
</tr>
<tr>
<td> 
</td>
<td>The thermostat on the sealed combustion manifold on the bottom of the storage tank controls the temperature of the water in the tank. Most heating coils in the AHU were specified for 150°F water at 800 cfm. Also visible in this photo is a containment pan for tank leakage or PRV release. The pan is plumbed to a floor drain.</td>
</tr>
</table>

Type 2
Heating: Return air fan-driven over SS heat exchanger surface
Cooling: Return air fan-driven through cooling coil (evaporator)
DHW: Heater/storage tank, *separate* from space heating.

	The space-conditioning unit comprises return air plenum at the bottom, surmounted by filter, fan, heat exchange surfaces and A/C components. The combustion chamber and heat exchange surfaces are organized in a way very similar to conventional residential forced air furnaces. The fan draws return air through the filter across the heat exchange surfaces – heating or cooling, and out the supply air plenum to distribution ductwork. Compressor, condenser and evaporator contained in the package provide air conditioning.
	A cut-away drawing of the MagicPak™ in-suite heating and air-conditioning packaged unit. (Courtesy MagicPak.)

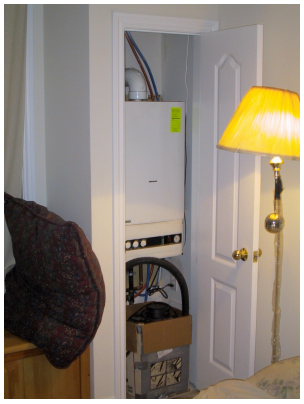
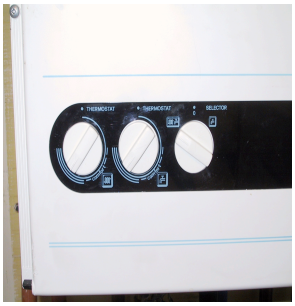
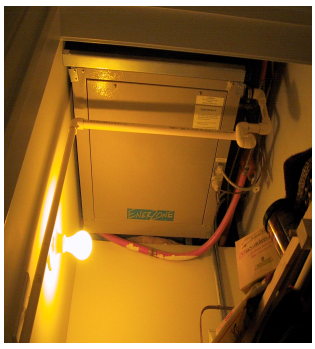
 	Type 2 (Magic Pak™, Sky Pak™, or Complete Heat™) units are installed against an exterior wall. The louvre protects the unit from the elements, and allows free flow of combustion air and exhaust gases. The white PVC elbows visible above the louvres are the terminations for fan-powered exhaust and combustion air for the water heater typically located in the same closet. Architects and developers complain about the wall space this system ties up, and the compromised aesthetics.
A standard residential storage water heater, power vented for combustion and exhaust is located in the same mechanical closet. Note the gas meter (usually remote-read) located next to the equipment	

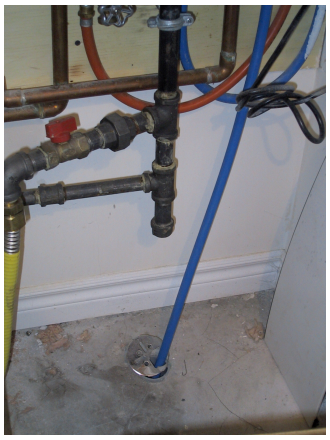
Type 3

Heating: Return air fan-driven through hot water coil supplied by on-demand water heater (no storage) dedicated to space heating, and separate from DW heating.

Cooling: Return air fan-driven through cooling coil (evaporator)

DHW: Separate from space heating, supplied by on-demand water heater (no storage). The on-demand water heaters for both space heating and DW heating are in the same packaged unit, with controls to select space DHW heating, or DHW heating AND space heating.

<table>
<tr>
<td>  </td>
<td>The on-demand package (Ocean Luna™) is mounted in a closet on an exterior wall, and occupies little floor space. Combustion air and exhaust gases are transported in a concentric pipe fitting (interior and exterior shown at right) with very short horizontal run.</td>
<td>  </td>
</tr>
<tr>
<td>  </td>
<td>The photo on the left show the separate thermostats for space heating loop and DHW temps and a switch to select DHW only, space heating and DHW, and OFF.</td>
<td>  </td>
</tr>
<tr>
<td>  </td>
<td colspan="2">The air handling unit is usually located overhead in an interior closet in the suite, and combines mechanical room and storage space for residents' personal gear.
This AHU consists of return and supply air plenums, filter, fan, heating coil and evaporator coil. The compressor/condenser component of the air conditioner is roof-mounted in this building, but can also be located in its own niche in an exterior wall. Access to compressor/condenser units is often a challenge in in-suite systems.</td>
</tr>
</table>

	Combustion condensate is plumbed to a floor drain directly below on-demand heater package.

In-Suite Systems Drainage

Central fan coil systems provide a riser to drain cooling coil condensate. In-suite systems require floor drains for…

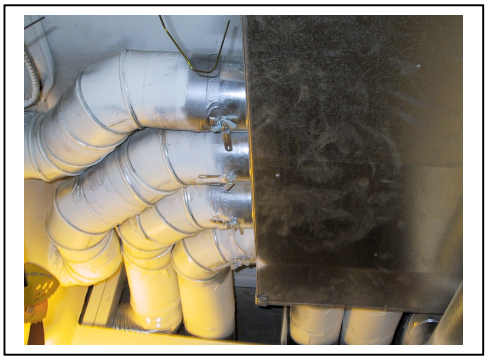
- combustion condensate
- cooling coil condensate
- PRV leakage or release
- tank leakage

Note the use of neutralizer cartridge required by many building codes in the combustion condensate drain line.

Most drains in our survey had easy maintenance access. This one however, could only be seen with a mirror (or outstretched camera).

The result of a failed drain scheme. Occasionally, the storage and retrieval of personal effects in the mechanical closet pulls the drain line out of the drain.

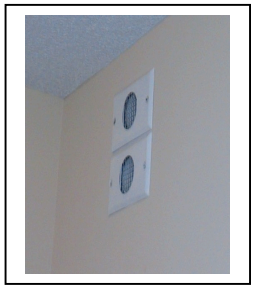
In-Suite Systems Air Distribution



All buildings in our survey used ducts (6”, except in the case of high-velocity system) to distribute conditioned air to the various rooms in the suite. Air balancing is typically achieved through butterfly valves at the supply air plenum (left).

Ductwork in concealed in valences, bulkheads, interior walls, and dropped ceilings. One builder dropped the ceiling throughout the entire suite specifically to hide ductwork and avoid the look of valences. This definitely has the effect of making the suite look larger.

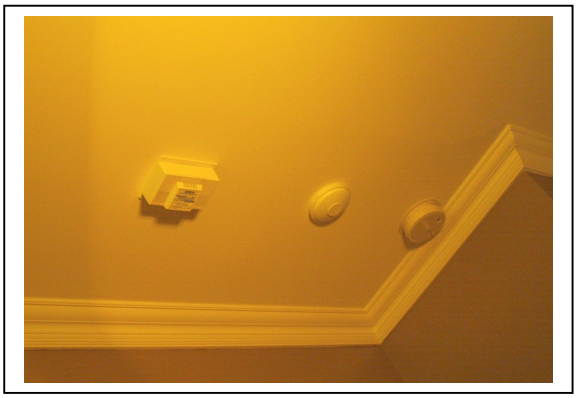
Another builder chose to go with a high velocity system, allowing for smaller diameter ducts and in-wall concealment. (Occupants complained of high air noise in this building.)



