The C-2000 Program

Achieving High Performance Through Better Technologies and Changes in the Design Process

September 2000

The C-2000 Program for Advanced Commercial Buildings is a small demonstration program for high-performance office buildings, developed and sponsored by the CANMET Energy Technology Centre (CETC), Natural Resources Canada. The emphases of this program are on energy and environmental performance, but criteria have been developed for a wide range of other parameters. The program was launched in 1993, and thirteen buildings have been designed, some of which have been built, while others are in, or approaching, construction. The goal of the program has been to demonstrate the feasibility of achieving a high level of energy and environmental performance through the application of modern technologies.

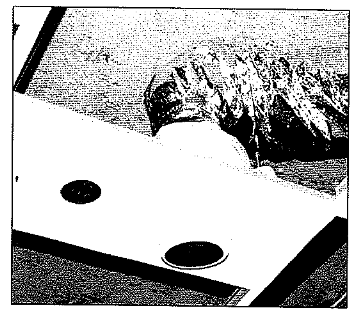
While the program has undergone continuous evolution in its structure, several elements have remained constant: the provision of incremental financial support and technical assistance to a small number of development teams for the design who agree to conform to the program's whole-building performance requirements. The overall strategy has been to assist in the completion of projects that meet the performance criteria, to monitor their actual performance and to inform the industry of the results. Program goals are achieved by the application of explicit performance targets, careful selection of qualified teams and the development of close working relationships with other experts in the field. It was recognized from the outset that the minimum threshold of effort needed for the sophisticated design approach would make the program more cost-effective for larger projects.

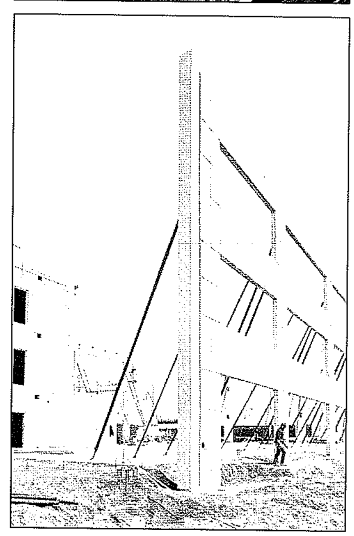
Although the C-2000 program was limited to office buildings, the program criteria were applied to a program for multi-residential buildings called Ideas Challenge, which was jointly operated by CETC and the Canada Mortgage and Housing Corporation, Canada's national housing agency. This paper focuses on the C-2000 Program.

The Strategy

Explicit procedures and objectives are always desirable, since they reduce the labour of interpretation for participants, and since outcomes can easily be related to them. On the other hand, an emphasis on leading edge systems makes it more difficult to frame requirements in an exact manner. Such an approach also reduces flexibility, increases the administrative burden, and can easily lead to an undesirable top-down mode of operation.

In the C-2000 program, the program developers tried to create a balance between structure and flexibility. Process and performance criteria were therefore explicitly defined where issues were well characterized, but only stated as general intent where the issue was still developmental. Technical support was made available to design teams, and the process as a whole was designed to allow the design team to integrate C-2000 requirements into the normal design task. The program manager made himself available to teams at short notice, so that the development process would not be delayed by bureaucratic decision-making processes. All of these measures improved the possibility that design





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In 1993, the benchmark was ASHRAE 90.1, but now the Canadian Model National Energy Code for Buildings (MNECB) is used to serve as a performance benchmark

teams would take ownership of the program and champion it to their financial backers, who are mainly interested in financial return.

This philosophy resulted in design teams being able to define specific solutions that took account of factors specific to the region and site, the client's functional requirements and the preferences of the designers themselves. The last point is not a trivial one, for there are many ways of achieving high-performance solutions and if the program manager were to insist on his or her "best" solution (e.g. fibreglass window frames or direct/indirect lighting), there would have been a distinct danger of alienating the design teams.

One method used to maximize the chance that the design team would select appropriate solutions was the provision of technical support to design teams in the form of free consulting services by subject experts. These consulting experts reported to the design team leader, and thus the control was retained by him or her.

A final element in the program strategy was to require the design teams to prepare thorough documentation of the design process, simulations and decision points so that other developers and designers could follow the flow of logic and understand issues encountered during the design development process.

Program Requirements

Technical and procedural requirements for the program were completed in 1993 and published as a 200-page document entitled C-2000 Program Requirements [1]. Requirements cover a broad range of performance criteria, including demonstration of annual energy consumption that is less than half that required industry standards of good practise. In 1993, the benchmark was ASHRAE 90.1, but now the Canadian Model National Energy Code for Buildings (MNECB) is used to serve as a performance benchmark. Other performance requirements were established to assure minimal environmental impact, a high quality indoor environment, adaptability, long-lived building components and facilitation of future maintenance.

