Review of GBTool and
Analysis of GBC 2002 Case-Study Projects

Report submitted to: **Nils Larsson**
Buildings Group/CETC
Natural Resources Canada
580 Booth Street – 13th Floor
Ottawa, Ontario K1A 0E4

By: **Dr Raymond J Cole**
School of Architecture
University of British Columbia
6333 Memorial Road
Vancouver, BC V6T 1Z2

Date: **12th November 2002**

ANALYSIS OF GBC 2002 CASE-STUDY PROJECTS

1.0 Introduction

Green Building Challenge (GBC) is an international collaborative effort to develop a building environmental assessment tool that exposes and addresses controversial aspects of building performance and from which the participating countries can selectively draw ideas to either incorporate into or modify their own tools.

The GBC process is managed by the *International Initiative for a Sustainable Built Environment* (iiSBE), whose web-site is www.iisbe.org. The task of organizing Sustainable Building conferences that include GBC presentations is now being carried out by iiSBE.

1.1 GBC 2002

Green Building Challenge 2002 was a continuation of the *GBC '98* and *GBC 2000* process. It culminated in the presentation of the assessed buildings at the *Sustainable Building 2002 Conference (SB 2002)* in Oslo, Norway, September 23-25th 2002. This conference attracted over 1000 delegates from 68 countries. As in the 2000 conference in Maastrict, the scope of green and sustainability covered in the program was significantly greater than in *GBC 98.* GBC was one of five streams in *SB2000.*

16 countries participated in *GBC 2002:*

- Australia
- Brazil
- Canada
- Chile
- Finland
- France
- Hong Kong
- Israel
- Italy
- Japan
- Korea
- Norway
- Poland
- Spain
- Sweden
- United States of America

Other countries – P.R. China, Greece and Wales – were anticipated to submit case-study projects but ultimately did not. Austria, Germany, The Netherlands, Switzerland, South Africa and the United Kingdom had participated in one or both of the previous rounds of GBC, but also did not participate in *GBC 2002*. The reasons for their non-participation are, for the main part, related to not being able to secure financial support to make the assessments. However, as experience with building environmental assessment matures and countries develop their own methods interest will continue to diminish. In one sense, the GBC process would have fulfilled its role, and will have to reassess its role if it is to maintain its value.

2.0 GBTool

GBTool is the method used to assess the potential energy and environmental performance of the case-study projects in the Green Building Challenge process. A feature of *GBTool* that sets it apart from existing assessment systems, is that the method is designed from the outset to reflect the very different priorities, technologies, building traditions and even cultural values that exist in various regions and countries.

Although it is not intended for direct application by end users, members of national GBC teams and others are free to draw from it in whole or part for use in the creation of assessment tools.

The version of *GBTool* used in *GBC 2002* consisted of a single *Microsoft Excel*™ workbook. In addition to two worksheets intended for all users (Intro and ID), the worksheets are divided into four main sections, arranged primarily according to those responsible for their completion:

Section One: This section contains four worksheets - Cntxt (Context), Vote, EnGen (Energy Generation), and Bmark (Benchmark). These worksheets are to be completed by persons who are not linked to the design, or by persons who are undertaking the assessment.

Section Two: Contains seven worksheets dealing with design data: Area, Arch, Tech, Matrl (Material), Ops (Operations), LCC (Life-cycle Costing). These are intended to be completed by a team of persons who are knowledgeable about the design, presumably the designers themselves.

Section Three: This contains the *Assessment* worksheet (Assess). This key worksheet contains scoring fields for all the sub-criteria and criteria and then applies the weights assigned in the Vote and Weight worksheets to these scores.

Section Four: Contains three worksheets - Rprt (Report), Weight and Result. These summarize and show results of all previous inputs and, as such, there contain no user-modifiable fields.

2.1 Assessment Framework

The GBC assessment framework represents the scope and organisation of the performance issues covered within an assessment. The GBC framework and *GBTool* used in GBC 2002 did not include any significant conceptual or intellectual advances over the previous versions. The emphasis of the development process was directed at streamlining and automating the data input and handling.

2.1.1 Performance Issues

Assessment of green performance is made in six (6) general *Performance Issues:*

- Resource Consumption
- Loadings
- Indoor Environmental Quality
- Quality of Service
- Economics
- Pre-Operations Management

The first three Issues were mandatory in GBC2002, but others optional. A seventh performance issue - Commuting Transportation – was not operational in GBC 2002.