Ease of access to the filter is a primary influence on how frequently it is replaced. This filter has never been changed.

In-Suite Controls

In suite systems controls are characterized by simplicity: a “cooling”, “heating” and “off” selector and temperature selector. We encountered only low voltage non-programmable units mounted on an interior wall. The installation guide from the natural gas utility recommends avoidance of programmable thermostats.



One builder provided each suite with C0, $C0_2$ and smoke detection, ceiling mounted in the hallway leading to bedroom.

Appendix F – Utilities Costs

Obtaining billing information from building owners (developers and condominium corporations) proved more difficult than we imagined. Utilities were reluctant to send data even when provided with signed releases. Only some of the suite owners and tenants authorized us to obtain their billing histories. Some data we received was for the wrong account. We were not able to convert all authorizations to billing histories from utilities.

The table below summarizes what data we were able to obtain.

Common area consumption and cost for gas	2 buildings
Common area consumption and cost for electricity	2 buildings
Suite-metered consumption and cost for gas	7 suites
Suite-metered consumption and cost for electricity	6 suites

Due to some questions around the data we were unable to answer (address/account conflicts and suspect data values), we are not reporting common area costs and consumption. We estimate common area costs in multiresidential buildings to be around 50% of the total.

For both gas and electricity, the cost and consumption data we were able to obtain for the suites looks to us to be trustworthy. However, due to the small sample, we believe these numbers are only indicative of cost and consumption. Gas and electricity consumption can swing dramatically from suite to suite – even with the same layout and floor area - due to variables such as:

- lifestyle
- daily and monthly occupancy patterns
- number and age of occupants
- suite exposure
- fenestration proportions

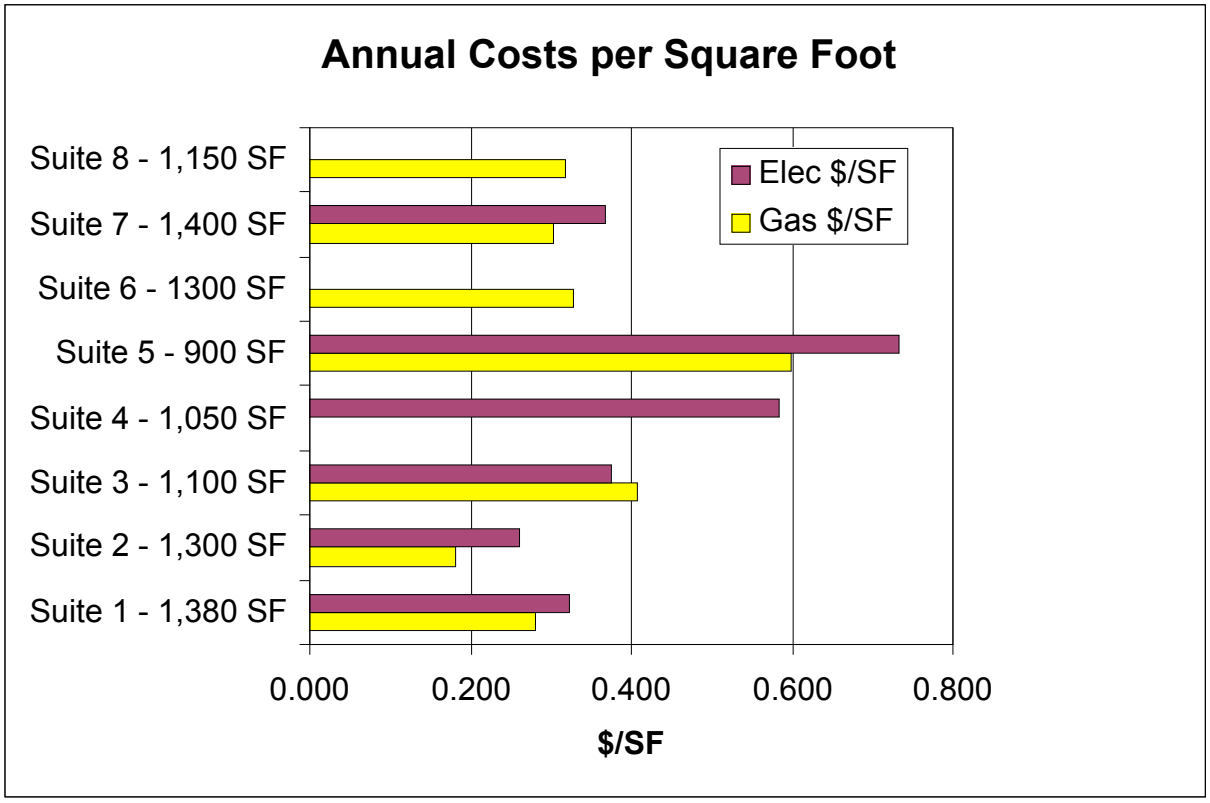
From our responses for 6 suites for electricity:

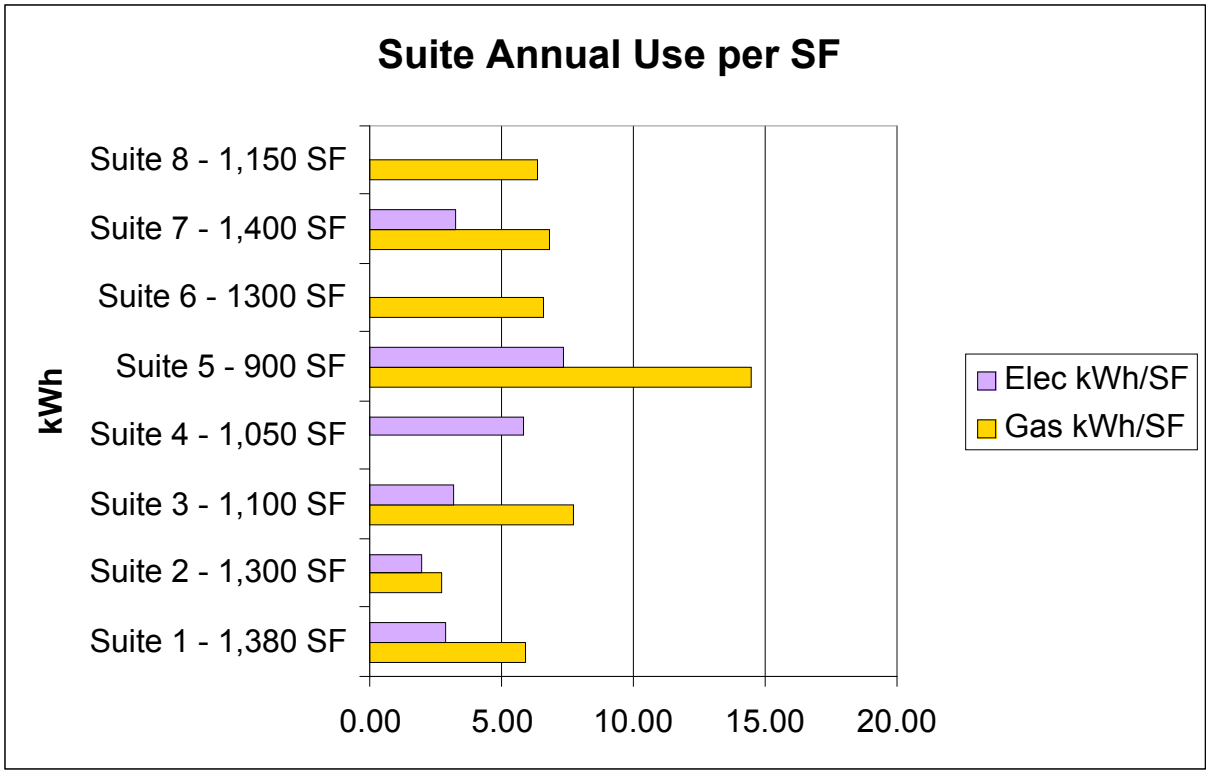
Average total bill per month per suite	$41
Average consumption per month per suite	379 kWh

