PROCESS MAKES PRODUCT:

THE C.K. CHOI BUILDING FOR THE INSTITUTE OF ASIAN RESEARCH AT THE UNIVERSITY OF BRITISH COLUMBIA

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INTRODUCTION

The University of British Columbia (UBC) recently completed a ten year, 500 million dollar building expansion program. Dr. David Strangway, then president of the university, initiated a fundraising campaign that became the most successful in Canadian history. As part of the building program the university set an objective of making the C.K. Choi Building for the Institute of Asian Research a demonstration ‘green’ building. One of the selection criteria for the prime consultant became an expertise with or at least knowledge of and interest in ‘green’ buildings. The successful consultants were Matsuzaki Wright Architects. Subsequently, the architects used similar criterion for their sub-consultant selection.

The C.K. Choi Building for the Institute of Asian Research is a graduate research building of 3,000 square metres [30,000 ft²] made up of offices, graduate student workstations and seminar rooms. The Institute has five centres carrying out research representing China, Japan, Korea, South Asia and Southeast Asia.

The Associate Director, Project Development discussed with senior university officials and the users the possibility of establishing the facility as a demonstration project in sustainable design. Approval was given provided that the original program, schedule and budget were maintained. In March, 1993 a workshop was planned that would involve the entire project team in the setting of objectives for the project. Bob Berkebile (founding chair of the American Institute of Architects' Environment Committee) was brought in to facilitate the workshop.

Bob led the team in an inspirational and intensive two days of learning and exploration, concluding with a joint statement of goals and principles for the project. The workshop was attended by the Dean in charge of the facility, the Director of the Institute, representatives of the user group, a representative from the university's physical plant department, the architect and the sub-consultants (the structural, mechanical, and electrical engineers and the landscape architects). Additionally Dr. Ray Cole (a well-known researcher in ‘green’ buildings) from the UBC School of Architecture was present as a resource.

The workshop was a critical step in establishing a shared vision of the project as a building that would:

- establish the benchmark for state-of-the-art collaborative research
- express the character of the cultures participating in the research
- set new standards for sustainable design, construction and operation

The sustainable design principles and goals were organized under the following headings:

- site development issues
- materials
- energy
- indoor environmental quality
- facility character
- construction
- operation

Some of the specific targets that were set for resource and energy use:

- 50% less water use than normal
- no sewer connection
- 50% re-used/recycled materials
- 50% recyclable materials
- reduction of energy use below ASHRAE 90.1 levels by 35%
- lighting for less than 5 watts per square metre [0.5 W/ft^2]

The architects worked closely with their sub-consultants from the outset of the project. The implementation of a team approach to all work sessions facilitated an early and comprehensive understanding of the cross-disciplinary relationships of different aspects of the project.

Both synergies and conflicts were identified, which in turn assisted the team in determining design options with the greatest impact. Identifying and focusing on the synergies also helped to build momentum and commitment within the team that became invaluable during the difficult aspects of implementing the design objectives.

The team focused largely on first principles and keeping things simple. Innovations such as greywater recycling systems, composting toilets, integrating re-used building materials and naturally ventilated conference rooms meant taking risks in deviating from standard practice.

The final building has in some ways exceeded the expectations established at the workshop. While the numerical targets have not been calculated in all instances and have not been met in some others, the project has indeed set new standards. The University has been monitoring the performance of the building and has developed preliminary figures for electrical energy use, steam use, and water use.

PROJECT DESCRIPTION

The University of British Columbia lies at the tip of a peninsula to the west of Vancouver. The C.K. Choi Building is situated on a long, narrow site running north-south with a forested edge to the west and a road along the east. Initially, the design team members were skeptical of the possibility of an energy efficient building on a site with little solar access. However, they were able ultimately to capitalize on the ambient conditions of the site. The forest became a source of cool fresh air for the hot summer months. The road edge became a source of daylight for all the interior spaces. The five research centres were organized linearly around individual atriums which serve a number of roles: as identifiable expressions of each centre on the exterior; as visual links between the second and third floors; and as exhaust vents for stack ventilation.

WATER

Composting toilets save more than 1,000 litres [264 gal.] of water a day and a greywater recycling system processes the 'tea' from the composting toilets as well as the waste water from the sinks and reuses it for irrigation. Rainwater from the roof is stored on the site for irrigation during the summer. Excess water from the heavy Vancouver rains is diverted into the storm system.

ENERGY

The project participated in the BC Hydro Power Smart *New Building Design Program*. As part of the program, a study was conducted using the DOE-2E simulation program. The study indicated the building would achieve electricity savings of 57 per cent over a prototype building built to ASHRAE Standard 90.1. Overall energy use was estimated at nine per percent less than the ASHRAE 90.1 prototype building. However, it should be noted that this was not a typical prototype: this prototype building did not include air conditioning since it is UBC policy to not provide mechanical cooling. Consequently, the prototype building modeled for the comparison actually used less energy than one would normally expect for this type of office building.

The building is served by 100 per cent natural ventilation all year round. Fixed air-grilles below operable windows provide 9.4 litres per second [20 cfm] per person of outdoor air. Hot water baseboard heaters temper the air below the windows. As it moves through the office space, the air picks up the heat dissipated from people and equipment, and rises through the atria to relief openings at the top. Small fans provide additional circulation when the ambient temperature becomes too warm.

Steam from the university steam plant is passed through a heat exchanger and the hot water is distributed throughout the building to provide space heating. Domestic hot water is produced in an electric hot water tank, which includes a pre-heat coil in a nearby steam manhole. The intent was to recover the waste heat from the manhole, but in practice the heat gain has been negligible.

The building is retrofit-ready for solar power when the technology becomes financially feasible in a northwest coastal climate with overcast conditions.

The interior lighting strategy is based on lowered ambient lighting levels with supplementary task lighting where required. Facilitating interior daylighting was a high priority in the building design. Wherever possible natural light was introduced from two directions to soften and balance the lighting conditions. Daylight sensors and continuous dimming ballasts ensure that electric lighting is used only to supplement the available daylight. Occupancy sensors are also used to turn off artificial lights when they are not required. The connected lighting load is approximately nine watts per square metre [0.9 W/ft^2]. The capital premium for the lighting strategies was calculated at $43,000.

Total energy consumption costs were projected as reduced to $8,900 from $14,000 for the ASHRAE prototype building.

MATERIALS

Approximately 65 per cent of the heavy timber structure is re-used material from a demolished building across the road. The exterior brick is re-used material from old Vancouver city streets. The main interior stair handrail and atrium guardrails, all doors, sinks, toilet accessories and some electrical conduit are also re-used. Concrete, steel, insulation, drywall and ceramic tile have recycled content. Decorative finishes to functional materials, such as suspended ceilings, paint to the wiring trays and exposed pipes, floor finishes to concrete slabs, and cabinetwork, were eliminated wherever possible.

BUILDING PERFORMANCE

Due to various problems with the utility metering, actual consumption data has been limited since the building was commissioned. However, even this limited data shows that the building is exceeding the expectations formed during the design process.

WATER

As with the steam and electricity meters, the water meter was designed to be read electronically through the centralized Building Management System (BMS). However, due to a problem with the transducer, this water meter BMS has not been able to communicate with the meter. The main problem appears to be that the building uses such low quantities of water that that the signal does not register with the BMS system.

Manual meter readings from September to December 1998 indicate that the building consumes approximately 218 litres [58 gal.] per day, on average.

ENERGY

The building utilizes two forms of energy: steam is used to provide space heating, and electricity is used for lighting, ventilation, domestic hot water and to power office equipment and computers.

Steam

Much like the water meter, the steam meter installed during construction was oversized for the normal steam flows to the building. As a result, the meter produced inaccurate readings much of the time. The original two-inch Vortex meter was replaced with a one-inch meter and data has been collected since November 1998.