Within these performance issues there were over 100 different criteria and sub-criteria. The large number of criteria that could potentially be assessed within GBC raises several issues that have been evident in previous versions of *GBTool*, and still not effectively resolved:

- A large number of performance criteria clearly translate into time and effort on the part of the assessment team.
- Perhaps more importantly, limited time and effort devoted to the assessment of often unfamiliar performance issues means that misinterpretations and errors are inevitable. This is evident in *GBC2002* and it worrisome not knowing if the results are accurate due to user error, internal inconsistencies, bugs within *GBToo*l, etc. A critical requirement in any "research" project is having confidence in the results. Indeed being able to explain the results is as important as the results themselves.
- It seems important to distinguish between information required to perform an analysis from that required to explain the results and to radically reduce the number of both. More performance criteria clearly does not produce a better tool if there is little confidence in their individual and collective scores.
- Economics was either not completed at all, or National Teams inputted the same numbers for benchmark and case-study. Although the latter could suggest that the case-study building was delivered at no additional cost, it most probably represented a conscious decision on the part of the assessors not to engage in this performance issue. Even if the overall cost data is presented and dependable, since it is not possible to *explain* any differences at a detail level (e.g., what features more or less expensive), it is not a particularly useful metric. It is suggested that Economics be dropped from *GBTool.*

2.1.2 Environmental Sustainability Indicators (ESI)

Environmental Sustainability Indicators (ESIs) are a limited set of *absolute* performance measures that characterize sustainable building practices and that facilitate international comparability. Twelve (12) *Environmental Sustainability Indicators* are assessed:

- ESI-1: Total net consumption of primary embodied energy, GJ
- ESI-2: Net annualized consumption of primary embodied energy, MJ
- ESI-3: Net annual consumption of primary energy for building operations, MJ
- ESI-4: Net annual consumption of primary non-renewable energy for building operations, MJ
- ESI-5: Net annualized primary embodied energy and annual operating primary energy, MJ
- ESI-6: Net area of land consumed for building and related works, m^2
- ESI-7: Net annual consumption of potable water for building operations, m^3
- ESI-8: Annual use of grey water and rainwater for building operations, m^3

- ESI-9: Net annual GHG emissions from building operations, normalized for net area and occupancy, kg. CO2 equivalent
- ESI-10 Predicted CFC-11 equivalent leakage per year
- ESI-11: Total weight of materials re-used in Design from on-site or off-site uses, kg.
- ESI-12: Total weight of new materials used in Design from off-site uses, kg.

As in *GBC 2000*, National Teams were asked to normalise the performance results by both intensity of use (e.g., annual person-hours of occupancy) and the more typical building area.

The version of *GBTool* used in *GBC2002* had several key differences from that used in *GBC 2000*. These will be discussed within the relevant sections of this report. However the following general characteristics are important:

- Whereas previous versions of *GBTool* had focussed on three distinct building types – Office buildings, Multi-Unit Residential and Schools, the current version provided the opportunity for more generic description of buildings with up to four different occupancies. This enabled a wider variety of building types to be assessed and presented at *GBC 2002* than in previous rounds (e.g., university projects, industrial buildings etc.,) that provided greater interest to the project presentations and testing of *GBTool*. On the negative side:
  - Having fewer numbers of buildings within specific “types” makes any overall characterisation of their performance difficult if not impossible.
  - Projects are now described by their *primary* use. With mixed-use projects is difficult to directly compare performance of their “office” or “residential” etc. component without being able to isolate the individual performances of the constituent elements.
- A greater amount of automation was provided within *GBTool*. Although reducing the effort required by the National Teams to complete *GBTool* and derive overall performance scores, it significantly increased the potential number of bugs/errors that can diminish the overall confidence in using the tool. Many of these were exposed and corrected as the National Teams began to apply *GBTool* during the undertaking of the case-study assessments in the two or three month period prior to the SB2002 conference.
- Though still requiring a considerable amount of data input, the various sections of *GBTool* data sheets were colour coded to identify what must be completed by the user and what should be untouched. Moreover, the use of drop-down menus significantly enhance the ease with which data is inputted.
- As would expected, and as in other previous rounds, a wide variety of degrees of completion of the *GBTool.* Some National Teams worked methodically through *GBTool* completing all key sections for which they had access to relevant data. These were typically, but not universally, new participants in the GBC process. Others only provided scant input reflecting either time pressures or lack of interest. The GBC process clearly must acknowledge this reality and create the capability

within *GBTool* to enable teams to input necessary information to derive performance scores via alternative paths. In particular, this should probably enable them to input performance data derived from other tools. The downside to this is the increased difficulty in being able to interpret the results without the supporting building charactersitics.