From our responses for 7 suites for gas:

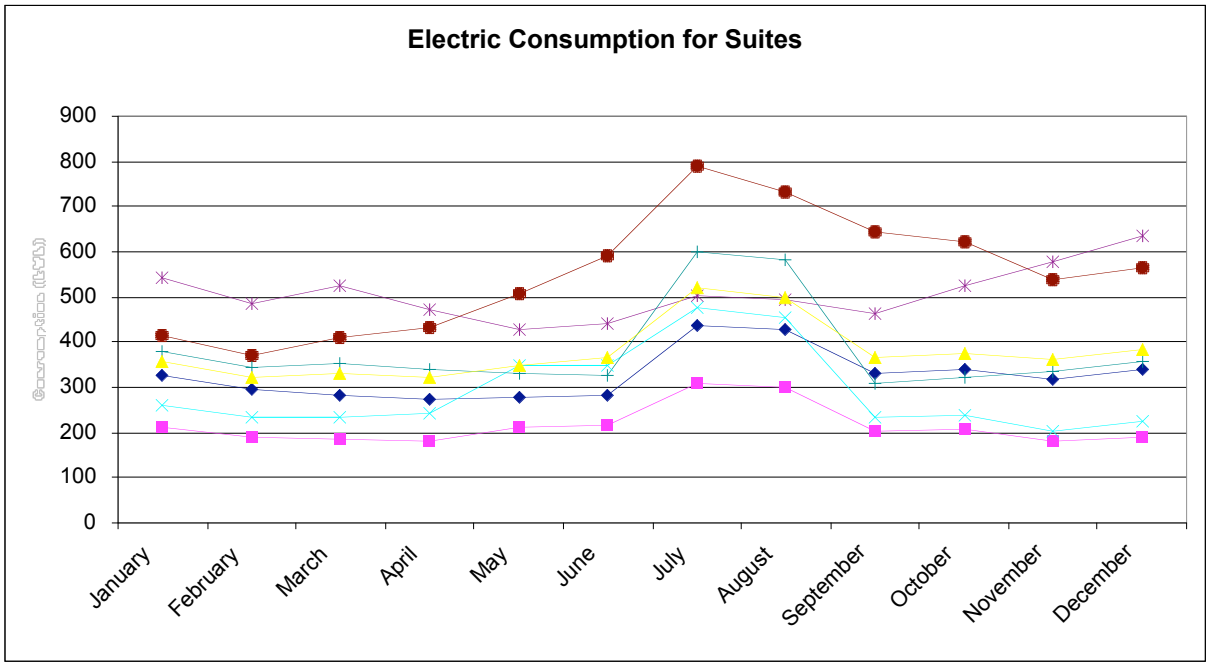
Average total bill cost per month per suite	$34
Average consumption per month per suite	67 m^3

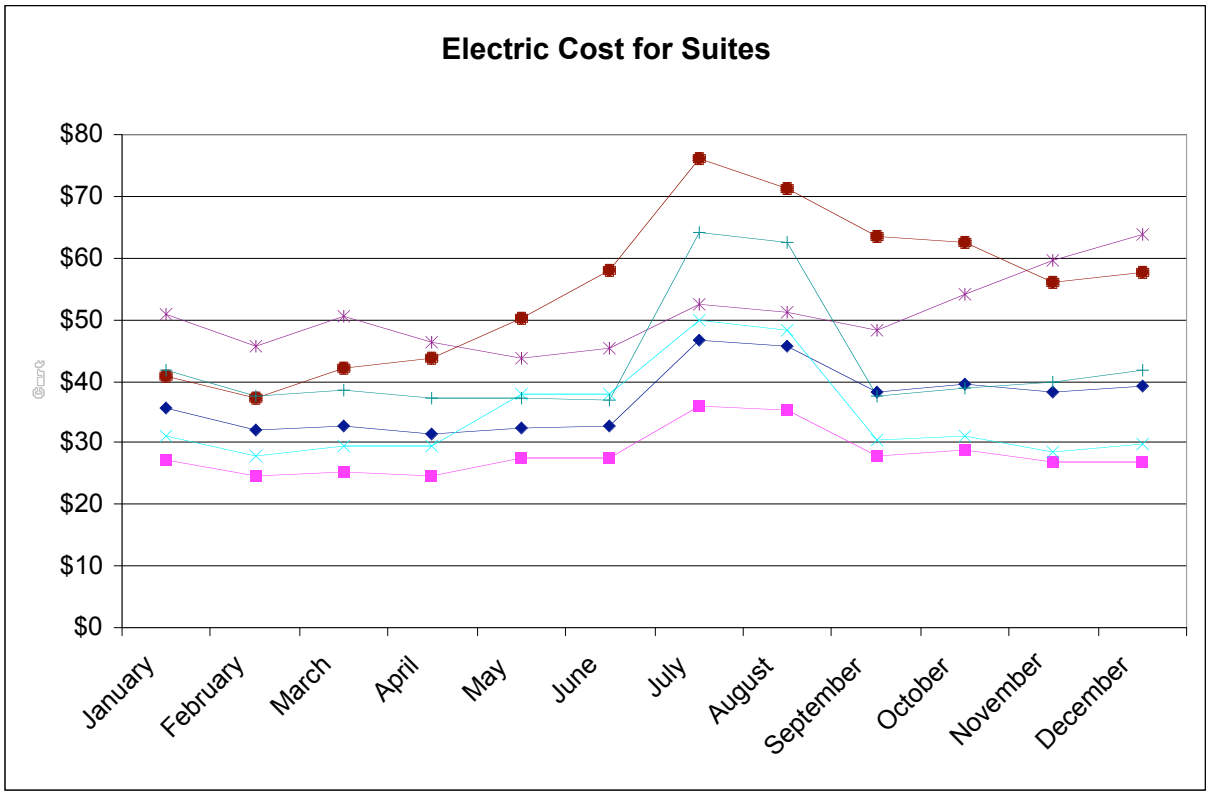
The graphs and tables below provided details by month.