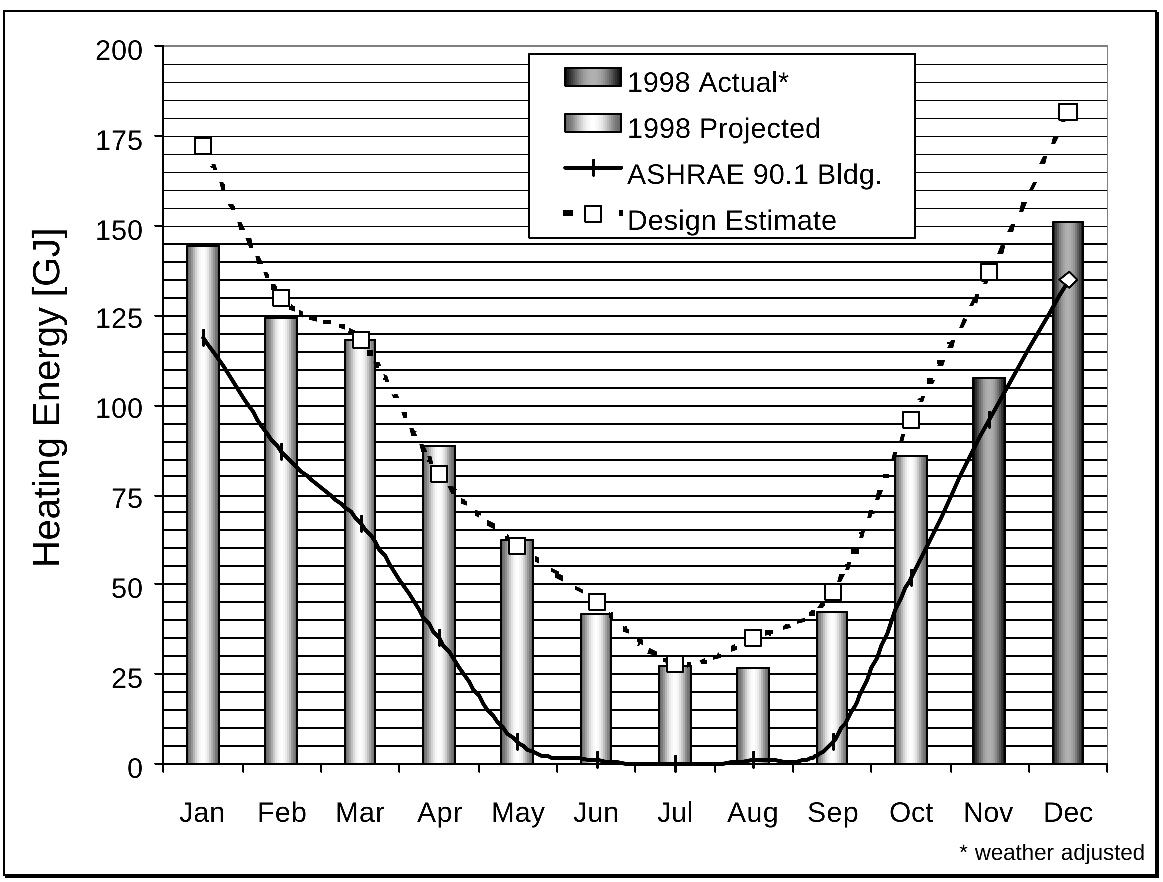

Figure 1. 1998 Monthly Heating Energy Use

The original design estimate, modeled with DOE-2, projected that this building would require 1,133 GJ [1,074,000 MBtu] per year for space heating, compared to 605 GJ [573,000 MBtu] for the prototype building—a 69 per cent increase. This higher heating requirement is due to the high window-to-wall ratio as well as the constant 9.4 litres per second [20 cfm] per person of fresh air entering the building year-round. This fresh air flow is essentially just additional infiltration adding to the heating load of the building.

The meter readings for November and December, adjusted to typical weather conditions, show that the heating requirements were 17 per cent less than the design estimate and 12 per cent more than the ASHRAE 90.1 prototype building for the same period. Projections of the heating energy use for the remainder of the year were based on the correlation between degree-days and steam consumption developed from these two months of data. Based on these projections, the C.K. Choi Building uses 69 per cent more heating energy than the ASHRAE 90.1 prototype and 10 per cent less than the design estimate. These projections will be verified over the next year.

Table 1. Monthly Heating Energy

	ASHRAE 90.1 Bldg. (GJ)	Design Estimate (GJ)	CK Choi Bldg. (GJ)
January	119	172	145*
February	87	130	124*
March	67	118	118*
April	35	81	89*
May	6	61	63*
June	1	45	42*
July	0	28	27*
August	1	35	27*
September	6	48	43*
October	52	96	86*
November	96	137	107**
December	135	182	151**
Total	**695**	**1,133**	**1,828***

* Projected
** Weather adjusted

Electricity

Electric metering over the last 15 months shows that the building has more than exceeded the design estimates. Monthly peak demand has averaged 24 kW compared to the design estimate of 44 kW and 97 kW for the ASHRAE 90.1 prototype building—reductions of 45 per cent and 75 per cent, respectively.

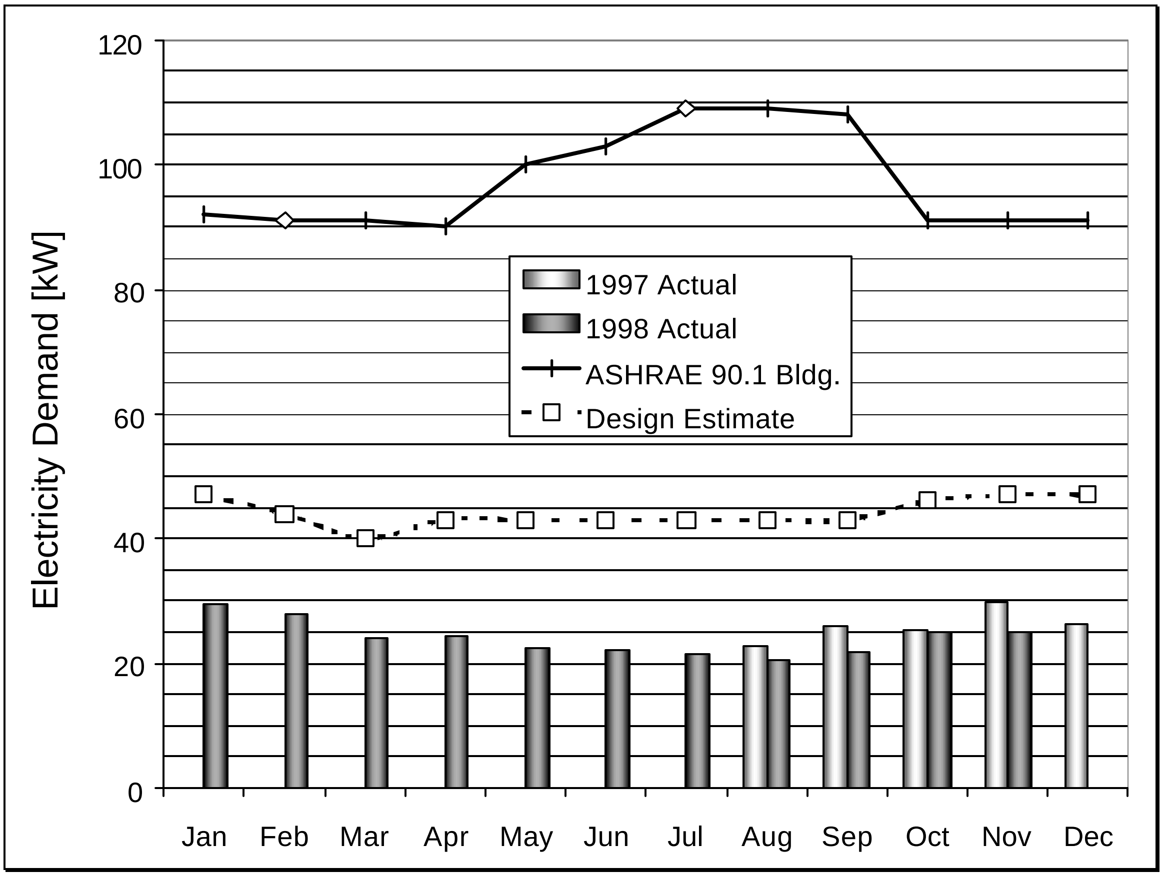

Figure 2. Monthly Electricity Peak Demand

Similarly, the metering shows that actual electricity consumption is 28 per cent below the design estimate and 69 per cent lower than a similar ASHRAE 90.1 prototype building: annual electricity consumption is approximately 101,000 kWh, compared to the design estimate of 142,500 kWh and 334,000 kWh for the ASHRAE 90.1 prototype.

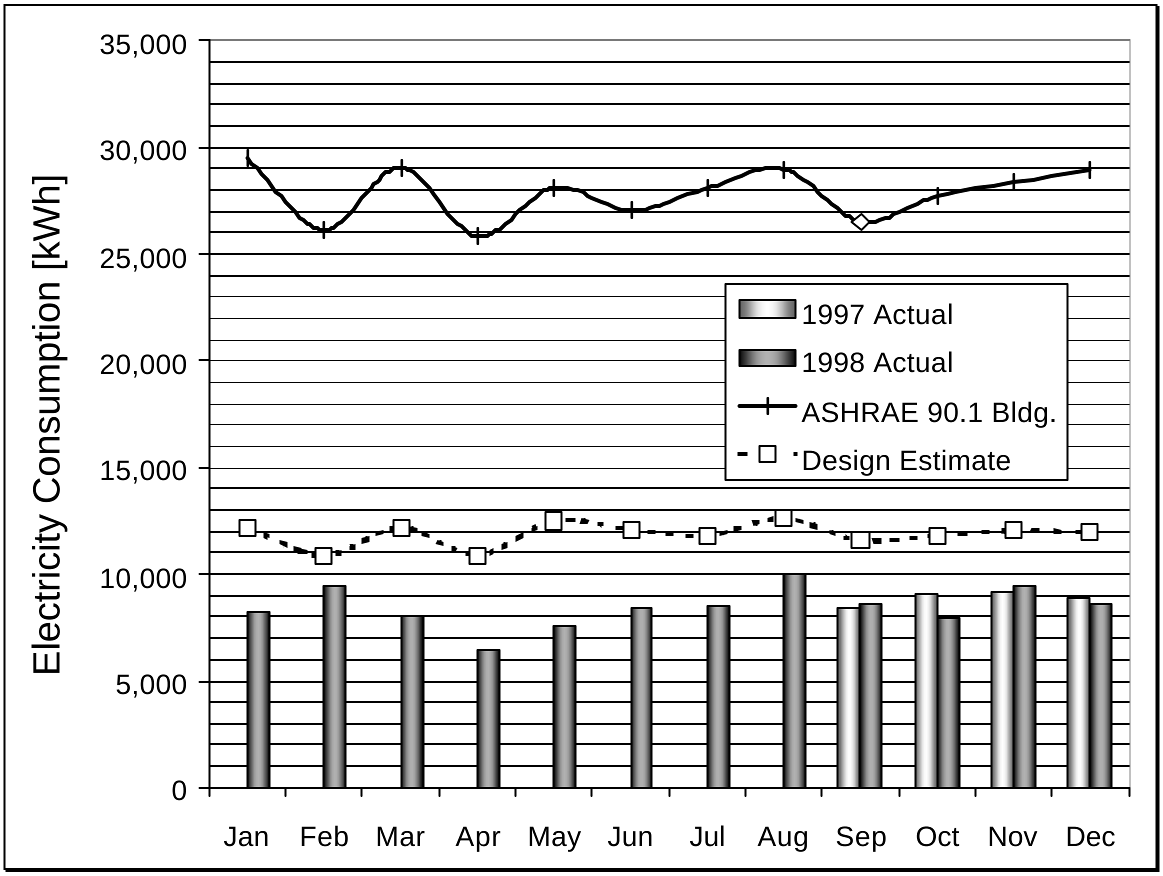

Figure 2. Monthly Electricity Consumption

Table 2. Monthly Electricity Peak Demand

	ASHRAE 90.1 Bldg. (kW)	Design Estimate (kW)	CK Choi Bldg. 1997 (kW)	CK Choi Bldg. 1998 (kW)
January	92	47		29.5
February	91	44		27.8
Mar	91	40		24.0
Apr	90	43		24.4
May	100	43		22.3
Jun	103	43		22.0
Jul	109	43		21.6
Aug	109	43	22.8	20.4
Sep	108	43	25.9	21.7
Oct	91	46	25.2	25.1
Nov	91	47	29.8	25.1
Dec	91	47	26.4	
Average	**97**	**44**	**26.0**	**24.0**