The program requirements were divided into four major areas:

- ❑ Process Requirements, relating to stages and procedures in the design, development, construction and operation of the building.
- ❑ Performance Requirements, relating to eight performance issues.
- ❑ Building Design Requirements, relating to the facilities provided and general design issues pertinent to the two building types under consideration.
- ❑ Building System Requirements, outlining the performance and prescriptive requirements that relate to specific building systems.

Process Requirements

Two issues are of interest with respect to program requirements for the design process: a requirement for teamwork and the basis for payment. The proponent was required "to ensure that architects and engineers will work as an integrated team to the extent possible", and to include an energy specialist on the team. The proponent was also required to "compensate architects and engineers on the basis of a stipulated sum, or some other basis to ensure that innovation is not penalized", to compensate for the fact that mechanical engineers normally receive fees based on a percentage of the mechanical system cost, and an improvement in performance resulting in a reduced plant cost would normally thereforereduce the fee.

Teams were provided with five binders of background information and case studies to assist their work. In addition, each team was given a quota of consulting time from a group of 79 subject specialists in order to supplement the range of skills available within design teams.

Reporting is of course a normal bureaucratic requirement, but in C-2000 the preparation of reports has been a critical component of the overall strategy. Design teams were required to submit reports at the end of the concept design phase and the design development phase, with some later updating. Each team was required to provide a report at the end of the concept design phase and another at the end of the design development phase. The reports were designed to provide information on team objectives and performance targets, as well as descriptions and discussions of design solutions at both building and system levels.

Within the overall design reports, design teams were required to prepare separate written strategy statements for each performance area, including a description of approach and specific performance targets. The main reason for this requirement was that, although some technical requirements could be specified with exactitude (e.g. energy consumption or ventilation requirements), many others (e.g. environmental impact or adaptability) were not fully understood by the industry or by the program developers. In such cases, it was therefore very difficult to state specific program requirements. It was further reasoned that the process of developing the strategies would require the design team to have a series of focussed discussions during design development, and would therefore have a beneficial effect on the design. The strategy documents were prepared in draft form for the concept design phase report, then completed for the design development phase report.

Performance Requirements

A fundamental objective of the program was to achieve a significant industry takeup of the ideas demonstrated in the program. Although the main focus, from a public policy perspective, was on energy and environmental performance, it was recognized that a program focused very tightly on these objectives might reduce the chances of widespread adoption. In North America energy is a relatively small proportion of building operating expenses, and the objective of minimizing environmental impact, while generally agreed to in principle, provides relatively limited financial reward to the developer. It was decided, therefore, to develop requirements for a broad range of performance parameters that are of concern to developers and designers, and to present them in a form where they might be viewed as a helpful tool in designing and building superior buildings.

Specific performance requirements were developed for the issue areas listed below. More emphasis was placed on close adherence to the requirements of the first three sets of criteria than on the others, in which some project-specific deviation was permitted.

- ❑ Energy Efficiency of the building and its sub-systems
- ❑ Environmental Impact of the building's construction and operations

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Below: A construction photo of Green on the Grand, showing the use of engineered wood for structural components.

Bottom: the completed building, showing the pool in the foreground which, in conjunction with a fountain, takes the place of a cooling tower.

- Health, Comfort and Productivity of occupants and tenants
- Functional Performance of building systems
- Longevity of building systems
- Adaptability of building designs and systems to future requirements
- Operations and Maintenance issues related to building systems
- Economic Viability of the building, considered on a life-cycle basis

Phase 1 of the Program

The program has evolved through three distinct phases, reflecting lessons learned, altered budgets and new opportunities.

The first phase (from 1993 to 1995) was based on a competitive process and on the provision of incremental, or supplementary, funding to cover the extra design and construction costs needed to improve performance from the baseline ASHRAE 90.1 level to C-2000 requirements. The incremental funding available to individual projects, including in-kind contributions, ranged from $315,000 to $850,000, depending on the size of the project (from a minimum area of 5,000 m^2 to a maximum of 15,000 m^2). These incremental costs were shared by the developer, CANMET and participating utilities, and payments covered design as well as the capital costs of construction and commissioning. The incremental costs of C-2000 represent anywhere from $57 to $150 per m^2 of gross area, or approximately 4% to 14% of total construction cost.

The selection of projects for Phase 1 was a competitive process, impeccably timed to coincide with the start of a major recession in the Canadian building industry. Six projects were initially selected, but some projects dropped out and were replaced by others on a protracted negotiation basis. Six of the seven buildings designed reached or exceeded the energy performance target as per DOE2.1E simulations.