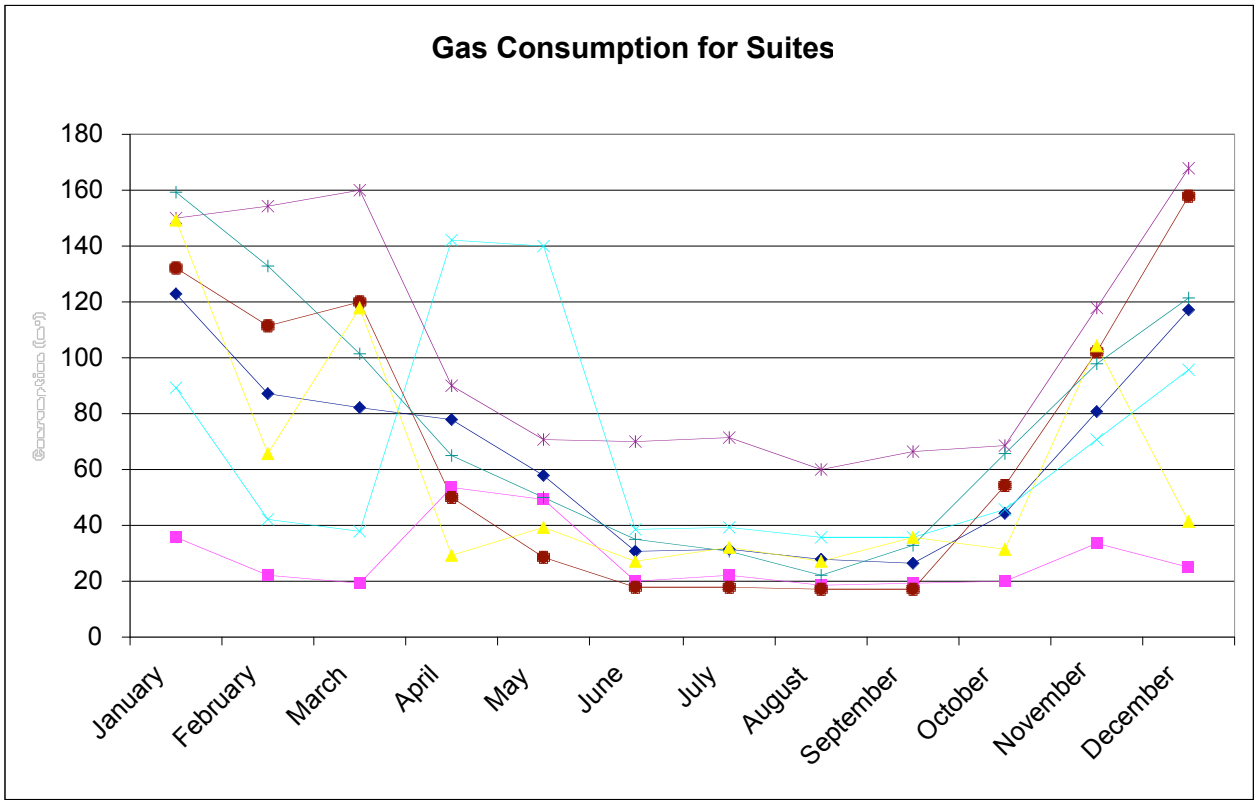


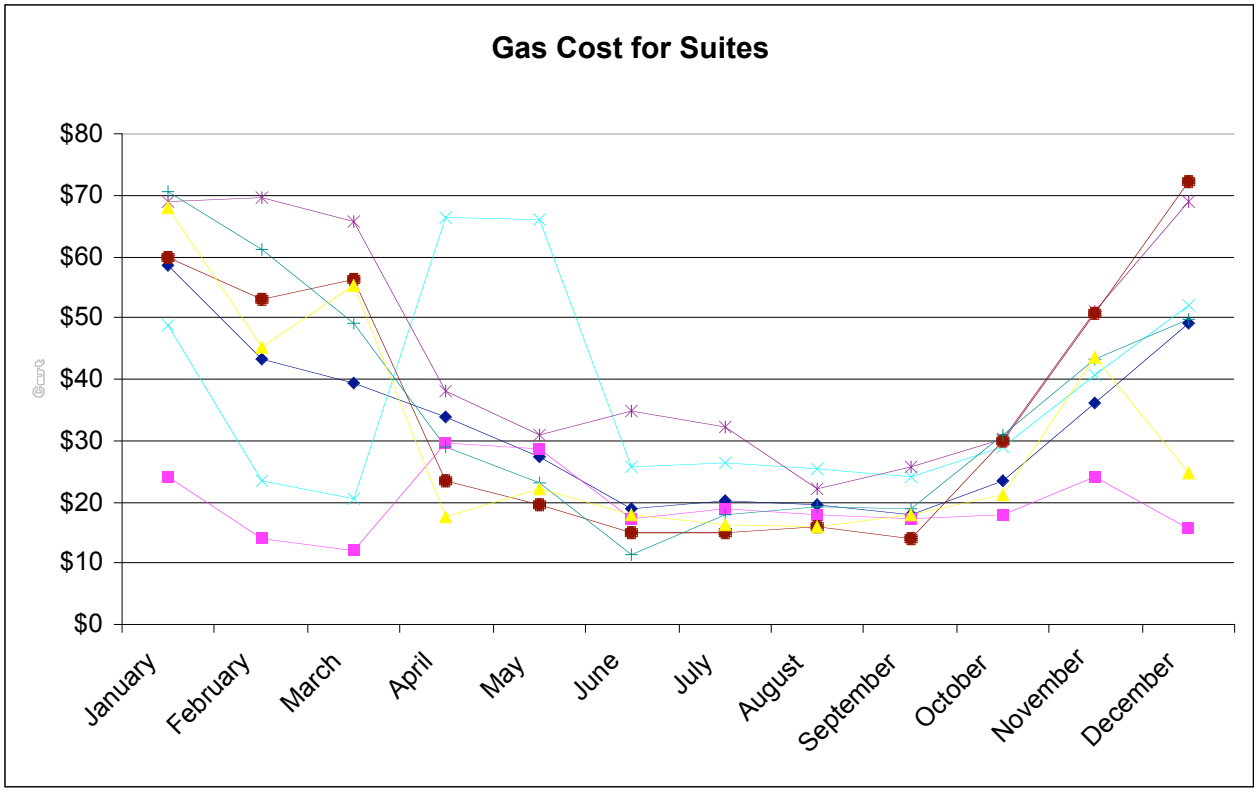


Energy content of natural gas is assumed to be 10.44 kWh, or 37.6 MJ per cubic metre. There is no correction for equipment efficiency: these numbers are based on metered consumption of all gas consumed in the suite.