Table 3. Monthly Electricity Consumption

	ASHRAE 90.1 Bldg. (kWh)	Design Estimate (kWh)	CK Choi Bldg. 1997 (kWh)	CK Choi Bldg. 1998 (kWh)
January	29,477	12,186		8,218
February	26,129	10,876		9,463
Mar	29,055	12,178		8,093
Apr	25,825	10,895		6,500
May	28,112	12,490		7,578
Jun	27,036	12,111		8,402
Jul	28,076	11,812		8,483
Aug	28,974	12,613		9,986
Sep	26,525	11,582	8,468	8,570
Oct	27,726	11,816	9,123	7,918
Nov	28,363	12,057	9,188	9,432
Dec	28,924	11,964	8,905	8,569
Total	334,222	142,580		101,210

Overall Energy Performance

Overall energy use (steam and electricity combined) is about 23 per cent less than the ASHRAE 90.1 prototype building—annual savings total about 423 GJ [401,000 Mbtu]. Although this does not meet the original target of 35 per cent less than ASHRAE 90.1 standards, it is nevertheless a significant accomplishment given that the design estimates suggested a reduction of only nine per cent. In addition, a true ASHRAE 90.1 prototype building would include mechanical cooling, meaning that energy savings would be significantly greater than 23 per cent.

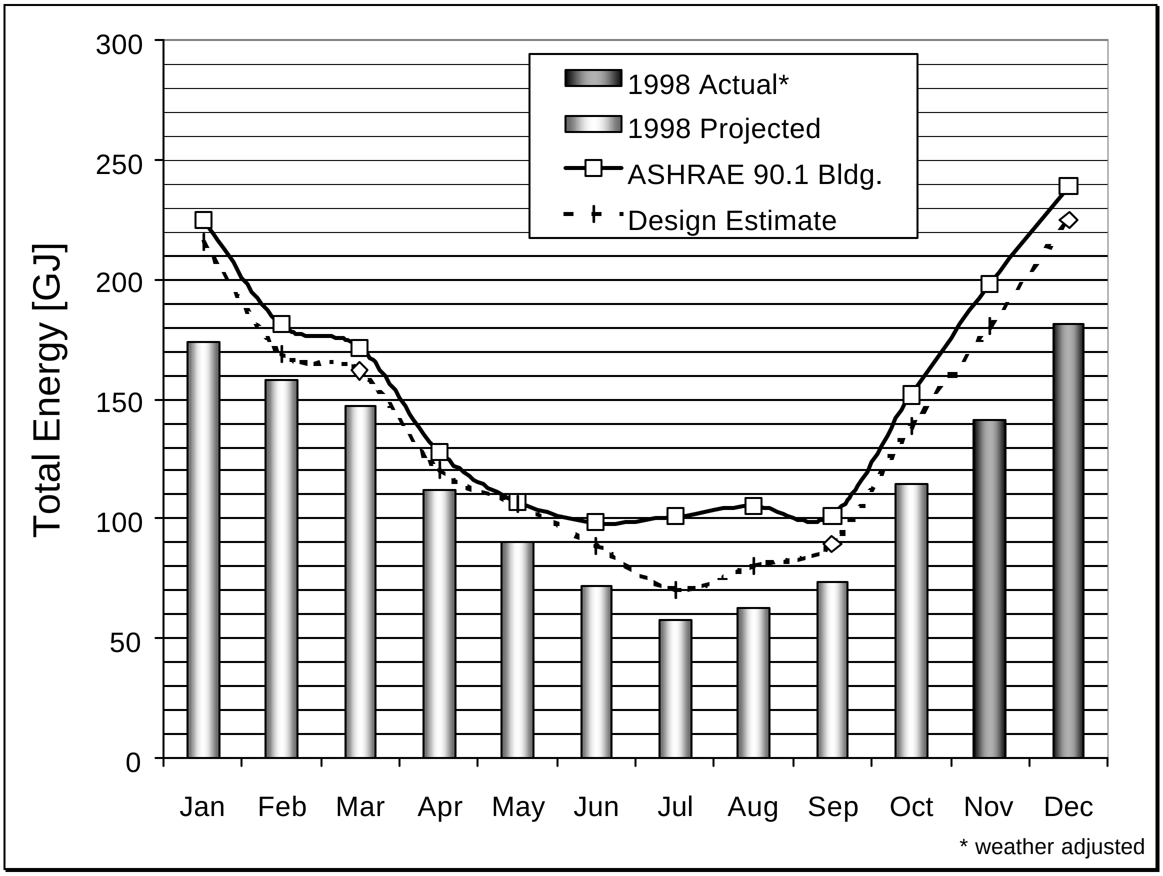

Figure 3. Combined Monthly Energy Use

Table 4. Monthly Energy Use

	ASHRAE 90.1 Bldg. (GJ)	Design Estimate (GJ)	CK Choi Bldg. (GJ)
January	225	216	174*
February	181	169	158*
March	172	162	147*
April	128	120	112*
May	107	106	90*
June	98	89	72*
July	101	71	58*
August	105	80	63*
September	101	90	73*
October	152	139	114*
November	198	180	141**
December	239	225	182**
Total	**1,808**	**1,646**	**1,385***

* Projected
** Weather adjusted

Energy Costs

Based on actual electricity, steam and natural gas (the heating fuel source for the ASHRAE 90.1 prototype building) on a month-by-month basis, the annual energy costs for the CK Choi building are 50 per cent less than the costs for the prototype building—an annual savings of $7,000. The cost savings are higher than the energy savings due to the differences in heating fuel (lower cost steam vs. higher cost natural gas) as well as the significant reduction in electricity consumption, which is about twice as expensive as steam on an energy unit cost basis.

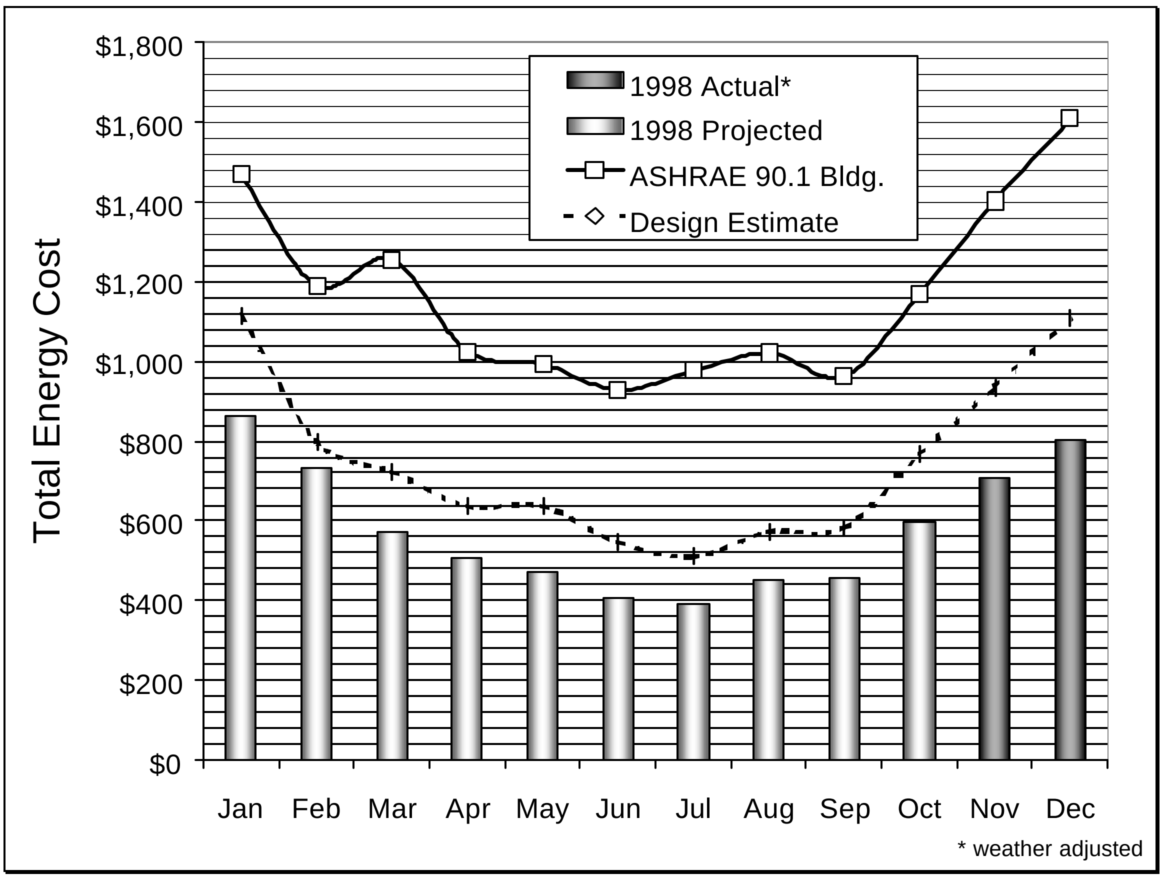

Figure 4. Combined Monthly Energy Cost

Table 5. Monthly Energy Use

	ASHRAE 90.1 Bldg. ($)	Design Estimate ($)	CK Choi Bldg. ($)
January	$1,470	$1,115	$865*
February	$1,190	$799	$731*
March	$1,257	$722	$573*
April	$1,025	$637	$508*
May	$993	$636	$472*
June	$928	$545	$409*
July	$976	$510	$391*
August	$1,021	$572	$450*
September	$963	$584	$457*
October	$1,169	$767	$598*
November	$1,402	$935	$708**
December	$1,609	$1,108	$803**
Total	**$14,002**	**$8,930**	**$6,964***