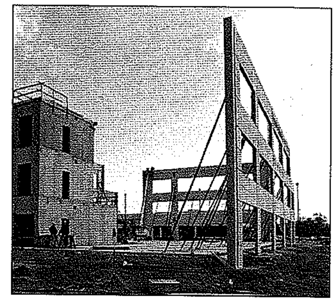
Three Phase 1 Case Studies

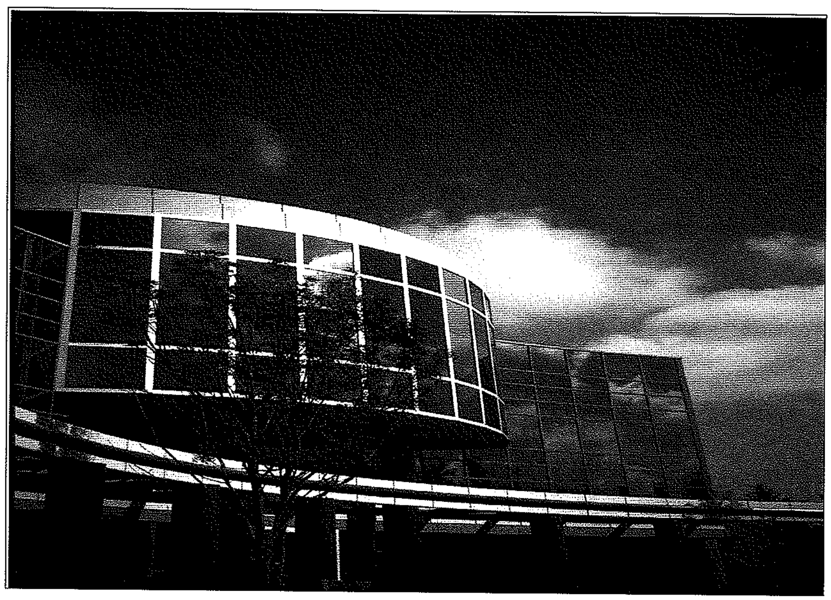
Of the initial batch of projects, two were built and one may be in the near future:

The design for "Green on the Grand", located in Kitchener, Ontario, beat the energy target and incorporates a number of interesting technologies and materials, as might be expected in a project led by an engineer with extensive R&D experience[2]. Innovations include a double-stud manufactured wood frame, a gas-fired heater and absorption chiller combination, the separation of heating and cooling requirements from ventilation air needs (logical when heating and cooling loads are very small), radiant heating and cooling achieved by means of hydronic panels and a storm water retention pond with a fountain functioning as a heat sink. Materials have been carefully selected for low emissions of VOCs and all construction waste has been carefully sorted for recycling. Initial monitoring results indicate that actual energy performance does not match projections: reasons include longer operating hours, tenant improvements incompatible with design aims, and the part-load performance of the innovative gas-fired boiler and absorption cooling combination unit.

From a program point of view, however, the two B.C. projects are more significant in that both developers are large-scale organizations that are very cost-conscious and have a well-established way of carrying out the design and development process. Results that satisfy these organizations, therefore, are more likely to be readily adopted by the industry at large. The major finding in these two B.C. Projects is that they meet or exceed the energy target through the use of relatively conventional technologies. This is a surprise, since it was expected that advanced or leading-edge technologies would have to be used to reach the requisite performance levels. The high performance level has been reached at a very modest incremental cost within or below the anticipated range. It should be noted that these costs include amounts for environmental features which have no cash payback, as well as energy features, which do.

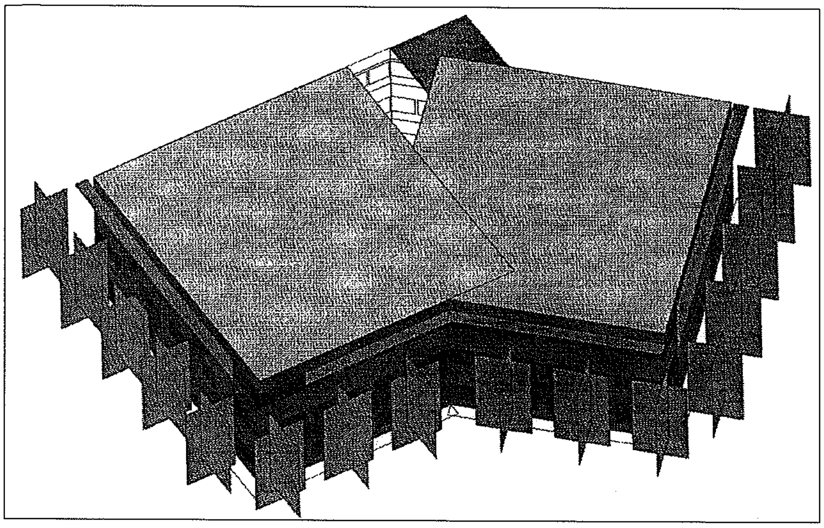
One of the completed B.C. Projects, the Crestwood 8 building[3] developed by the Bentall Corporation, reached the target of 50% of ASHRAE 90.1 through the use of a well-insulated building envelope, compartmental fan coil system, T-8 lamps in direct/indirect fixtures and double-glazed, spectrally-selective low-E glazing mounted in thermally broken aluminum frames. There are many other items of interest, including a careful selection of materials to ensure low off-gassing and high recycled content, but there are few unusual items or systems. This performance was achieved at an incremental cost of 7.8% over base-building construction costs of about $750 per m², without tenant improvements. The developer has since built another office building in the same office park which retains many of the features of the first





Top: the Bentall Crestwood 8 building under construction, showing the very economical tilt-up concrete construction method used.