- It was planned to have the case-study projects submitted earlier than in the past to permit sufficient time to analyse the collective results. Many National Teams complied with the early submission date and enabled an initial level of quality control to be provided by the GBC secretariat in the form of review and feed-back. This was an extremely important improvement to the process. Other projects were presented directly at the Oslo conference without having been submitted to the GBC secretariat.

2.2.2 Numerical Scales

In previous versions of *GBTool*, the scales were all expressed as percentage reductions or increases relative to the benchmark and were inputted directly during the assessment. In the current version of *GBTool*, the performance scales for those criteria and sub-criteria that are described quantitatively are automatically generated within *GBTool* in one of three ways:

- By the difference between a "best" performance target and the benchmark divided by 5, i.e., the target value is explicitly declared.
- By the declaration of a fixed interval, and the subsequent values for scores of 1, 2, 3, 4 and 5 simply determined by subtracting from the benchmark value (or adding for the –1 and –2 scores).
- For criteria that are measured in terms of the percentage of resource saved or used (e.g., the amount and quality of off-site materials use) the scales are expressed as a percentage. The benchmark value is the typical percentage associated with the performance issue and, as above, the scale intervals can be set to determine the full range.

Although this automation process links the performance scale more specifically to the context, there are two major changes:

- The resulting quantitative scales are now no longer set against percentage reductions/improvements over the benchmark as in previous versions of *GBTool*, are now represented by absolute values derived from scaling between the benchmark (0) and target values (0). This procedure is done automatically by algorithms built into *GBTool* and so, while the difficulty of deciding the target value remains, the opportunities for errors is reduced.
- In earlier versions of *GBTool*, the scaling intervals were simply 10%, 20% etc. The automatic scaling between the benchmark and declared target value now creates very precise scaling intervals. In many instances, the implied accuracy and intervals of the scales is not consistent with our current ability to either measure or interpret, e.g., The scoring scale for *R1.2 Net Primary Energy* has the benchmark at 2352 MJ/m^2/year; 1

point at 2142 MJ/m^2/year; 2 at 1932 MJ/m^2/year etc., intervals that are far too refined relative to the accuracy of their estimation.

2.2.3 Benchmarks

A critical feature of *GBTool* is that scoring is made relative to explicitly declared benchmarks. National teams were requested to complete a section of *GBTool* specifically designated for the benchmark values that are subsequently automatically accessed and referenced in the analysis. The choice of benchmark value is therefore critical is the overall performance assessment and a feature that requires much clear direction on their selection and use within *GBTool*.

2.2.4 Customizing GBTool

Since the *GBTool* is to be applicable across a wide range of regions and building types, each having differing building practices, energy costs, materials choices and performance expectations, it is impossible to offer a precise and universally applicable metric. Thus, a major requirement of *GBTool* is to have a common approach and structure, but with adaptations made by each National Team to suit national or regional needs.

Although National Teams were encouraged to make as many changes to *GBTool* as necessary to customise it to suit the environmental issues and priorities of the case-study building and context, teams chose not to use this option.

- *Selecting Performance Issues:* Resource Consumption, Loadings and Indoor Environmental Quality represent core requirements within the GBC process and were required to be assessed in all *GBC 2002* projects. National Teams were encouraged to complete the remaining three performance issues – Quality of Service; Economics and Pre-Operations Management – but their completion was optional in *GBC 2002*. The majority of the National Teams opted to complete all six performance issues. In hindsight, as will be discussed later, it would have been more effective to require all a teams to complete the same performance issues.
- *Customizing the Performance Scales:* The scoring scales in the *Assess* Worksheet include default values to meet performance scores of the *benchmark* (0) and demanding (5) performance respectively and, where appropriate, intermediate performance levels characterize this intention. While meeting the overall intent of the sub-criterion/criterion, these scales can be customized by authorities within the respective regions into specific strategies, targets and, if necessary, appropriate language for the building type and location.
- *Customizing the Weightings: GBTool* assesses approximately 100 individual sub-criteria and criteria. It is therefore necessary to reduce the assessment scores to a manageable number in the output profiles. The output profiles are derived through the weighting of the scores at the lower levels, i.e.,
    - *Criterion* scores are obtained through the weighted scores of constituent *sub-criteria.*