* Projected
** Weather adjusted

MATERIALS

Specifications

Initially the design team considered the project goal to incorporate 50% recycled and 50% recyclable materials in the building to be ambitious and perhaps idealistic. The design team's strategy was to look at all possible options, focusing first on reusing materials and second on sourcing materials with recycled content. To make this target, it was important to incorporate a significant amount of reused material in the large scale structural and surface components of the building. The architects began by looking at all building components and challenging the design team to explore alternatives. The majority of the responsibility is, however, in the hands of the architect who traditionally specifies the building materials. A network with the local demolition contractors was established. The architects then visited buildings scheduled to be demolished to search for potential materials. On identification of potential materials, research was required to determine suitability vis a vis acceptability within existing building codes, testing of materials, long term durability, and technical aspects of detailing with older or alternative products. The design process needed to remain flexible to accommodate the reused materials as they came available. The specifics of size, quantity or required orientation are not known until the materials are sourced and prepurchased. The design process therefore paralleled that of a renovation.

A summary of materials considered and used in the Choi Building can be found in appendix A. The design team estimates that the Choi Building's reused and recycled content exceeds the 50% target. This estimate is based on intuitive knowledge as no detailed assessments have been performed. To confirm this would require establishing a format to catalogue all building components in weight and volume on a base building. The actual materials used in the Choi building could then be input to evaluate the degree of success.

An analytical exercise to evaluate the reused and recycled content building material content of the Choi Building would be interesting, however, the value of the data would be questionable as so few buildings are currently designed and built this way. The importance of the precedent lies in:

1) Promoting dialogue on and awareness of the value of reused and recycled content materials.

2) Demonstrating that reused and recycled content materials are not inferior and can be used in institutional and urban projects

3) Demonstrating to suppliers of building materials that building design professionals have changed their expectations regarding material value.

The traditional design process and responsibilities of an architect do not address management of reused and recycled building materials. Additional time is required to source, evaluate, negotiate purchase and storage agreements, and then incorporate these materials into a building design. There is also the potential of additional liability. If more projects are to be done this way, the additional effort and liability must be recognized. The decision to approach a project in this manner requires a partnership between consultants and building owners with each recognizing both the benefits and difficulties. One possibility is to introduce an additional team member who works closely with the architect and takes on the responsibility for sourcing, testing, prepurchasing, storage, etc.

Construction Site Recycling

A construction site materials separation and recycling program was a contractual requirement in the public tender process. The contract documents outlined on site requirements for separation of materials, as well as documentation requirements for hauling and disposal. This documentation was a required submittal with monthly claims for progress payments. Additionally, a waste management plan was to be submitted prior to work commencing on site. The contractor was initially hesitant about implementing this program. Concerns were raised about adequacy of space on site, monitoring of the subtrades, interference with project schedule, etc. Different types of collection and storage systems were then worked out for different phases of the project. For example, site preparation and foundation work produce different scales of excess materials than do framing and miscellaneous metals work. Once on site systems were established, the contractor became more convinced of the value of on site separation and recycling. Hauling costs from the site were reduced. Separating and stocking piling wood ends on site provided an alternate source of wood for small framing. The contractor reported that less wood was required on the Choi Building site than had been anticipated from their initial estimates. These savings accrued to the contractor who thus became a supporter of site separation. The local government responsible for handling waste (the Greater Vancouver Regional District (GVRD)) carried out an analysis of waste diversion data from the C.K. Choi Building which shows that approximately 95% of construction waste was diverted from the landfill. A full assessment report complete with cost analysis is expected from the GVRD in 1999.

CONCLUSION

In reflecting on why this particular was successful, the authors have concluded that there were several key differences in the process of developing the building. First, the owner gave a specific direction to the project team to develop a demonstration ‘green’ building. Second, the project participants took a ‘team’ approach from the outset. The consultant team had previously worked together. The architect had a history of taking a team work approach to working with their subconsultants. This project enabled the optimization of this type of design process where the contributions of all members of team are valued. Early decisions relating to the form and siting of the building were made with the input of the specialist expertise from the subconsultants regarding impacts on performance in their area of expertise. The team approach also facilitated ownership and pride in individual contributions and encouraged each participant to excel. Most individuals came to the team with strongly established personal environmental priorities and were encouraged to employ these to contribute to the overall vision for the project.

Third, the setting of specific targets for resource consumption for the building as well as the more usual functional and social objectives was an important stimulus to the team. These seemingly daunting targets actually worked to enhance the design performance of the team. This will not be surprising to those who are familiar with management research that shows improved performance when team objectives are clear and shared. While external rewards will assist performance to a certain degree, research has also shown that internal motivation is a more powerful stimulus to creativity. The authors believe that both discipline and creativity will be required of design professionals as they address the environmental challenges that lie ahead.

APPENDIX A: REUSED AND RECYCLED CONTENT BUILDING MATERIALS

Subgrade Material

Option: Crushed glass:
Comments: -Approval from Authority Having Jurisdiction may be difficult.
-Acceptable in some municipalities.
-Not acceptable to the governing regulatory office at UBC.
Option: Crushed concrete:
Comments: -Widely used in road building industry
-Less common in the building industry in British Columbia

Choi: Fill used from excavation on another project on campus:
-Geotechnical Engineer worked with contractor to determine a method of excavation resulting in minimal disturbance and fill requirements.

Structural System

Option: First design was a thin slab concrete structure:
-Thin slab with more columns required the least volume of concrete.
-Specifications to minimize cement content of concrete.

Choi: Heavy timber post and beam structure:
-Over 65% of timbers were reused from a demolished building on campus
-All timber required regrading, initially a random sample for design purposes, all were regraded prior to erection.
Comments: -Graders typically assess new timbers. Timbers with previous coring or checking were initially rejected by the grader. Structural engineer and grader worked together to enable more than 90% of materials to be reused.
-Timber prepurchased to ensure availability to contractor.
-Design must accommodate predetermined timber dimensions.
-Some resistance from Authority Having Jurisdiction.

Choi: Structural steel for timber connections, concrete reinforcing, steel decks, and seismic bracing.
-75% or greater recycled steel content.
Comment: -Reported to be somewhat more difficult to weld but not problematic
-Specify criteria for recycled content and request verification from supplier.

Exterior Building Envelope

Choi: Red brick to the majority of vertical surfaces
-100% reused brick
Comments: -Sourcing and prepurchase required to ensure availability to contractor
-Assessment and testing critical to determine durability and strength

-Technical aspects of detailing with bricks without internal cores different. Reliance on chemical bond versus combined mechanical and chemical bond with new bricks.

Exterior Window System

Option: Aluminum frame with recycled aluminum content
Comments: -Recycled content not available from the window extrusion manufacturers
-Impurities in recycled aluminum results in inconsistent anodized finish, believed by extrusion manufacturer to not be acceptable to industry.

Choi: Modified PVC frame with pressure equalized cavity system
Comments: -No recycled content but fully recyclable (manufacturer takes back units)
-Superior thermal performance to aluminum system
-Incorporates trickle ventilation system within sill sections for natural ventilation when operable windows are closed

Roofing System

Options: Water based rubberized adhesion system with polyester felts made from recycled plastic
Comments: -UL rated but not ULC (Canada) rated
-Not recognized by the Roofing Contractors Association of British Columbia therefore not acceptable to the University Facilities Management.