Above: the completed building,, design features of which which have been emulated by the owner in a recent project without assistance from the C-2000 program.



Above: A rendition of the Kamloops office building design as seen by the DOE2.1E simulation program. The strange shapes are the program's way of representing trees, which in this case provided a considerable reduction in summer cooling loads.

building, and the second building was constructed without any program financial support.

An office building designed for the British Columbia Buildings Corporation (BCBC) in Kamloops B.C. has not been tendered because of a provincial budget freeze, but enough data is available to paint a similar picture[4]. A well-insulated manufactured wood-frame structure has been selected, while mechanical and electrical systems are again relatively straight-forward. Unusual features include glazing percentages varied according to orientation, the use of fibreglass window frames and warm-edge technology, and the inclusion of trees on the south and west facades as an integral part of the building envelope design. Simulations showed that the building would exceed the performance target and, more surprisingly, that the final capital cost is likely to be less than the anticipated base building cost of about \$810 per m^2, net of tenant improvements. BCBC reports that at least two private-sector office buildings have been built in the region, following the design principles established in this building.

Feedback on Program Requirements

The program requirements, procedural and performance, have been well accepted by design and development teams. This is partly fortuitous, partly due to a pre-screening of participants, and partly due to the mode of implementation by CETC. With regard to the latter point, it should be recalled that CETC placed special emphasis on making quick decisions and on flexible interpretation except for the core issues of energy and indoor air quality. Also, since design teams were asked to take the initiative in operationalizing performance requirements, they naturally developed a greater sense of commitment to the program as a whole.

The Importance of Process

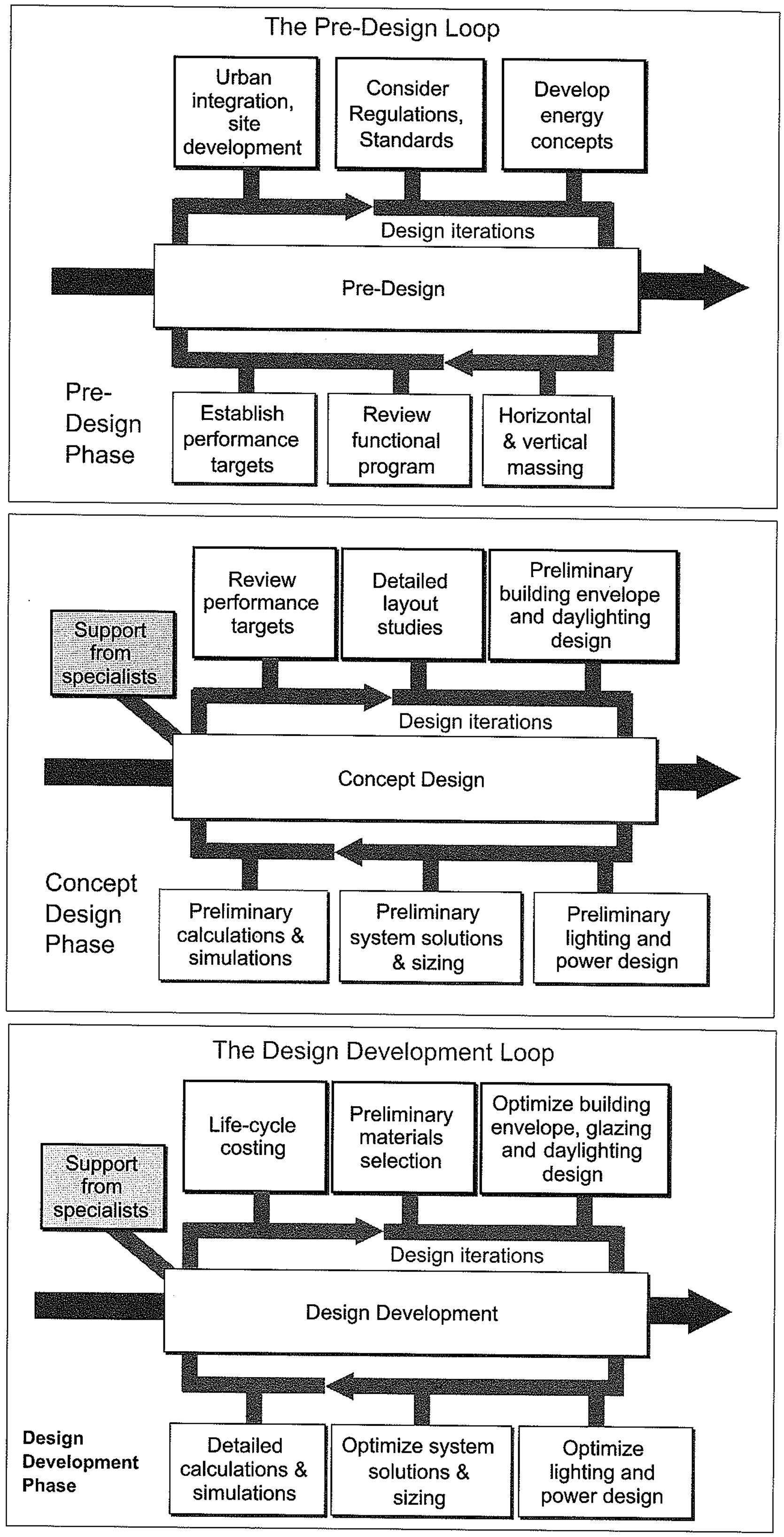
It should be recalled that demanding performance targets are being met in three projects through the use of relatively conventional technologies with modest or zero incremental capital costs. Although the availability of expert support and the C-2000 performance requirements certainly contributed to these results, there is a consensus amongst participants that the largest single factor appeared to be the strong teamwork amongst architects, engineers, energy analysts and others that begins early in the design process. Specifically, the two west coast projects benefitted from the elaboration of the general program requirements into a formal sequence of steps, with all or most team members involved in each. This formal process was largely developed by Teresa Coady, the architect of the Bentall project. The steps include the following:

1) Orientation and configuration
2) Site design
3) Envelope design
4) Lighting and power
5) Heating and cooling
6) Ventilation stage
7) Building material selection
8) Value engineering
9) Quality assurance strategy

The process described above was worked out during the Bentall design and was formally applied to the BCBC Kamloops design, with the addition of some Value Engineering procedures. A qualification must be added that the steps are somewhat iterative, in that work in one step may lead to a reconsideration of work in previous stages. In the Kamloops case, the Bentall architect served as a facilitator, to introduce the concepts to the BCBC design team. The Kamloops design also took the process further by having a quantity surveyor present at all meetings, providing the design team with real-time costing as well as continuous energy simulations as the process unfolded.

Thus, a preliminary but significant result of the first phase of the C-2000 program was the apparent importance of process as compared to technical wizardry in achieving high performance; a somewhat unexpected result. It may be concluded that, although technologies are important, it appears to be teamwork and the careful integration of a number of relatively conventional technologies into the process that allowed C-2000 designers to achieve relatively high performance levels with minimal costs.

The abstract schematics at the right show another way of looking at the integrated design process: a series of iterative design loops punctuated by a series of increasingly detailed tasks.

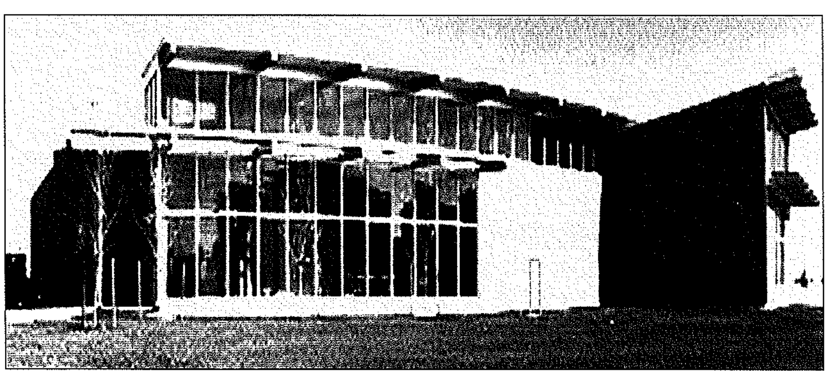


Phase 2: Design Facilitation

Consideration of the first phase results led to the conclusion that the financial and technical support provided by CETC to the design process was the most cost-effective part of the program and that the limited funds available to the program would be much better concentrated on the design phase. The second phase of the program was therefore launched as the C-2000 Design Facilitation or C-2000 DF program. Projects participating in Phase have included a branch Library in Saskatoon, a Native Friendship Centre in Prince George BC, a condominium in Victoria BC, and another condominium in Dundas, Ontario.

Below: The interior daylit area of the Alice Turner Library nearing completion.

Bottom: An exterior view of the Library.



As in the first phase, participating design and development teams have been expected to conform to the C-2000 DF criteria on a best-efforts basis. An area of uncertainty exists, however, as to the feasibility of imposing the previous energy performance requirement under the new conditions of no capital support. In addition, the C-2000 DF energy requirements are now being re-structured so that they reference the National Energy Code for Buildings (NECB) instead of the previous ASHRAE 90.1 benchmark. The performance criteria for the projects funded under C-2000 DF have therefore been developed on a custom basis until a performance requirement is established that is shown to be both demanding and achievable.