Electric Consumption for Suites
900
800
700
600
500
400
300
200
100
0
January
February
March
April
May
June
July
August
September
October
November
December


Electric Cost for Suites
$80
$70
$60
$50
$40
$30
$20
$10
$0
January
February
March
April
May
June
July
August
September
October
November
December


Gas Consumption for Suites
180
160
140
120
100
80
60
40
20
0
January
February
March
April
May
June
July
August
September
October
November
December


Gas Cost for Suites
$80
$70
$60
$50
$40
$30
$20
$10
$0
January
February
March
April
May
June
July
August
September
October
November
December

Appendix G – Data and Information for Buildings in the Sample Set

Building 1

General

Number of Floors	13
Number of Living Units	105
Type of Building	Condominium
Occupant Profile	Young professionals, a few empty nesters
Suite area range	
First Year Occupied	Fall 2002
Gas metering	Meters adjacent to equipment in individual suites, and for common area
Electricity metering	LDC meters and bills total building and individual suites. Suite meters located in metering closets on alternate floors
In-Suite Systems (Heating, A/C, DHW)	MagicPak direct-fired furnaces for heat and A/C; separate gas-fired water heaters for DHW. MagicPak unit includes combustion and steel heat exchange surface for space heating, compressor/condenser/evaporator for A/C.
Ownership and maintenance	Gas utility owns and services both the storage water heater *and* the MagicPak furnace and air-conditioning package. Suite owner pays monthly rent for the equipment on their gas bill.
Air distribution	High wall diffusers at the perimeters of the suite connected to ducts in valences.

System Drainage

	Drain to DWV stack	**Drip pan**	**Direct to building exterior**	**Other**
Space heater combustion condensate			Yes	
A/C condensate			Yes	
Tank leaks and PRV	Yes,			
Any rust (or other) stains on bldg exterior near grille-work?	No.			

Air handling ductwork

In-slab	No.
Dropped ceiling	No.
Room valances	Yes.
High interior sidewall diffusers	Yes.
Perimeter diffusers	Yes.
Central or distributed return air	Central
Other?	

Combustion air intake and Exhaust venting

	DHW: Sealed combustion, forced draft, common fan for combustion air and exhaust. Separate uninsulated PVC pipes for combustion air and exhaust, power-vented horizontally to exterior wall. Space conditioning: package includes heating and A/C. Natural draft and exhaust combustion.

Exterior venting arrangement

Space Heating: All combustion air intake and exhaust takes place in unconditioned space behind a louvre that protects the equipment from the weather. DHW: Intake air and exhaust terminate on exterior wall in 45-degree PVC elbows.

Gas Meter

Adjacent to equipment in-suite	Yes
In meter closet outside suite	
Remotely/locally read by utility	Remote
Measures all in-suite consumption	Yes

Electricity Meter

Adjacent to equipment in-suite	
In meter closet outside suite	Yes
Remotely/locally read by utility	Local
Measures all in-suite consumption	Yes

Controls: Non-programmable, 24V thermostat with Heat, A/C, Off switch.

CO, CO2 detection? No., location of alarms? Smoke, CO2 and CO each have their own detection and alarm, ceiling mounted near entry, in hallway to bedrooms.
Domestic Hot Water Temperature Adjustment Thermostat on water heater unit.

Apartment Ventilation

Corridor air supply with *in-suite* bathroom and kitchen exhaust	Yes
Corridor air supply with *Central* bathroom-kitchen exhaust	

Other:

Building 2

General

Number of Floors	12
Number of Living Units	156
Type of Building	Condominium
Occupant Profile	Families with children, a few empty nesters, young professionals
Suite area range	
First Year Occupied	1996
Gas metering	Meters adjacent to equipment in individual suites, and for common area
Electricity metering	LDC meters and bills total building and individual suites. Suite meters located in metering closets on alternate floors
In-Suite Systems (Heating, A/C, DHW)	Combo system. High efficiency gas-fired storage water heater provides 140 F water to the heating coil in the AHU, and through a tempering (anti-scald) valve to the kitchen and baths. Air-conditioning provided by water-cooled condenser/compressor unit mounted with evaporator coil in AHU. All condensers connected in a water loop to roof-mounted cooling tower. Loop pumped continuously year round.
Ownership and maintenance	Gas utility owns and services the storage water heater. Suite owner owns and is responsible for space conditioning package including combustion chamber, heat exchange surface, fan, filter A/C coil, compressor evaporator and condenser unit.
Air distribution	High wall diffusers at the perimeters of the suite connected to ducts in valences and dropped ceiling.

System Drainage

	Drain to DWV stack	**Drip pan**	**Direct to building exterior**	**Other**
Space heater combustion condensate	Yes			
A/C condensate	Yes			
Tank leaks and PRV	Yes			
Any rust (or other) stains on bldg exterior near grille-work?	Clean and clear.			

Air handling ductwork

In-slab	No.
Dropped ceiling	Yes.
Room valances	Yes.
High interior sidewall diffusers	Yes.
Perimeter diffusers	Yes.
Central or distributed return air	Central.
Other?	

Combustion air intake and Exhaust venting

Note: combo unit – storage water heater provides space and water heating	Sealed combustion, forced draft, common fan for combustion air and exhaust. Concentric pipe arrangement to intake/exhaust termination mounted on exterior wall. Intake pipe not insulated. Combustion air/exhaust conduits run horizontally to exterior wall. No opportunity for residents' gear to block combustion air or exhaust. Possibility of ice build-up blocking exhaust?

Exterior venting arrangement

Concentric pipes. Inner exhaust pipe 2.5" DIA PVC projects 18" past exterior wall plane. Clearly well designed and approved terminal; no possibility of short-circuit. Outer combustion air intake pipe 6" PVC ends in coarse debris screen flush with exterior wall surface.
White PVC assembly unattractive, difficult to incorporate in building aesthetics. No perceptible noise.
Kitchen and bath exhausts share common fan.

Gas Meter

Adjacent to equipment in-suite	Yes
In meter closet outside suite	
Remotely/locally read by utility	Remote
Measures all in-suite consumption	Yes

Electricity Meter

Adjacent to equipment in-suite	
In meter closet outside suite	Yes
Remotely/locally read by utility	Local
Measures all in-suite consumption	Yes

Controls:
Non-programmable, 24V thermostat with Heat, A/C, Off switch.

CO, CO_2 detection? No., location of alarms?
Smoke, detector/alarm.

Domestic Hot Water Temperature Adjustment
Thermostat on water heater unit.

Apartment Ventilation

Corridor air supply with *in-suite* bathroom and kitchen exhaust	Yes
Corridor air supply with *Central* bathroom-kitchen exhaust	

Other:

Building 3

General

Number of Floors	4
Number of Living Units	46
Type of Building	Condominium
Occupant Profile	Young professionals, a few families with children, a few empty nesters
Suite area range	700 to 1450 square feet
First Year Occupied	2000
Gas metering	Meters adjacent to equipment in individual suites, and for common area
Electricity metering	LDC meters and bills total building and individual suites. Suite meters located in metering closets on alternate floors
In-Suite Systems (Heating, A/C, DHW)	On-demand (Ocean Luna) water heaters – one for space heating, the other for DHW separate controls and combustion but integrated into single wall-mounted package. Split system air-conditioning comprising evaporator coil in AHU, condenser/compressor unit on roof. Ladder/hatch access to roof.
Ownership and maintenance	Gas utility owns and services the on-demand water heater, up to but not including heating coil. Suite owner owns and is responsible for AHU, including heating coil, fan, circulating pump, A/C coil, compressor and condenser unit.
Air distribution	High wall diffusers at the perimeters of the suite connected to ducts in valences and dropped ceiling.