Choi: Flat Roofs: Loose laid EPDM with gravel ballast
-Easy to recycle
-Gravel ballast specified as reused but new used to maintain warranty
Curved Roofs: Steel
-20% recycled content
-Gavalume coating finish will facilitate future recycling

Interior Walls

Options: Homosote Boards: Made from recycled newsprint cellulose
FibreBond Boards: Blend of recycled cellulose fibre, perlite and gypsum

Choi: Gypsum Wall Board
-Core from 18% recycled gypsum and 37%recycled paper
-Facing from 100% recycled newsprint
Comments: -Local industry supported
-More cost effective than other options
-Greater recycled gypsum content possible when fire rating not required

Insulation

Options: Fibre Glass Batt Insulation
-25 to 80% recycled glass content available
-Check for post-consumer versus pre-consumer waste
Foam Insulation
-50 to 100% recycled polystyrene content

Choi: Blow-in cellulose insulation
-Made with 100% recycled cellulose fibre
-Borate additive for fire retardancy and mold, also insect and rodent inhibitor
-Latex binder to minimize settling

Interior Wood Doors and Frames

Choi: 100% reused from a downtown office building renovated to residential units
Comments: -Sourcing and prepurchasing necessary to complete design and ensure availability to contractor
-Design must accommodate predetermined sizes and door swings
-Refinishing required

Steel Doors and Frames

Choi: 90% reused
Comment: -Same issues as above
-Labels must be intact on both doors and frames for rated assemblies

Interior Guardrails and Handrails

Choi: 100% reused aluminum from a demolished six year old golf club house
Comment: -Some on site modification to accommodate new design, more labour than new
-New base plates connections required to meet current building code
-New glazing required for modified sections

Washroom Accessories

Choi: All sinks, paper towel dispensers, and garbage receptacles reused
Toilet partitions reused

Carpet

Option: Carpet from recycled PET (plastic softdrink bottles)
Comment: -Not recyclable and not acceptable to the University Facilities Management

Choi: Wool-polypropylene blend product
Comment: -Recyclable and acceptable durability to the University Facilitie Management

Underlay

Option: Undercushion from recycled tires
Comment: -Odour not acceptable

Choi: Fibre underlay from Chris Craft Industries
-100% pre-consumer recycled fibre from industrial textile industry

Wall Tile

Choi: Stoneware Tile Company
-70% recycled glass from automotive industry

Miscellaneous Hidden Components

Wood: -Reused plywood formwork became sheathing material
-Wherever possible, finger jointed materials were used
-Reused cut ends were stockpiled and used for small framing

Concrete: -Increased flyash and silican fume content for decreased cement content
-Increased admixtures and superplasticizers for decreased cement content

Electrical Conduit:
-Approximately 40% reused, dry storage required, conduit was internally brushed prior to installation

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Both synergies and conflicts were identified, which in turn assisted the team in determining design options with the greatest impact. Identifying and focusing on the synergies also helped to build momentum and commitment within the team that became invaluable during the difficult aspects of implementing the design objectives.

The team focused largely on first principles and keeping things simple. Innovations such as greywater recycling systems, composting toilets, integrating re-used building materials and naturally ventilated conference rooms meant taking risks in deviating from standard practice.

The final building has in some ways exceeded the expectations established at the workshop. While the numerical targets have not been calculated in all instances and have not been met in some others, the project has indeed set new standards. The University has been monitoring the performance of the building and has developed preliminary figures for electrical energy use, steam use, and water use.

PROJECT DESCRIPTION

The University of British Columbia lies at the tip of a peninsula to the west of Vancouver. The C.K. Choi Building is situated on a long, narrow site running north-south with a forested edge to the west and a road along the east. Initially, the design team members were skeptical of the possibility of an energy efficient building on a site with little solar access. However, they were able ultimately to capitalize on the ambient conditions of the site. The forest became a source of cool fresh air for the hot summer months. The road edge became a source of daylight for all the interior spaces. The five research centres were organized linearly around individual atriums which serve a number of roles: as identifiable expressions of each centre on the exterior; as visual links between the second and third floors; and as exhaust vents for stack ventilation.

WATER

Composting toilets save more than 1,000 litres [264 gal.] of water a day and a greywater recycling system processes the 'tea' from the composting toilets as well as the waste water from the sinks and reuses it for irrigation. Rainwater from the roof is stored on the site for irrigation during the summer. Excess water from the heavy Vancouver rains is diverted into the storm system.

ENERGY

The project participated in the BC Hydro Power Smart *New Building Design Program*. As part of the program, a study was conducted using the DOE-2E simulation program. The study indicated the building would achieve electricity savings of 57 per cent over a prototype building built to ASHRAE Standard 90.1. Overall energy use was estimated at nine per percent less than the ASHRAE 90.1 prototype building. However, it should be noted that this was not a typical prototype: this prototype building did not include air conditioning since it is UBC policy to not provide mechanical cooling. Consequently, the prototype building modeled for the comparison actually used less energy than one would normally expect for this type of office building.

The building is served by 100 per cent natural ventilation all year round. Fixed air-grilles below operable windows provide 9.4 litres per second [20 cfm] per person of outdoor air. Hot water baseboard heaters temper the air below the windows. As it moves through the office space, the air picks up the heat dissipated from people and equipment, and rises through the atria to relief openings at the top. Small fans provide additional circulation when the ambient temperature becomes too warm.

Steam from the university steam plant is passed through a heat exchanger and the hot water is distributed throughout the building to provide space heating. Domestic hot water is produced in an electric hot water tank, which includes a pre-heat coil in a nearby steam manhole. The intent was to recover the waste heat from the manhole, but in practice the heat gain has been negligible.

The building is retrofit-ready for solar power when the technology becomes financially feasible in a northwest coastal climate with overcast conditions.

The interior lighting strategy is based on lowered ambient lighting levels with supplementary task lighting where required. Facilitating interior daylighting was a high priority in the building design. Wherever possible natural light was introduced from two directions to soften and balance the lighting conditions. Daylight sensors and continuous dimming ballasts ensure that electric lighting is used only to supplement the available daylight. Occupancy sensors are also used to turn off artificial lights when they are not required. The connected lighting load is approximately nine watts per square metre [0.9 W/ft²]. The capital premium for the lighting strategies was calculated at $43,000.

Total energy consumption costs were projected as reduced to $8,900 from $14,000 for the ASHRAE prototype building.

MATERIALS

Approximately 65 per cent of the heavy timber structure is re-used material from a demolished building across the road. The exterior brick is re-used material from old Vancouver city streets. The main interior stair handrail and atrium guardrails, all doors, sinks, toilet accessories and some electrical conduit are also re-used. Concrete, steel, insulation, drywall and ceramic tile have recycled content. Decorative finishes to functional materials, such as suspended ceilings, paint to the wiring trays and exposed pipes, floor finishes to concrete slabs, and cabinetwork, were eliminated wherever possible.

BUILDING PERFORMANCE

Due to various problems with the utility metering, actual consumption data has been limited since the building was commissioned. However, even this limited data shows that the building is exceeding the expectations formed during the design process.

WATER

As with the steam and electricity meters, the water meter was designed to be read electronically through the centralized Building Management System (BMS). However, due to a problem with the transducer, this water meter BMS has not been able to communicate with the meter. The main problem appears to be that the building uses such low quantities of water that that the signal does not register with the BMS system.

Manual meter readings from September to December 1998 indicate that the building consumes approximately 218 litres [58 gal.] per day, on average.

ENERGY

The building utilizes two forms of energy: steam is used to provide space heating, and electricity is used for lighting, ventilation, domestic hot water and to power office equipment and computers.

Steam

Much like the water meter, the steam meter installed during construction was oversized for the normal steam flows to the building. As a result, the meter produced inaccurate readings much of the time. The original two-inch Vortex meter was replaced with a one-inch meter and data has been collected since November 1998.

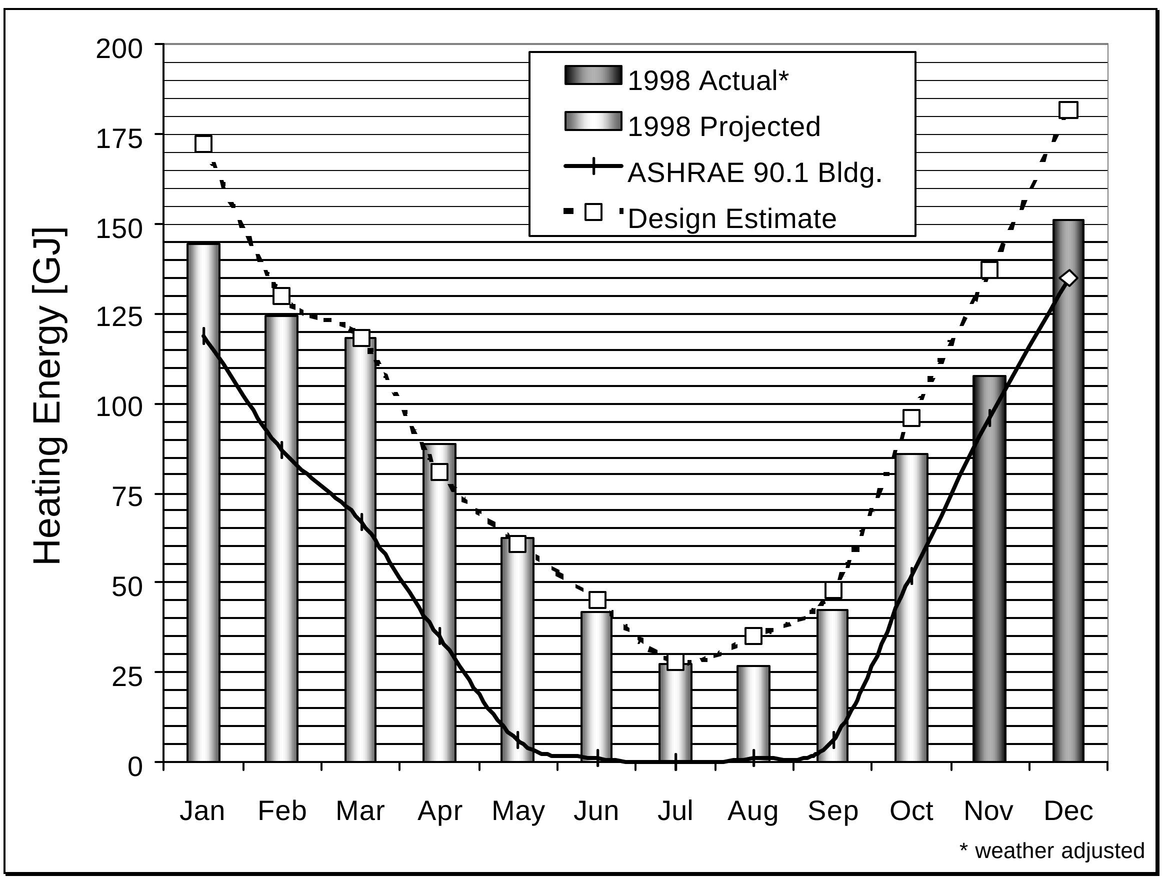

Figure 1. 1998 Monthly Heating Energy Use

The original design estimate, modeled with DOE-2, projected that this building would require 1,133 GJ [1,074,000 MBtu] per year for space heating, compared to 605 GJ [573,000 MBtu] for the prototype building—a 69 per cent increase. This higher heating requirement is due to the high window-to-wall ratio as well as the constant 9.4 litres per second [20 cfm] per person of fresh air entering the building year-round. This fresh air flow is essentially just additional infiltration adding to the heating load of the building.