- *Category* scores are obtained through the weighted scores of constituent *criteria.*
- *Issue* scores are obtained through the weighted scores of constituent *categories.*
- The *overall building* score is obtained through the weighted scores of *issues.*

▪ Some flexibility is permitted in customizing the weighting. Whereas weightings at the sub-criteria and criteria level are fixed, those at the *Category* and *Issue* levels were established by the National Teams. The position taken here was that the highest level *Issue* weights are not amenable to an objective determination, and teams were therefore invited to either use the GBC defaults or to use their own weights, while indicating their reasons for doing so.

▪ National team members were asked to allocate points to indicate the relative importance of the Category and Issue weights. Each National Team could decide on the appropriate way to develop weightings complete the Vote Worksheet. The worksheet permitted up to 6 persons to enter votes. Alternatively, experts could have discussed the issues and collectively arrived at an appropriate set of category weightings and enter a single set. In the absence of a consistent methodology, it was proposed that a multi-criteria decision-making technique be used to establish their values. Although these techniques (Analytic Hierarchy Process, the Simple Additive Weighting approach etc.) still depend on value judgements, they at least establish the weightings in a more methodical way. The basis for weightings and the extent of their application within *GBTool* remains contentious and is, again, an area that requires greater scrutiny.

3. Case-study Projects

Table 1 shows the range of building types (listed by their primary occupancy) and their geographical distribution. For discussion purposes the geographical distribution is as follows:

Europe: France, Italy, Norway, Spain, Sweden, and Israel

North America: Canada and United States of America

Asia: Hong Kong, Japan and Korea

Southern Hemisphere: Australia, Brazil and Chile

	Europe	*N. America*	*Asia*	*S. Hemis*	
Offices	4	2	9	2	17
MURBS	5	1	2	1	9
Schools	1	2	1	0	4
College	2	1	1	1	5
Retail/Industrial	1	2	0	0	3
	13	8	13	4	**38**

Table 1: GBC 2002 Projects

4. Weightings

Figure 1 shows the relative weightings provided by the National Teams for Resource Use, Environmental Loadings and Indoor Environmental Quality respectively:

- All but one of the National Teams made changes to the relative weightings from the default values. This is different from in previous rounds where several National Teams simply accepted the defaults and can be attributed to the weightings being an explicit and accessible section of *GBTool.*
- There is no clear or consistent higher priority between Resource Use, Environmental Loadings and Indoor Environmental Quality. This reinforces the importance of ensuring that, within the realm of building environmental performance assessment, indoor environmental quality issues are considered alongside energy, water and other resource use issues and green house gas emissions etc.

Figure 2 shows weightings for Quality of Service, Management and Economics respectively:

- As would be anticipated, all three performance issues are weighted lower than the core performance issues.
- Quality of Service typically represents the most significant issue within these secondary concerns.

A major difficulty in interpreting the relative weightings shown in *Figures 1* and *2*, is the inconsistency in the basis for allocating the weightings across the six performance issues. Most teams distributed the points in all six; others who only assessed the core issues distributed weighting across the three, while others distributed the weightings across the core issues and one of the secondary ones. Since fewer weighting "percentage points" were directed at the secondary issues, either of these two latter conditions clearly created higher overall weighting values in the core issues.

It would have been useful to have seen how all the National Teams would have distributed the weightings solely among the three core performance areas rather than having these tempered by having to simultaneous allocate some weighting to the secondary issues.

Greater variation is evident within the distribution of the weightings for the categories within the main performance areas. *Figures 3, 4* and *5* show the relative category weightings for offices within the *Resource Use, Loadings* and *IEQ* performance areas.

The following points are evident:

- Energy use (R1) is consistently the most important resource use issues, often by a considerable margin.
- The distinction within the materials categories (R4) and R5 is influenced regarding whether there is an existing building within the scope of the project and therefore distorts the direct comparison.