Based on the experience in Phase 1, the C-2000 DF process relies on the following elements to increase the likelihood of high performance:

- ❑ an insistence on close teamwork by all members of the design team from the beginning of the design process, so that the performance and cost implications of various design options are considered in a holistic way, and at an early stage,
- ❑ the involvement of one or more design facilitators in most design meetings, to act as a guide to performance options and a link to various contracted specialists,
- ❑ augmentation of normal design team expertise with an energy engineer, an environmental specialist and a cost consultant,
- ❑ the availability of a roster of specialized technical experts who can be called in at short notice to assist the design team in issues such as daylighting, thermal storage or other specialized technical areas,

- the use of a clear and comprehensive technical guideline document, such as that developed for the C-2000 program,
- the development of short written performance strategies by the design team, so that performance targets can be established within each performance area and the costs and benefits of each option examined, and
- during the construction phase, commissioning of all major systems including the building envelope to ensure that systems are properly installed and perform to designed levels.

One of the Phase 2 buildings, the Alice Turner Library, in Saskatoon, Saskatchewan[5, 6], has now been completed. The building is projected to use about 51% of the energy of the base building (ASHRAE 90.1 basis), and will incur only 42% of the energy cost, because of a reduction in electrical consumption. Moreover, the cost of the building was close to the original construction budget, and most of the other C-2000 performance criteria have been thoroughly considered and addressed.

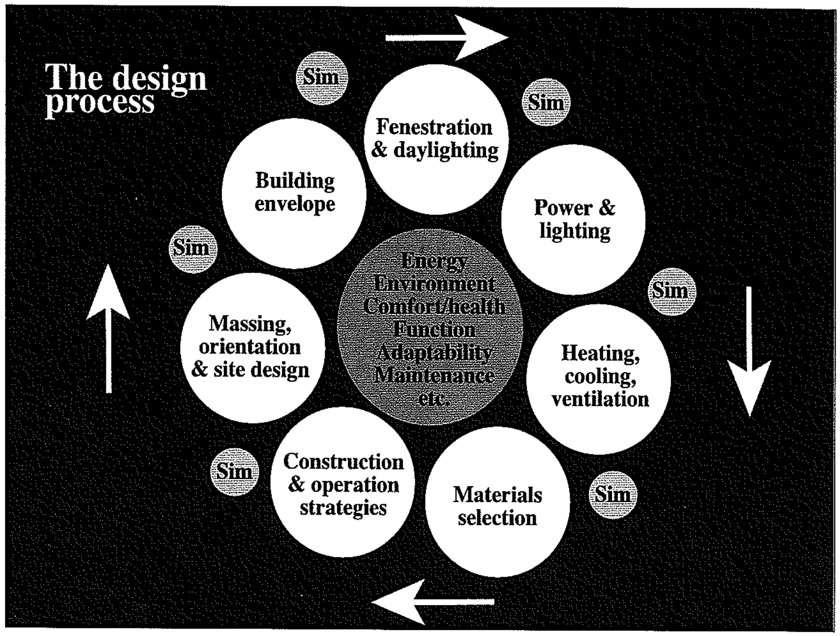
Phase 3: The CBIP / C-2000 Combination

The program has recently entered its third formulation; as a partnership with the Commercial Buildings Incentive Program (CBIP), another program established by NRCan. The combined offering reflects a good fit between the two programs, as well as the pragmatic effort to make dollars go further.

The CBIP program became operative on April 1, 1998. Its structure builds on the C-2000 experience by providing supplementary funds for the design stage for commercial buildings to improve performance. It is, however, different in several respects: it is open to all applicants who can pass the performance threshold, it is targeted on energy performance only, and it provides relatively generous benefits to supplement design phase expenses.

Projects qualify by demonstrating that the anticipated energy consumption will improve on the requirements of the Model National Energy Code for Buildings (MNECB) by at least 25% as well as conforming to certain other mandatory energy-related criteria. Such projects are then eligible for financial assistance equal to three times the projected annual energy cost savings, up to a maximum of $80,000.

The complementary between the two programs comes from the fact that applicants can obtain significant design-stage support from CBIP, but can also obtain from C-2000 additional financial help, as well as design facilitation and expert support for design development issues related to



The illustration above is a highly schematic representation of the types of performance areas covered by C-2000, related to those covered by the CBIP program and building codes.

environmental impact reduction, indoor environment improvement and other non-energy issues.

The combination is proving to be popular, and six projects are now planned or underway on this basis.

The first, a combination of offices and a control centre for the Yukon Power Corporation in Whitehorse, Yukon, has already been completed [7]. Project tenders came in at $1.5 million, substantially less than the project budget of $1.7 million. DOE 2.1E computer simulations show that the projected annual energy consumption will be 58% of a comparable building conforming to requirements of the MNECB, while projected annual energy costs are estimated to be 51% of the MNECB reference building. The owner is reportedly very pleased with the result.

Two other projects are nearing completion: a Town Hall for Hinton, Alberta, and a school in Mayo, Yukon. As Table 1 indicates, both of these projects have an excellent level of potential performance and, while extra costs are not yet in, they appear to be quite modest.