The meter readings for November and December, adjusted to typical weather conditions, show that the heating requirements were 17 per cent less than the design estimate and 12 per cent more than the ASHRAE 90.1 prototype building for the same period. Projections of the heating energy use for the remainder of the year were based on the correlation between degree-days and steam consumption developed from these two months of data. Based on these projections, the C.K. Choi Building uses 69 per cent more heating energy than the ASHRAE 90.1 prototype and 10 per cent less than the design estimate. These projections will be verified over the next year.

Table 1. Monthly Heating Energy

	ASHRAE 90.1 Bldg. (GJ)	Design Estimate (GJ)	CK Choi Bldg. (GJ)
January	119	172	145*
February	87	130	124*
March	67	118	118*
April	35	81	89*
May	6	61	63*
June	1	45	42*
July	0	28	27*
August	1	35	27*
September	6	48	43*
October	52	96	86*
November	96	137	107**
December	135	182	151**
Total	**695**	**1,133**	**1,828***

* Projected
** Weather adjusted

Electricity

Electric metering over the last 15 months shows that the building has more than exceeded the design estimates. Monthly peak demand has averaged 24 kW compared to the design estimate of 44 kW and 97 kW for the ASHRAE 90.1 prototype building—reductions of 45 per cent and 75 per cent, respectively.

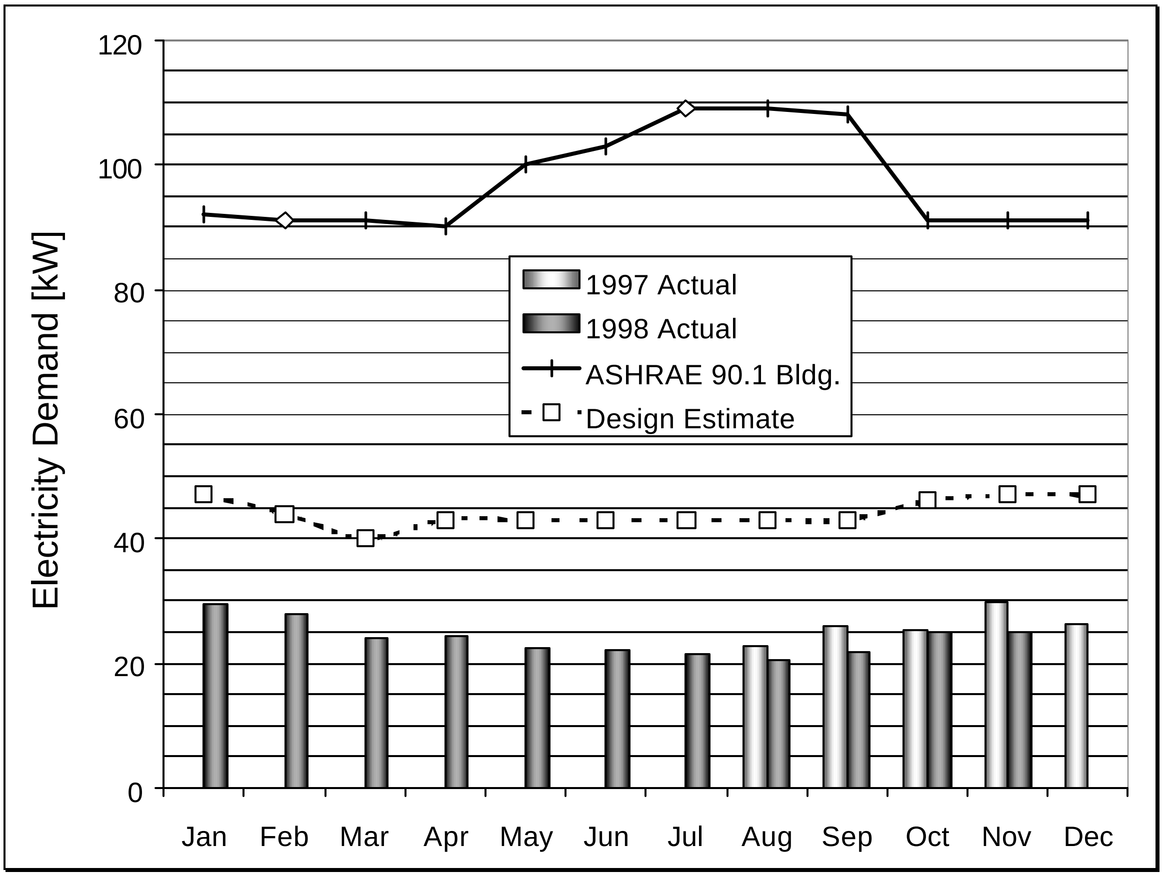

Figure 2. Monthly Electricity Peak Demand

Similarly, the metering shows that actual electricity consumption is 28 per cent below the design estimate and 69 per cent lower than a similar ASHRAE 90.1 prototype building: annual electricity consumption is approximately 101,000 kWh, compared to the design estimate of 142,500 kWh and 334,000 kWh for the ASHRAE 90.1 prototype.

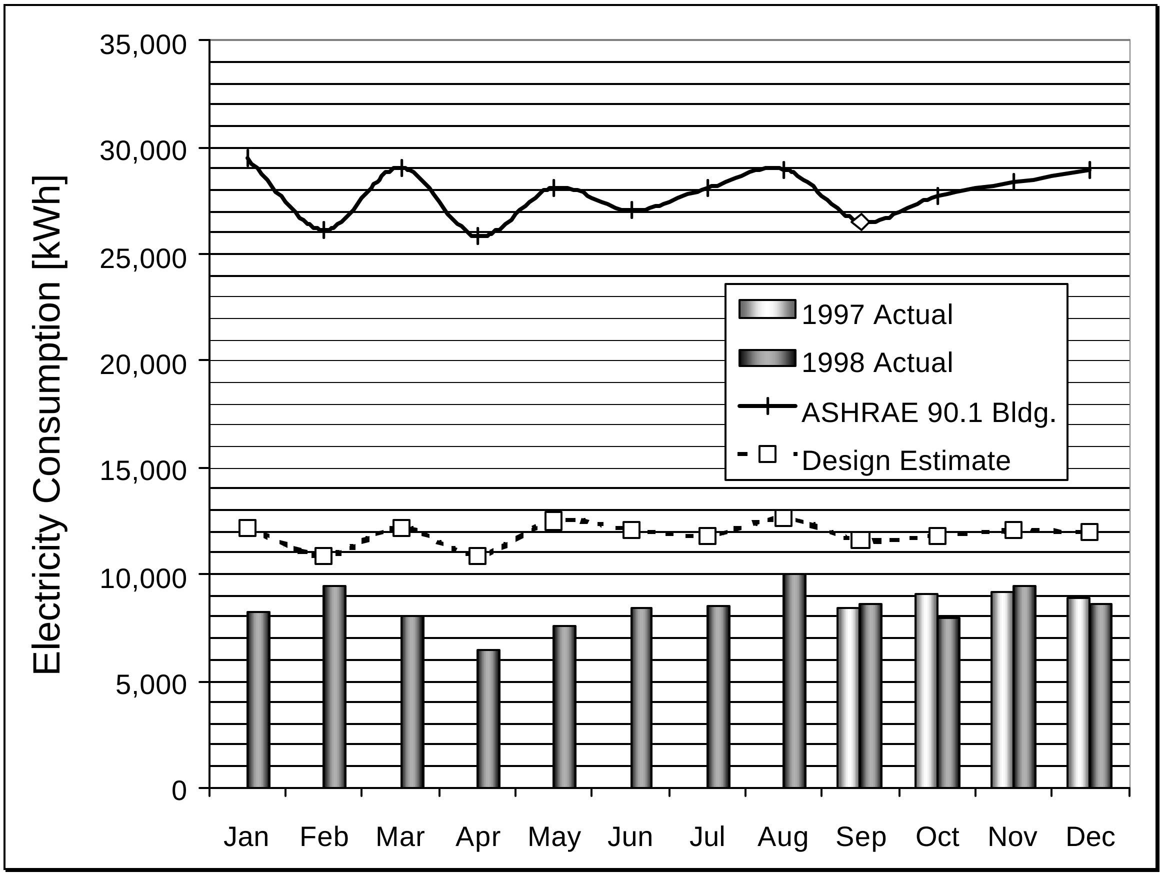

Figure 2. Monthly Electricity Consumption

Table 2. Monthly Electricity Peak Demand

	ASHRAE 90.1 Bldg. (kW)	Design Estimate (kW)	CK Choi Bldg. 1997 (kW)	CK Choi Bldg. 1998 (kW)
January	92	47		29.5
February	91	44		27.8
Mar	91	40		24.0
Apr	90	43		24.4
May	100	43		22.3
Jun	103	43		22.0
Jul	109	43		21.6
Aug	109	43	22.8	20.4
Sep	108	43	25.9	21.7
Oct	91	46	25.2	25.1
Nov	91	47	29.8	25.1
Dec	91	47	26.4	
Average	**97**	**44**	**26.0**	**24.0**

Table 3. Monthly Electricity Consumption

	ASHRAE 90.1 Bldg. (kWh)	Design Estimate (kWh)	CK Choi Bldg. 1997 (kWh)	CK Choi Bldg. 1998 (kWh)
January	29,477	12,186		8,218
February	26,129	10,876		9,463
Mar	29,055	12,178		8,093
Apr	25,825	10,895		6,500
May	28,112	12,490		7,578
Jun	27,036	12,111		8,402
Jul	28,076	11,812		8,483
Aug	28,974	12,613		9,986
Sep	26,525	11,582	8,468	8,570
Oct	27,726	11,816	9,123	7,918
Nov	28,363	12,057	9,188	9,432
Dec	28,924	11,964	8,905	8,569
Total	334,222	142,580		101,210

Overall Energy Performance

Overall energy use (steam and electricity combined) is about 23 per cent less than the ASHRAE 90.1 prototype building—annual savings total about 423 GJ [401,000 Mbtu]. Although this does not meet the original target of 35 per cent less than ASHRAE 90.1 standards, it is nevertheless a significant accomplishment given that the design estimates suggested a reduction of only nine per cent. In addition, a true ASHRAE 90.1 prototype building would include mechanical cooling, meaning that energy savings would be significantly greater than 23 per cent.