- For the Loadings, green house gas emissions is the dominant priority issue, again often by significant margin. This also was consistent with other building types and with previous rounds of GBC.
- Within IEQ, Air Quality and Thermal conditions are most important. This is consistent with previous rounds of GBC. Electromagnetic Fields (EMF) was introduced for the first time in *GBC 2002*. It was consistently weighted very low and perhaps should be dropped from *GBTool*.

5. Performance Results for GBC2002 Office Projects

Office building represented the dominated building type within *GBC 2002*, with 13 projects submitted and included in this analysis. *Table 2* shows the distribution of these office buildings by region, together with general characteristics of secondary use (if any), height (in storeys) Gross Area (m^2), Efficiency (Net/Gross Area) and Occupancy (numbers).

Table 2: GBC 2002 Offices Projects

	2nd Use	*Project #*	*Height*	*Area*	*Efficiency*	Occupancy
Europe		1	5	360	95	191
	University	2	2	1940	71	113
N. Amer.	Laboratory	3	4	12989	76	203
		4	3	3206	86	126
Asia		5	26	79554	81	1750
		6	6	159054	49	11000
		7	5	4000	64	120
		8	19	33295	56	1996
		9	10	9135	93	391
		10	5	5447	88	316
		11	5	6185	88	143
S. Hemis	Hotel	12	2	4613	96	176
	Support/Gym	13	4	20567/5882	93	428/295

5.1 Performance Scores

Since the performance scoring in *GBTool* is relative to regional benchmarks it is not appropriate to compare and contrast the performance profiles or overall building "scores" for the various GBC submissions (with the exception of the same building type from the same region). However, it is instructive to examine the range of scores evident in the case study projects, in particular, the overall building score.

The final building score derives from the weighted aggregation of four levels – sub-criteria, criteria, categories and performance areas, within the three core Issue areas. This successive deployment of essentially subjective weightings to the performance scores has been contentious from the outset of GBC but has been tempered to some extent by fixing the weightings at the lower two levels. In *GBC2002*, it was accepted that the final building score would only comprise of the weighted values of the core performance areas – Resource Consumption, Loadings and IEQ. Since the three core performance issues were not explicitly weighted relative to one another (unless the National Team only chose to consider these three issues), the weightings applied to derive the final score were derived by proportioning them as if they were the sole weights. The assumption is that these weighting would be the same as if the weights were distributed amoung the three choices.

The final results are alarmingly similar, e.g., for Office projects 10 of the 13 had scores of 2.5 +/- a little more than 0.2. (See *Figure 6*) Clearly this, in part, derives from the enormous number of individual performance criteria having the obvious consequence that the more criteria and sub-weightings means distinctions in overall building scores diminish. Only the ones that did not complete all categories did the scores vary due to a combination of low category scores plus fewer elements in the weighting process. Though this may be a statistical glitch, but points to the need for further investigation. If the scoring of a building based on a large number of performance issues tempers the differences in the overall score, this has profound implications:

- The scoring scales must be reviewed to ascertain their implications on the category, issue and overall building performance scores.
- Greater emphasis needs to be placed on how to interpret an overall score.
- For a market place tool, the building development community would typically want to be able to distinguish the *environmental* merits of their projects, i.e., be provided with a building score that highlights or emphasises improvements relative to that of others. Providing the means to show this distinction by ensuring that building scores are *always* accompanied by the more detailed performance profiles seems critical in this regard.

5.2 Building Life

The assumption made about the anticipated building life – both for the benchmark and case-study buildings – has a critical impact on many of the performance results, e.g., the annualized embodied energy. *Figure 7* shows the building life assumed in the *GBC 2002* office buildings:

- There is clearly an enormous range of assumed building life-spans assumed in the case-study projects. Although the typical life is 75 years (the default value), many have made the assumption of a longer life of 100 years. By contrast, some projects in Asia assumed lives of only 25 years. Although this short life may be a reflection of regional economic realities, it is somewhat surprisingly within the context of environmental responsibility.
- *GBTool* had fixed formulas that kept the same life-time for the case-study and benchmark buildings so as not to inadvertently enhance the performance results of the case-study building. Although this was done in the majority of cases, some teams over wrote the formula box and extended the life of the case-study building beyond that in typical practice. Since this represents the more realistic scenario to show the

shift in expectation, it requires further investigation within the GBC process to provide ways of accounting for different time-frames.