Conclusions

Results to date indicate that, if an integrated teamwork process can be implemented in the context of well-articulated guidelines and specialized support we may expect a 35% to 50% improvement in current energy performance levels with only modest increases in design budgets. The combination of such an approach with truly advanced technologies could have spectacular results. However, there is an undoubted reluctance within the design profession, particularly amongst architects, to change their established relationships, and this will require years of patient prodding to overcome.

References

1. C-2000 Program Requirements; N. Larsson, editor; CETC, Natural Resources Canada; October 1993 (updated October 1996).
2. Green on the Grand C-2000 Report, Enermodal Engineering Inc.; Kitchener, ON.; April, 1996.
3. Crestwood 8 C-2000 Report, Bunting Coady Architects; Vancouver, B.C.; April, 1996.
4. Ministry of Transport and Highways Project, C-2000 Report, British Columbia Buildings Corporation; Vancouver, B.C.; March, 1997.
5. Alice Turner Branch Library C-2000 Report, G.F. Shymko and Associates Inc.; Vancouver, B.C.; April, 1998.
6. C-2000 Design Facilitation, Overview of Facilitation Experiences in the Alice Turner Branch Library, G.F. Shymko and Associates Inc.; Vancouver, B.C.; May, 1998.
7. Yukon Energy Corporation Corporate Office Building, Whitehorse, Yukon: C-2000 Design Facilitation, G.F. Shymko and Associates Inc.; Vancouver, B.C.; November, 1998.

Further Information

The C-2000 Program Requirements are currently under revision.

You will find relevant information on C-2000, commercial building technologies and integrated design at the following websites:

http://buildingsgroup.net

http://greenbuilding.ca

http://advancedbuildings.org

Table 1. Summary Characteristics, Selected C-2000 projects

Name	**Crestwood 8**	**Green on the Grand**	**Alice Turner Library**
Status (September 2000)	Completed	Completed	Completed
Location	Richmond, BC	Kitchener, ON	Saskatoon, SK
Type	Speculative office	Speculative office	Branch Library
Developer/owner	Bentall Development	Ian Cook Const. Ltd	City of Saskatoon
Gross area and floors	7,435 m^2, 3 floors	2,174 m^2, 2 floors	1,400 m^2 on one floor
Energy consumption and as % of reference building	92 $ekWh/m^2$ per year, 51% of reference building	82 $ekWh/m^2$ per year, 44% of reference building	205 $ekWh/m^2$ per year, 51% of reference building
Added capital $, as percent of base building	7.0% actual	7.4%	3% estimated
Structure and building envelope type	Tilt-up concrete wall, steel frame, steel deck, concrete topping	Manufactured wood frame, double stud wall	Wood frame over concrete crawlspace
Fenestration	Double glazed, spectrally selective, low-E, thermally broken aluminum frames	Triple glazed argon fill, 2 low-E coats, spectrally selective, warm edge, fibreglass frame	Double glazed, argon filled, low-E; operable windows in stack areas
Mechanical systems	Condensing gas boilers, air-cooled 110 ton chiller, 4-Pipe fan coil, small zones	Gas-fired heater / absorption chiller; latent & sensible heat recovery, hydronic radiant panels for heat/cool	Low-temp. boiler and air-cooled chiller; 4-pipe fancoil and radiant system; Variable speed ventilation w. enthalpy heat recovery.
Lighting	T8 direct, max. daylighting	T8 direct/indirect, max. daylighting	Recessed & surface mounted T8; most with 3-stage control.
Other	Low emission materials chosen, leases being developed to guide tenants in EE use of building	Storm water retention pond used as cooling tower, gas cooling greatly reduces CO_2 emission	Materials chosen for low emission

Name	**Yukon Power HQ**	**Hinton Town Hall**	**Mayo School**
Status (September 2000)	Completed	Nearing completion	Nearing completion
Location	Whitehorse, Yukon	Hinton, Alberta	Mayo, Yukon
Type	Offices and control centre	Offices and public meeting rooms	Classrooms and support spaces
Developer/owner	Yukon Power Corp.	Town of Hinton	Mayo, Yukon
Gross area and floors	1,200 m^2 two-storey with partial third floor	3,017 m^2 three-storey	3,206 m^2 single storey
Energy consumption and as % of reference building	249 $ekWh/m^2$ per year, 57.7% of reference building	192 $ekWh/m^2$ per year, 46.3% of reference building	268 $ekWh/m^2$ per year, 52.6% of reference building
Added capital $, as percent of base building	11.8% under budget	negligible	To be determined
Structure and building envelope type	Wood frame, slab on grade	Wood frame, slab on grade	Wood frame over crawlspace
Fenestration	Triple pane spectrally selective low-e glazing, vinyl or fibreglass frames	Double pane low-e glazing, fibreglass frames	Triple pane spectrally selective clear low-e glazing, vinyl frames
Mechanical systems	Compartmentalized 4-pipe fan coil, groundwater cooling, combination oil & off-peak electric boilers	Compartmentalized 4-pipe fan coil, raised floor supply in some areas, municipal water cooling, hi-efficiency boilers	Compartmentalized 4-pipe fan coil and single-zone air handlers, occupant-sensing control of ventilation, groundwater cooling, combination oil & off-peak electric boilers
Lighting	Suspended direct/indirect fixtures with T8 lamps and electronic ballasts; active single-step daylight control and occupancy sensors	Suspended direct/indirect and recessed deep cell fixtures with T8 lamps and electronic ballasts; active single-step daylight control and occupancy sensors	Suspended direct/indirect and recessed deep cell fixtures with T8 lamps and electronic ballasts; active three-step daylight control in classrooms and occupancy sensors
Other	Materials chosen for low embodied energy and local contextual considerations	Intensive analysis conducted to optimize building orientation within site constraints	Classrooms and teaching areas are fully daylight from two directions with windows and clerestories