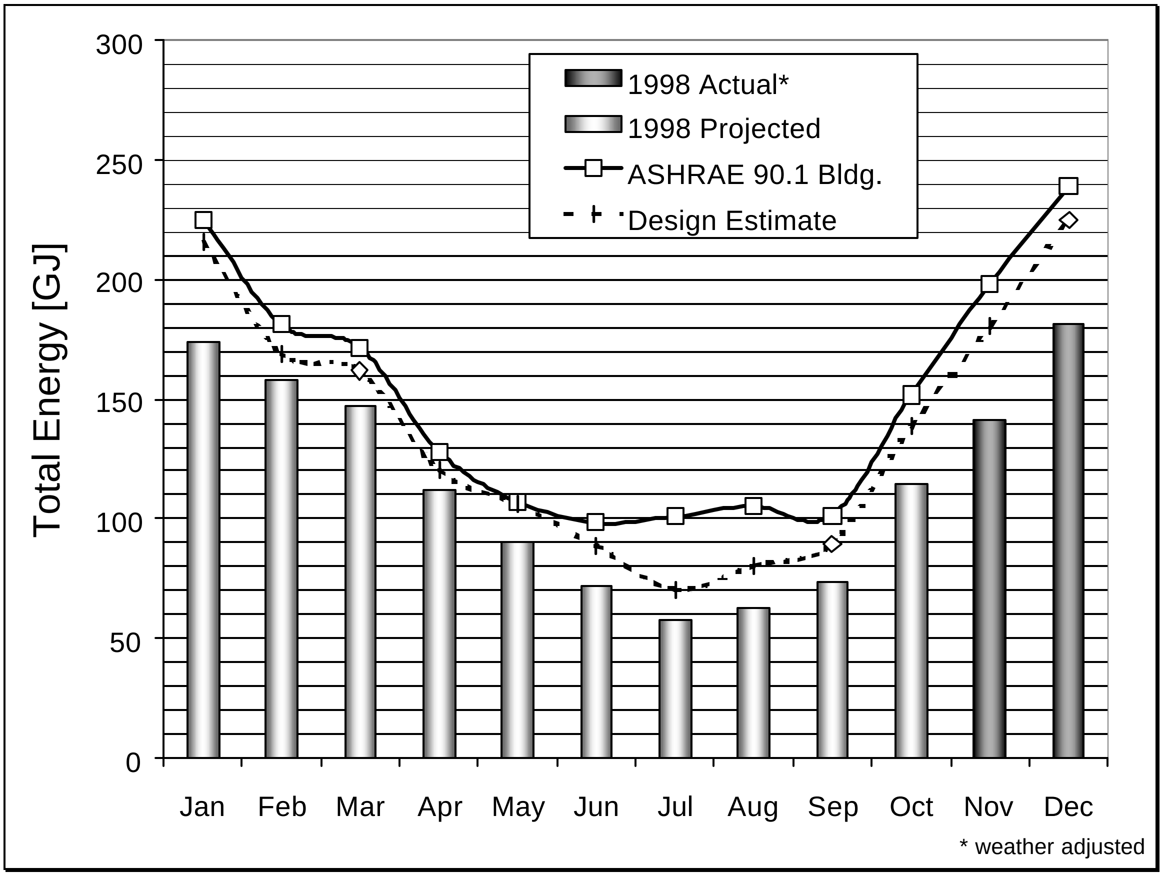

Figure 3. Combined Monthly Energy Use

Table 4. Monthly Energy Use

	ASHRAE 90.1 Bldg. (GJ)	Design Estimate (GJ)	CK Choi Bldg. (GJ)
January	225	216	174*
February	181	169	158*
March	172	162	147*
April	128	120	112*
May	107	106	90*
June	98	89	72*
July	101	71	58*
August	105	80	63*
September	101	90	73*
October	152	139	114*
November	198	180	141**
December	239	225	182**
Total	**1,808**	**1,646**	**1,385***

* Projected
** Weather adjusted

Energy Costs

Based on actual electricity, steam and natural gas (the heating fuel source for the ASHRAE 90.1 prototype building) on a month-by-month basis, the annual energy costs for the CK Choi building are 50 per cent less than the costs for the prototype building—an annual savings of $7,000. The cost savings are higher than the energy savings due to the differences in heating fuel (lower cost steam vs. higher cost natural gas) as well as the significant reduction in electricity consumption, which is about twice as expensive as steam on an energy unit cost basis.

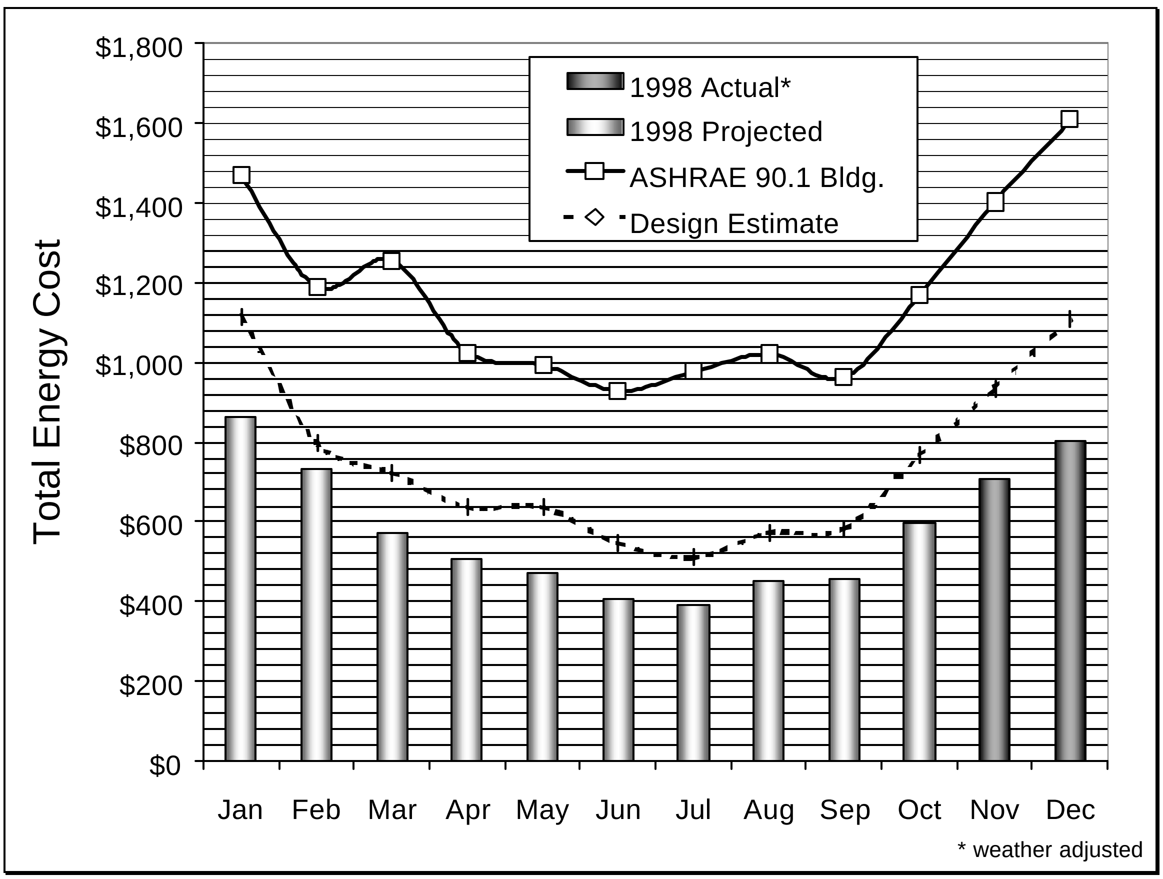

Figure 4. Combined Monthly Energy Cost

Table 5. Monthly Energy Use

	ASHRAE 90.1 Bldg. ($)	Design Estimate ($)	CK Choi Bldg. ($)
January	$1,470	$1,115	$865*
February	$1,190	$799	$731*
March	$1,257	$722	$573*
April	$1,025	$637	$508*
May	$993	$636	$472*
June	$928	$545	$409*
July	$976	$510	$391*
August	$1,021	$572	$450*
September	$963	$584	$457*
October	$1,169	$767	$598*
November	$1,402	$935	$708**
December	$1,609	$1,108	$803**
Total	**$14,002**	**$8,930**	**$6,964***

* Projected
** Weather adjusted

MATERIALS

Specifications

Initially the design team considered the project goal to incorporate 50% recycled and 50% recyclable materials in the building to be ambitious and perhaps idealistic. The design team's strategy was to look at all possible options, focusing first on reusing materials and second on sourcing materials with recycled content. To make this target, it was important to incorporate a significant amount of reused material in the large scale structural and surface components of the building. The architects began by looking at all building components and challenging the design team to explore alternatives. The majority of the responsibility is, however, in the hands of the architect who traditionally specifies the building materials. A network with the local demolition contractors was established. The architects then visited buildings scheduled to be demolished to search for potential materials. On identification of potential materials, research was required to determine suitability vis a vis acceptability within existing building codes, testing of materials, long term durability, and technical aspects of detailing with older or alternative products. The design process needed to remain flexible to accommodate the reused materials as they came available. The specifics of size, quantity or required orientation are not known until the materials are sourced and prepurchased. The design process therefore paralleled that of a renovation.