5.3 Environmental Sustainability Indicators

The Environmental Sustainability Indicators offer a more appropriate basis to compare and contrast the case-study projects internationally. Moreover, since there is an emerging emphasis on developing "indicators of sustainability" at the national and regional scales, these may represent the logical basis for identifying the contribution that buildings may make within a wider context. The following observations emerge from these results.

5.3.1 Primary Energy

Primary energy, i.e., accounting for upstream losses is clearly the most important metric to assess energy improvement since it couples the amount of energy with the fuel type and production. There is enormous variation in amount of primary energy used in the case-study buildings reflecting differences in building efficiency, climate and regional fuel-mix and distribution.

Within *GBC 2002* there seems to be a difficulty in the Teams distinguishing between "Net annual consumption of primary energy for building operations" and "Net annual consumption of primary non-renewable energy for building operations." Perhaps the renewable contributions should be explicit.

5.3.2 Delivered (Operational) Energy

Delivered energy, i.e., that delivered across the building boundary and used in the operation of the building is the more typical basis for energy accounting. Again there is considerable variation in delivered energy across the 13 office projects., which confirms the importance in the normalisation process (i.e., by area or by occupancy). Differences in the Asian projects are not as distinctive as in *GBC 2000*.

5.3.3 Embodied Energy/Operating Energy

Embodied energy remains a difficult performance criterion for the National Teams to assess. This difficulty derives largely from the absence of current, regionally applicable energy intensity data for the materials of construction and tools to assist in this process, combined with the overall time and effort required to make the assessment. *GBTool* included a simple set of defaults, although it is considered only a crude estimate. More National Teams attempted to derive the embodied energy using their own values that in previous rounds, representing a general maturing of this performance issue. The majority, however, relied on the default values. It is difficult to place too much confidence in the embodied energy values and as such are reported on here.

For *GBC 2000*, the embodied energy (also derived either by using default values or by calculation) expressed as a percentage of delivered energy (assuming a 75 year life) show a shift from 13% to 21% from benchmark to case study projects. It was not possible to confirm this trend in *GBC 2002*. For some of the projects, the embodied energy represented approximately 50% of the life-cycle energy use. This suggests that in the future, embodied energy will become and increasingly important and dominant portion of the life-cycle energy use.

5.3.4 Changes in Indoor Environmental Conditions

It is useful to explore the extent to which the case-study projects were achieving lower energy use and environmental loadings while maintaining or enhancing the indoor environmental quality. Several design and operational changes relate to this issue:

- *Temperature Set-points:* Setting the summer temperature set-points higher in the summer and lower in the winter can yield significant energy savings. This can move the resulting indoor temperatures outside of accepted comfort ranges and, unless occupants are accepting of the greater potential discomfort, compromise performance. In the GBC 2002 case-study projects, several changes were made in the case-study temperature settings from benchmark levels, although there doesn't appear to be any clear cultural trends. The two European projects increased the winter temperatures, although the increase from 20C to 25C in project #2 may be an inputting error, as is project #9 that shows a relatively low benchmark of 17C. The two North American projects tended to extend the temperature ranges relative to the benchmark.
- *Lighting Levels:* The variation in illuminance levels in the primary working areas of the office buildings for the respective countries is equally telling. First there is an enormous difference in what constitutes acceptable design illuminance levels. Values range from 200 Lux to 750 Lux. It is not possible to identify if these values are the ambient levels of combined task-ambient levels at the workstations. The majority of the projects kept the illuminance level in the Case-study projects the same as the benchmark; three reduced the illuminance level by 50-100 Lux, and one increased it by 50 Lux.
- *Ventilation rates*: Increasing the ventilation rate can increase heating and cooling energy requirements. The range of ventilation rates provided by the National Teams was considerable and the internal manipulation of these within *GBTool* produced values that do not align with typically deemed appropriate for Office buildings. However, while the absolute value of the ventilation rates are suspect, the relative differences between the case-study projects and the benchmark are instructive. Eight of the projects reported an increase in the case-study ventilation rate relative to the benchmark ranging from 20% to 500%.