The text at the right is excerpted from the still-developmental version of the C2k software, which will facilitate the work of integrated design teams in establishing their performance targets. For each of the performance areas listed, there is a corresponding layout with a discussion of the issue, an outline of C-2000 requirements, background information and space for the design teams to articulate their own targets and strategies for achieving these performance levels.

The software is expected to be available for distribution in February, 1999.

List of generic design steps, excerpted from C2k software

A. Examine assumptions and functional program
A1. Check functional program for completeness and ambiguities
A2. Determine if the proposed building is really necessary
A3. Determine if an existing building can be renovated to suit the functional needs
A4. Determine whether a mixed-use solution is possible and acceptable
A5. Check budget assumptions for realism; see if a life-cycle approach can be followed

B. Develop preliminary design to minimize impact on site ecology and on adjacent properties
B1. Minimize loss of solar or daylight potential of adjacent property
B2. Minimize damage to surface ecology
B3. Develop preliminary landscaping plans to provide windbreaks and shading
B4. Minimize alteration to subsurface ecology
B5. Ensure that the building will form a positive contribution to the streetscape

C. Arrange building volumes and layout to optimize for passive solar and functionality
C1. Lay out building to maximize functionality & minimize wasted space and volume
C2. Organize configuration & floor plate depth to balance daylighting & thermal performance
C3. Consider floor-to-floor height adequate for other future uses
C4. Orient the building to optimize passive solar potential
C5. Carry out a first set of energy simulations

D. Select building structure to optimize for efficiency and functionality
D1. Select structure type
D2. Consider column spacing and core position adequate for other future uses
D3. Consider access floor option for underfloor HVAC delivery and cabling flexibility

E. Design building envelope to optimize thermal and longevity performance
E1. Design exterior walls according to rain-screen and pressure-equalization principles
E2. Minimize the initial embodied energy of building envelope
E3. Optimize the thermal performance of the building envelope
E4. Provide air barrier to minimize air leakage

F. Locate and design fenestration for daylighting and thermal performance
F1. Optimize fenestration on each orientation to optimize daylighting benefits
F2. Optimize the daylighting and thermal performance of fenestration
F3. Consider use of operable windows

G. Design lighting system and determine power requirements
G1. Develop preliminary lighting system design
G2. Develop preliminary lighting control system
G3. Estimate the power requirements for future tenant office equipment
G4. Optimize the energy efficiency of vertical transportation systems
G5. Consider strategies to shave peak demand

H. Design HVAC system to meet heating, cooling and ventilation needs
H1. Develop preliminary ventilation system design
H2. Consider thermal storage options
H3. Develop preliminary design for HVAC central plant
H4. Develop preliminary design for HVAC delivery systems
H5. Develop preliminary HVAC control system
H6. Carry out a second set of energy simulations

J. Select materials to meet ecological and indoor environmental needs
J1. Consider re-use of components and recycled materials
J2. Design assemblies and their connections to facilitate future demountability
J3. Select indoor finishing materials to minimize VOC and other emissions
J4. Select materials for site uses that are durable, recycled and low in embodied energy
J5. Select materials for the building that are durable, recycled and low in embodied energy

K. Complete site and building design
K1. Develop landscaping plan to minimize potable water consumption
K2. Design wet services and select sanitary equipment to minimize water consumption
K3. Design telecom system
K4. Finalize HVAC system design
K5. Finalize lighting system design
K6. Select building management control systems
K7. Review the use of materials to minimize waste
K8. Carry out a final set of energy simulations

L. Develop QA, construction, maintenance and operation strategies
L1. Appoint a commissioning agent and develop a commissioning plan for all major systems
L2. Develop lease instruments with incentives for tenants to operate space efficiently
L3. Train building staff to operate equipment efficiently
L4. Develop plan to minimize C&D wastes during construction
L5. Develop plan to minimize ecosystem damage during construction
L6. Ensure that a full set of as-built contract documents are handed over

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