A summary of materials considered and used in the Choi Building can be found in appendix A. The design team estimates that the Choi Building's reused and recycled content exceeds the 50% target. This estimate is based on intuitive knowledge as no detailed assessments have been performed. To confirm this would require establishing a format to catalogue all building components in weight and volume on a base building. The actual materials used in the Choi building could then be input to evaluate the degree of success.

An analytical exercise to evaluate the reused and recycled content building material content of the Choi Building would be interesting, however, the value of the data would be questionable as so few buildings are currently designed and built this way. The importance of the precedent lies in:

1) Promoting dialogue on and awareness of the value of reused and recycled content materials.

2) Demonstrating that reused and recycled content materials are not inferior and can be used in institutional and urban projects

3) Demonstrating to suppliers of building materials that building design professionals have changed their expectations regarding material value.

The traditional design process and responsibilities of an architect do not address management of reused and recycled building materials. Additional time is required to source, evaluate, negotiate purchase and storage agreements, and then incorporate these materials into a building design. There is also the potential of additional liability. If more projects are to be done this way, the additional effort and liability must be recognized. The decision to approach a project in this manner requires a partnership between consultants and building owners with each recognizing both the benefits and difficulties. One possibility is to introduce an additional team member who works closely with the architect and takes on the responsibility for sourcing, testing, prepurchasing, storage, etc.

Construction Site Recycling

A construction site materials separation and recycling program was a contractual requirement in the public tender process. The contract documents outlined on site requirements for separation of materials, as well as documentation requirements for hauling and disposal. This documentation was a required submittal with monthly claims for progress payments. Additionally, a waste management plan was to be submitted prior to work commencing on site. The contractor was initially hesitant about implementing this program. Concerns were raised about adequacy of space on site, monitoring of the subtrades, interference with project schedule, etc. Different types of collection and storage systems were then worked out for different phases of the project. For example, site preparation and foundation work produce different scales of excess materials than do framing and miscellaneous metals work. Once on site systems were established, the contractor became more convinced of the value of on site separation and recycling. Hauling costs from the site were reduced. Separating and stocking piling wood ends on site provided an alternate source of wood for small framing. The contractor reported that less wood was required on the Choi Building site than had been anticipated from their initial estimates. These savings accrued to the contractor who thus became a supporter of site separation. The local government responsible for handling waste (the Greater Vancouver Regional District (GVRD)) carried out an analysis of waste diversion data from the C.K. Choi Building which shows that approximately 95% of construction waste was diverted from the landfill. A full assessment report complete with cost analysis is expected from the GVRD in 1999.

CONCLUSION

In reflecting on why this particular was successful, the authors have concluded that there were several key differences in the process of developing the building. First, the owner gave a specific direction to the project team to develop a demonstration ‘green’ building. Second, the project participants took a ‘team’ approach from the outset. The consultant team had previously worked together. The architect had a history of taking a team work approach to working with their subconsultants. This project enabled the optimization of this type of design process where the contributions of all members of team are valued. Early decisions relating to the form and siting of the building were made with the input of the specialist expertise from the subconsultants regarding impacts on performance in their area of expertise. The team approach also facilitated ownership and pride in individual contributions and encouraged each participant to excel. Most individuals came to the team with strongly established personal environmental priorities and were encouraged to employ these to contribute to the overall vision for the project.

Third, the setting of specific targets for resource consumption for the building as well as the more usual functional and social objectives was an important stimulus to the team. These seemingly daunting targets actually worked to enhance the design performance of the team. This will not be surprising to those who are familiar with management research that shows improved performance when team objectives are clear and shared. While external rewards will assist performance to a certain degree, research has also shown that internal motivation is a more powerful stimulus to creativity. The authors believe that both discipline and creativity will be required of design professionals as they address the environmental challenges that lie ahead.

APPENDIX A: REUSED AND RECYCLED CONTENT BUILDING MATERIALS

Subgrade Material

Option: Crushed glass:
Comments: -Approval from Authority Having Jurisdiction may be difficult.
-Acceptable in some municipalities.
-Not acceptable to the governing regulatory office at UBC.
Option: Crushed concrete:
Comments: -Widely used in road building industry
-Less common in the building industry in British Columbia

Choi: Fill used from excavation on another project on campus:
-Geotechnical Engineer worked with contractor to determine a method of excavation resulting in minimal disturbance and fill requirements.

Structural System

Option: First design was a thin slab concrete structure:
-Thin slab with more columns required the least volume of concrete.
-Specifications to minimize cement content of concrete.

Choi: Heavy timber post and beam structure:
-Over 65% of timbers were reused from a demolished building on campus
-All timber required regrading, initially a random sample for design purposes, all were regraded prior to erection.
Comments: -Graders typically assess new timbers. Timbers with previous coring or checking were initially rejected by the grader. Structural engineer and grader worked together to enable more than 90% of materials to be reused.
-Timber prepurchased to ensure availability to contractor.
-Design must accommodate predetermined timber dimensions.
-Some resistance from Authority Having Jurisdiction.

Choi: Structural steel for timber connections, concrete reinforcing, steel decks, and seismic bracing.
-75% or greater recycled steel content.
Comment: -Reported to be somewhat more difficult to weld but not problematic
-Specify criteria for recycled content and request verification from supplier.

Exterior Building Envelope

Choi: Red brick to the majority of vertical surfaces
-100% reused brick
Comments: -Sourcing and prepurchase required to ensure availability to contractor
-Assessment and testing critical to determine durability and strength

-Technical aspects of detailing with bricks without internal cores different. Reliance on chemical bond versus combined mechanical and chemical bond with new bricks.

Exterior Window System

Option: Aluminum frame with recycled aluminum content
Comments: -Recycled content not available from the window extrusion manufacturers
-Impurities in recycled aluminum results in inconsistent anodized finish, believed by extrusion manufacturer to not be acceptable to industry.

Choi: Modified PVC frame with pressure equalized cavity system
Comments: -No recycled content but fully recyclable (manufacturer takes back units)
-Superior thermal performance to aluminum system
-Incorporates trickle ventilation system within sill sections for natural ventilation when operable windows are closed

Roofing System

Options: Water based rubberized adhesion system with polyester felts made from recycled plastic
Comments: -UL rated but not ULC (Canada) rated
-Not recognized by the Roofing Contractors Association of British Columbia therefore not acceptable to the University Facilities Management.

Choi: Flat Roofs: Loose laid EPDM with gravel ballast
-Easy to recycle
-Gravel ballast specified as reused but new used to maintain warranty
Curved Roofs: Steel
-20% recycled content
-Gavalume coating finish will facilitate future recycling

Interior Walls

Options: Homosote Boards: Made from recycled newsprint cellulose
FibreBond Boards: Blend of recycled cellulose fibre, perlite and gypsum

Choi: Gypsum Wall Board
-Core from 18% recycled gypsum and 37%recycled paper
-Facing from 100% recycled newsprint
Comments: -Local industry supported
-More cost effective than other options
-Greater recycled gypsum content possible when fire rating not required

Insulation

Options: Fibre Glass Batt Insulation
-25 to 80% recycled glass content available
-Check for post-consumer versus pre-consumer waste
Foam Insulation
-50 to 100% recycled polystyrene content

Choi: Blow-in cellulose insulation
-Made with 100% recycled cellulose fibre
-Borate additive for fire retardancy and mold, also insect and rodent inhibitor
-Latex binder to minimize settling

Interior Wood Doors and Frames

Choi: 100% reused from a downtown office building renovated to residential units
Comments: -Sourcing and prepurchasing necessary to complete design and ensure availability to contractor
-Design must accommodate predetermined sizes and door swings
-Refinishing required

Steel Doors and Frames

Choi: 90% reused
Comment: -Same issues as above
-Labels must be intact on both doors and frames for rated assemblies

Interior Guardrails and Handrails

Choi: 100% reused aluminum from a demolished six year old golf club house
Comment: -Some on site modification to accommodate new design, more labour than new
-New base plates connections required to meet current building code
-New glazing required for modified sections

Washroom Accessories

Choi: All sinks, paper towel dispensers, and garbage receptacles reused
Toilet partitions reused

Carpet

Option: Carpet from recycled PET (plastic softdrink bottles)
Comment: -Not recyclable and not acceptable to the University Facilities Management

Choi: Wool-polypropylene blend product
Comment: -Recyclable and acceptable durability to the University Facilitie Management

Underlay

Option: Undercushion from recycled tires
Comment: -Odour not acceptable

Choi: Fibre underlay from Chris Craft Industries
-100% pre-consumer recycled fibre from industrial textile industry

Wall Tile

Choi: Stoneware Tile Company
-70% recycled glass from automotive industry

Miscellaneous Hidden Components

Wood:
-Reused plywood formwork became sheathing material
-Wherever possible, finger jointed materials were used
-Reused cut ends were stockpiled and used for small framing

Concrete:
-Increased flyash and silican fume content for decreased cement content
-Increased admixtures and superplasticizers for decreased cement content

Electrical Conduit:
-Approximately 40% reused, dry storage required, conduit was internally brushed prior to installation