System Drainage

	Drain to DWV stack	**Drip pan**	**Direct to building exterior**	**Other**
Space heater combustion condensate	Yes			
A/C condensate	Yes			
Tank leaks and PRV	Yes	No; relies on floor drain		
Any rust (or other) stains on bldg exterior near grille-work?	Auditor notes significant ice formation on walls under some exhaust pipes.			

Air handling ductwork

In-slab	
Dropped ceiling	Yes – entry area
Room valances	Yes
High interior sidewall diffusers	Yes
Perimeter diffusers	Yes
Central or distributed return air	Central
Other?	

Combustion air intake and Exhaust venting

Note: On-demand water heater provides space and water heating	Sealed combustion, forced draft, common fan for combustion air and exhaust. Concentric pipe arrangement from water heaters to intake/exhaust termination mounted on exterior wall. Combustion air/exhaust conduits run horizontally to exterior wall. On-demand water heater package mounted on exterior wall: combustion exhaust conduit less than 12 inches overall. Intake pipe not insulated. . No opportunity for residents' gear to block combustion air or exhaust.

Exterior venting arrangement

Concentric pipe termination, provided by manufacturer. Clearly well designed and approved terminal; no possibility of short –circuit. Outer combustion air intake pipe 6" PVC ends in coarse debris screen flush with exterior wall surface. While less noticeable (painted metal, more compact) than the white PVC assembly used in other installations, the terminal is still difficult to incorporate in building aesthetics. No perceptible noise. Kitchen and bath exhausts share common fan.

Gas Meter

Adjacent to equipment in-suite	Yes
In meter closet outside suite	
Remotely/locally read by utility	Remote
Measures all in-suite consumption	Yes

Electricity Meter

Adjacent to equipment in-suite	
In meter closet outside suite	Yes
Remotely/locally read by utility	Local
Measures all in-suite consumption	Yes

Controls:

Johnson Controls. Non-programmable, 24V thermostat with Heat, A/C, Off switch.

CO, CO_2 detection? No., location of alarms?

Smoke, CO_2 and CO each have their own detection and alarm, ceiling mounted near entry, in hallway to bedrooms.

Domestic Hot Water Temperature Adjustment

Thermostat on water heater unit.

Apartment Ventilation

Corridor air supply with *in-suite* bathroom and kitchen exhaust	Yes
Corridor air supply with *Central* bathroom-kitchen exhaust	

Other:

Building 4

General

Number of Floors	4
Number of Living Units	87
Type of Building	Condominium
Occupant Profile	Young professionals, a few families with children, a few empty nesters
Suite area range	
First Year Occupied	Fall 2002
Gas metering	Meters adjacent to equipment in individual suites, and for common area
Electricity metering	LDC meters and bills total building and individual suites. Suite meters located in metering closets on alternate floors
In-Suite Systems (Heating, A/C, DHW)	MagicPak gas-fired furnaces for heat and A/C; separate gas-fired water heaters for DHW. MagicPak unit includes combustion and steel heat exchange surface for space heating, compressor/condenser/evaporator for A/C.
Ownership and maintenance	Gas utility owns and services the storage water heater. Suite owner owns and is responsible for space conditioning package including combustion chamber, heat exchange surface, fan , filter A/C coil, compressor evaporator and condenser unit.
Air distribution	High wall diffusers at the perimeters of the suite connected to ducts in valences and dropped ceiling.

System Drainage

	Drain to DWV stack	**Drip pan**	**Direct to building exterior**	**Other**
Space heater combustion condensate			Yes	
A/C condensate			Yes	
Tank leaks and PRV		Yes		
Any rust (or other) stains on bldg exterior near grille-work?	Clean and clear (new building).			

Air handling ductwork

In-slab	No.
Dropped ceiling	Yes – 1 foot from floor slab overhead throughout suite.
Room valances	No.
High interior sidewall diffusers	No.
Perimeter diffusers	No.
Central or distributed return air	Central
Other?	Dropped ceiling throughout allows running of flex duct to space as needed

Combustion air intake and Exhaust venting

	DHW: Sealed combustion, forced draft, common fan for combustion air and exhaust. Separate uninsulated PVC pipes for combustion air and exhaust, power-vented horizontally to exterior wall. Space conditioning: package includes heating and A/C. Natural draft and exhaust combustion.

Exterior venting arrangement

Space Heating: All combustion air intake and exhaust takes place in unconditioned space behind a louvre that protects the equipment from the weather. DHW: Intake air and exhaust terminate on exterior wall in 45-degree PVC elbows

Gas Meter

Adjacent to equipment in-suite	Yes
In meter closet outside suite	
Remotely/locally read by utility	Remote
Measures all in-suite consumption	Yes

Electricity Meter

Adjacent to equipment in-suite	
In meter closet outside suite	Yes
Remotely/locally read by utility	Local
Measures all in-suite consumption	Yes

Controls:
Non-programmable, 24V thermostat with Heat, A/C, Off switch.

CO, CO_2 detection? No., location of alarms?
Smoke, CO_2 and CO each have their own detection and alarm, ceiling mounted near entry, in hallway to bedrooms.
Domestic Hot Water Temperature Adjustment
Thermostat on water heater unit.

Apartment Ventilation

Corridor air supply with *in-suite* bathroom and kitchen exhaust	Yes
Corridor air supply with *Central* bathroom-kitchen exhaust	

Other:

Building 5

General

Number of Floors	6
Number of Living Units	246
Type of Building	Condominium
Occupant Profile	Families, empty nesters, young professionals
Suite area range	700 to 1450 square feet
First Year Occupied	1997
Gas metering	Meters adjacent to equipment in individual suites, and for common area
Electricity metering	LDC meters and bills total building. Meter data management agency submeters individual suites and issues quarterly bills to residents.
In-Suite Systems (Heating, A/C, DHW)	Combo system. High efficiency gas-fired storage water heater provides 140 F water to the heating coil in the AHU, and through a tempering (anti-scald) valve to the kitchen and baths. Split system air-conditioning comprising evaporator coil in AHU, condenser/compressor unit on roof or in the parking garage.
Ownership and maintenance	Gas utility owns and services the storage water heater, up to but not including heating coil. Suite owner owns and is responsible for AHU, including heating coil, fan, circulating pump, A/C coil, compressor and condenser unit.
Air distribution	High wall diffusers at the perimeters of the suite connected to ducts in valences and dropped ceiling.

System Drainage

	Drain to DWV stack	**Drip pan**	**Direct to building exterior**	**Other**
Space heater combustion condensate	Yes, through neutralizer cartridge			
A/C condensate	Yes			
Tank leaks and PRV	Yes	No; relies on floor drain		
Any rust (or other) stains on bldg exterior near grille-work?	Auditor notes significant ice formation on walls under some exhaust pipes.			

Air handling ductwork

In-slab	
Dropped ceiling	Yes – entry area
Room valances	Yes
High interior sidewall diffusers	Yes
Perimeter diffusers	Yes
Central or distributed return air	Central
Other?	

Combustion air intake and Exhaust venting

Note: combo unit – storage water heater provides space and water heating	Sealed combustion, forced draft, common fan for combustion air and exhaust. Concentric pipe arrangement. to intake/exhaust termination mounted on exterior wall. Intake pipe not insulated. Combustion air/exhaust conduits run horizontally to exterior wall. No opportunity for residents' gear to block combustion air or exhaust. Possibility of ice build-up blocking exhaust? (Auditor notes significant ice build-up on brickwork under exhaust pipe.)

Exterior venting arrangement

Concentric pipes. Inner exhaust pipe 2.5" DIA PVC projects 18" past exterior wall plane. Clearly well designed and approved terminal; no possibility of short –circuit. Outer combustion air intake pipe 6" PVC ends in coarse debris screen flush with exterior wall surface.
White PVC assembly unattractive, difficult to incorporate in building aesthetics. No perceptible noise.
Kitchen and bath exhausts share common fan. (Guess - only one grille per suite visible on exterior walls.)

Gas Meter

Adjacent to equipment in-suite	Yes
In meter closet outside suite	
Remotely/locally read by utility	Remote
Measures all in-suite consumption	Yes

Electricity Meter

Adjacent to equipment in-suite	
In meter closet outside suite	Yes
Remotely/locally read by utility	Local
Measures all in-suite consumption	Yes

Controls:
Honeywell. Non-programmable, 24V thermostat with Heat, A/C, Off switch.

CO, CO_2 detection? No., location of alarms?
Smoke only.

Domestic Hot Water Temperature Adjustment
Sparco tempering valve.

Apartment Ventilation

Corridor air supply with *in-suite* bathroom and kitchen exhaust	Yes
Corridor air supply with *Central* bathroom-kitchen exhaust	

Other:
Access to roof, where most of the A/C condenser/compressor units are located, by hatch and ladder. Some are wall-mounted in the parking garage.

Building 6

General

Number of Floors	4
Number of Living Units	216
Type of Building	Condominium
Occupant Profile	Even mix of families, empty nesters, young professionals
First Year Occupied	1999
Gas metering	Meters adjacent to equipment in individual suites, and for common area
Electricity metering	LDC meters and bills total building. Meters in closets on alternate floors.
In-Suite Systems (Heating, A/C, DHW)	Combo system. High efficiency gas-fired storage water heater provides 140 F water to the heating coil in the AHU, and through a tempering (anti-scald) valve to the kitchen and baths. Split system air-conditioning comprising evaporator coil in AHU, condenser/compressor unit on roof.
Ownership and maintenance	Gas utility owns and services the storage water heater, up to but not including heating coil. Suite owner owns and is responsible for AHU, including heating coil, fan, circulating pump, A/C coil, compressor and condenser unit.
Air distribution	High wall diffusers at the perimeters of the suite connected to ducts in valences and dropped ceiling.

System Drainage

	Drain to DWV stack	**Drip pan**	**Direct to building exterior**	**Other**
Space heater combustion condensate	Yes.			
A/C condensate	Yes			
Tank leaks and PRV	Yes	Yes, plumbed to drain		
Any rust (or other) stains on bldg exterior near grille-work?	None.			

Air handling ductwork

In-slab	
Dropped ceiling	Yes – entry area for a grille to return air plenum.
Room valances	Yes
High interior sidewall diffusers	
Perimeter diffusers	Yes
Central or distributed return air	Central – grille in dropped ceiling. In addition, equipment room door has grille.
Other?	

Combustion air intake and Exhaust venting

Note: combo unit – storage water heater provides space and water heating	Sealed combustion, forced draft, common fan for combustion air and exhaust. Separate PVC pipes for intake of combustion air (not insulated) and exhaust of combustion gases. Pipes run horizontally to exterior wall. No opportunity for residents' gear to block combustion air or exhaust.

Exterior venting arrangement

Exhaust pipe 2.5" DIA PVC projects 3-4" past exterior wall plane, terminating in a 45 elbow. Intake air drawn through 8' X 10" stainless louvre. While this termination arrangement is no doubt functional, the parts count (and maybe the labour) goes up compared to the more common concentric pipe termination. As it's much closer to the wall plane, it could be argued this configuration is less obtrusive from a building aesthetics point of view. Kitchen and bath exhausts share common fan.

Gas Meter

Adjacent to equipment in-suite	Yes
In meter closet outside suite	
Remotely/locally read by utility	Remote
Measures all in-suite consumption	Yes

Electricity Meter

Adjacent to equipment in-suite	
In meter closet outside suite	Yes
Remotely/locally read by utility	Local
Measures all in-suite consumption	Yes

Controls:
Honeywell. Non-programmable, 24V thermostat with Heat, A/C, Off switch.

CO, CO_2 detection? No., location of alarms?
Smoke only.
Domestic Hot Water Temperature Adjustment
Tempering valve. Storage tank thermostat typically set around 140 F.

Apartment Ventilation

Corridor air supply with *in-suite* bathroom and kitchen exhaust	Yes
Corridor air supply with *Central* bathroom-kitchen exhaust	

Other:

Building 7

General

Number of Floors	3
Number of Living Units	15
Type of Building	Rental
Occupant Profile	Families, empty nesters.
Suite area range	
First Year Occupied	1995
Gas metering	Meters adjacent to equipment in individual suites
Electricity metering	LDC meters and bills individual suites.
In-Suite Systems (Heating, A/C, DHW)	Combo system. High efficiency gas-fired storage water heater provides 140 F water to the heating coil in the AHU, and through a tempering (anti-scald) valve to the kitchen and baths. Space heating loop to AHU not insulated. No air-conditioning.
Ownership and maintenance	Gas utility owns and services the storage water heater, up to but not including heating coil. Tenants pay monthly rental on their gas bill. Landlord owns and is responsible for all (in-suite and common area) HVAC components in the building.
Air distribution	High wall diffusers at the perimeters of the suite connected to ducts in valences and dropped ceiling.

System Drainage

	Drain to DWV stack	**Drip pan**	**Direct to building exterior**	**Other**
Space heater combustion condensate	Yes.			
A/C condensate	Yes			
Tank leaks and PRV	Yes	Yes, plumbed to floor drain		
Any rust (or other) stains on bldg exterior near grille-work?	None			

Air handling ductwork

In-slab	
Dropped ceiling	Yes.
Room valances	Yes.
High interior sidewall diffusers	Yes.
Perimeter diffusers	
Return air to AHU	Grille in wall, dropped ceiling, or mechanical closet door ensures unobstructed path for return air to filter.
Other?	

Combustion air intake and Exhaust venting

Note: combo unit – storage water heater provides space and water heating	Sealed combustion, forced draft, common fan for combustion air and exhaust. Concentric pipe arrangement. for combustion air/exhaust. Intake pipe not insulated. Combustion air/exhaust conduits run horizontally to exterior wall. No opportunity for residents' gear to block combustion air or exhaust.

Exterior venting arrangement

Concentric pipe fitting on brick exterior. Builder added a Tee to the end of what's normally a straight pipe protruding 15 inches or so beyond wall plane. Kitchen and bath exhausts share common fan.

Gas Meter

Adjacent to equipment in-suite	Yes
In meter closet outside suite	
Remotely/locally read by utility	Remote
Measures all in-suite consumption	Yes

Electricity Meter

Adjacent to equipment in-suite	
In meter closet outside suite	Yes
Remotely/locally read by utility	Local
Measures all in-suite consumption	Yes

Controls:

Non-programmable, 24V thermostat. Heat only.

CO, CO_2 detection? No., location of alarms?

Smoke only.

Domestic Hot Water Temperature Adjustment

Sparco tempering valve.

Apartment Ventilation

No mechanical ventilation to the corridors in this (small) building. Operable windows in corridors and stair landings. Electric baseboard heaters provide corridor heating.

Other:

Building 8

General

Number of Floors	4
Number of Living Units	84
Type of Building	Rental
Occupant Profile	Families, empty nesters.
Suite area range	
First Year Occupied	December 1995
Gas metering	Meters adjacent to equipment in individual suites, and for common area
Electricity metering	LDC meters and bills total building and individual suites.
In-Suite Systems (Heating, A/C, DHW)	Combo system. High efficiency gas-fired storage water heater provides 140 F water to the heating coil in the AHU, and through a tempering (anti-scald) valve to the kitchen and baths. Space heating loop to AHU well insulated. No air-conditioning.
Ownership and maintenance	Gas utility owns and services the storage water heater, up to but not including heating coil. Tenants pay monthly rental on their gas bill. Landlord owns and is responsible for all (in-suite and common area) HVAC components in the building.
Air distribution	High wall diffusers at the perimeters of the suite connected to ducts in valences and dropped ceiling.

System Drainage

	Drain to DWV stack	**Drip pan**	**Direct to building exterior**	**Other**
Space heater combustion condensate	Yes.			
A/C condensate	Yes			
Tank leaks and PRV	Yes	Yes, plumbed to floor drain		
Any rust (or other) stains on bldg exterior near grille-work?	None			

Air handling ductwork

In-slab	
Dropped ceiling	Yes.
Room valances	Yes.
High interior sidewall diffusers	
Perimeter diffusers	
Return air to AHU	Grille in wall, dropped ceiling, or mechanical closet door ensures unobstructed path for return air to filter.
Other?	

Combustion air intake and Exhaust venting

Note: combo unit – storage water heater provides space and water heating	Sealed combustion, forced draft, common fan for combustion air and exhaust. Separate, uninsulated PVC pipes for combustion air intake and exhaust, running horizontally to exterior wall. No opportunity for residents' gear to block combustion air or exhaust. Possibility of ice build-up blocking exhaust?

Exterior venting arrangement

Kitchen and bath exhausts share common fan.

Gas Meter

Adjacent to equipment in-suite	Yes
In meter closet outside suite	
Remotely/locally read by utility	Remote
Measures all in-suite consumption	Yes

Electricity Meter

Adjacent to equipment in-suite	
In meter closet outside suite	Yes
Remotely/locally read by utility	Local
Measures all in-suite consumption	Yes

Controls:

Non-programmable, 24V thermostat. Heat only.

CO, CO_2 detection? No., location of alarms?

Smoke only.

Domestic Hot Water Temperature Adjustment

Sparco tempering valve.

Apartment Ventilation

No mechanical ventilation to the corridors in this building. (Residents complained of stale air in corridors, particularly in winter; a retrofit was being considered to address this issue at the time of the audit.) Operable windows in corridors.
Apartments get direct fresh air (usually delivered to the mechanical closet) through an air-to-air heat exchange scheme. Some residents complained of occasional cross-contamination from the exhaust of one exchanger to the intake of another.

Other:

Compared to others in this survey, this building suffers from a lack of attention to service access for the mechanical equipment. Filter changes were particularly awkward. This was not a design issue – many equipment rooms had more than enough room to accommodate the overhead AHU and storage water heater. We conclude the trades on this project took no interest in any need to service the equipment, and simply installed it as fast as possible.

Building 9

General

Number of Floors	26
Number of Living Units	203
Type of Building	Condominium
Occupant Profile	Families, empty nesters, young professionals
First Year Occupied	1997
Gas metering	Meters adjacent to equipment in individual suites, and for common area. Monthly bills.
Electricity metering	LDC meters and bills total building and individual suites Issues bi-monthly bills to residents.
In-Suite Systems (Heating, A/C, DHW)	Combo system. High efficiency gas-fired storage water heater provides 140 F water to the heating coil in the AHU, and through a tempering (anti-scald) valve to the kitchen and baths. Heating loop through AHU is insulted. Split system air-conditioning comprising evaporator coil in AHU, condenser/compressor unit in niche on exterior wall, accessible through closet in bedroom, by removing wall panel
Ownership and maintenance	Gas utility owns and services the storage water heater, up to but not including heating coil. Suite owner owns and is responsible for AHU, including heating coil, fan, circulating pump, A/C coil, compressor and condenser unit.
Air distribution	High wall diffusers at the perimeters of the suite connected to ducts in valences and dropped ceiling.

System Drainage

	Drain to DWV stack	**Drip pan**	**Direct to building exterior**	**Other**
Space heater combustion condensate	Yes.	No.		
A/C condensate	Yes	No.		
Tank leaks and PRV	Yes	No; relies on floor drain		
Any rust (or other) stains on bldg exterior near grille-work?	No.			

Air handling ductwork

In-slab	
Dropped ceiling	Used in entryway to provide return air grille on AHU plenum.
Room valances	Not for heating/cooling air ducts. Bulkheads were used to conceal combustion air and exhaust pipes.
High interior sidewall diffusers	Yes. High-velocity system enables use of 3" ducts inside walls.
Perimeter diffusers	Yes
Central or distributed return air	Central
Other?	

Combustion air intake and Exhaust venting

Note: combo unit – storage water heater provides space and water heating	Sealed combustion, forced draft, common fan for combustion air and exhaust. Concentric pipe arrangement. to intake/exhaust termination mounted on exterior wall. Intake pipe not insulated. Combustion air/exhaust conduits run horizontally to exterior wall. No opportunity for residents' gear to block combustion air or exhaust.

Exterior venting arrangement

Concentric pipes. Inner exhaust pipe 2.5" DIA PVC projects 18" past exterior wall plane. Clearly well designed and approved terminal; no possibility of short –circuit. Outer combustion air intake pipe 6" PVC ends in coarse debris screen flush with exterior wall surface. White PVC assembly unattractive, difficult to incorporate in building aesthetics. No perceptible noise. Kitchen and bath exhausts share common fan.

Gas Meter

Adjacent to equipment in-suite	Yes
In meter closet outside suite	
Remotely/locally read by utility	Remote
Measures all in-suite consumption	Yes

Electricity Meter

Adjacent to equipment in-suite	
In meter closet outside suite	Yes
Remotely/locally read by utility	Local
Measures all in-suite consumption	Yes

Controls:

Honeywell. Non-programmable, 24V thermostat with Heat, A/C, Off switch, Fan ON, Fan AUTO

CO, CO_2 detection? No., location of alarms?

Smoke only.

Domestic Hot Water Temperature Adjustment

Sparco tempering valve.

Apartment Ventilation

Corridor air supply with *in-suite* bathroom and kitchen exhaust	Yes
Corridor air supply with *Central* bathroom-kitchen exhaust	

Other:

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