It will become increasingly important to understand changing user expectations and operational shifts in buildings and their environmental consequences as distinct from those associated with improvements in building design. There is a need to build within *GBTool* the capability to more readily make this distinction.

5.3.5 Normalising by Occupancy and Area

Using a common assessment scale offers the advantage of structuring the range of possible performances in a consistent and explicit manner. Comparing performance against a declared benchmark also requires the use of consistent performance measures for each assessed criterion, i.e., performance data for the case-study building is in the same units as the benchmark performance. Some level of normalizing is necessary to enable this comparison. Many environmental issues in other assessment systems are expressed per unit area of the building, e.g., energy in GJ/m^2 or kWh/m^2 to account for variations in building size (e.g., between the case-study building and the benchmark.)

As in *GBC 2000*, the current version of *GBTool* uses a further level of normalization to account for variations in building occupancy patterns. Appropriate criteria were normalized for occupancy; in most cases the annual person-hrs of occupancy but in a few cases, the number of occupants. This offers a more appropriate basis for comparing the performance of a *building design.* However, increasing the number of variables included in the normalization can also diminish the validity of performance score, i.e., an estimated value of annual operating energy will be divided by an area, then by estimates of annual occupancy hours. Since this is repeated or inherent in the benchmark, despite that it represents a more realistic situation, the accuracy of scores based on the relative differences can quickly diminish.

The intensity of building use varies considerably in the case-study projects. *Figure 8* shows the annual person hours of occupancy per are of the case-study office buildings in GBC 2000 and GBC 2002 (the larger number of buildings provides a statistically stronger sample). Within this set of buildings, 1-5 are European, 6-13 are North American, 14-25 are in Asia and 26-29 are in the Southern Hemisphere.

Two set of values are presented, annual person hours of occupancy divided by net area above grade and by net area above and below grade, the former being a more appropriate representation of intensity of use.

In *GBC 2000*, the results had suggested that although office buildings in Asia typically had higher annual energy per unit area, they had relative lower energy use per annual person hours of occupancy. The assumption was that this was primarily due to a combination of a greater number of occupancy hours and a greater density of occupation. Figure 8 suggests that this is not necessarily the case and that projects in other region have, in many instances, higher intensity of use. *Figures 9* and *10* show the values of the Primary energy used in the *GBC 2000* and 2002 office buildings normalised for area and occupancy respectively. It is clear that the relative performance of the buildings in a side by side comparison differs markedly depending on the normalisation method and that this whole issue requires considerably more acknowledgment generally and within *GBTool* specifically.

5.3.6 Water use
The analysis of annual water use in *GBC2002* was particularly difficult. Certainly there is a considerable range in water use, but it is not possible to easily explain these differences. The final water consumption figures are not broken down into building and landscape water use thus making it difficult to isolate effective building operational strategies from design choices associated with landscape design.

6. Multi-Unit Residential Buildings

The second major building type presented at *GBC 2002* was Multi-Unit Residential (MURB) projects, with 8 submitted in a timely fashion to be included in this analysis.

Table 3: GBC 2002 MURB Projects

	2nd Use	*Project #*	*Height, m*	*Area, m2*	*Efficiency, %*	Occupancy
Europe		1	6	16955	86	441
		2	9	5720	91	168
		3	7	11599	71	221
		4	8	18157	91	391
N. Amer.		5	16	33166	84	774
Asia		6	20	55231	79	1347
	School	7	4	5246	100	172
S. Hemis.		8	5	24205	81	450

As with the office buildings, there is considerable variation the heights, sizes and occupancies of these projects. The performance of the MURB projects showed several similar trends as identified in the office building results earlier. As would be expected, there are marked differences in the resource use and ecological loadings across the 8 projects reflecting the combination of design, climate and operational procedures. One of the most interesting differences lay in the implications of normalising for area and occupancy. *Figures 11* and *12* show the delivered energy normalised by area and occupancy respectively. Although the sample is quite small, the relative differences between the ranking of the projects is less marked than in the case of offices where radical differences occurred with the two methods of normalisation.

7. Conclusions

This report has provided a critique of the version of *GBTool* used in the most recent round of the GBC process that culminated in the *SB 2002* conference in Oslo in September 2002.

This third round did not add significant conceptual or intellectual advance over *GBC 98* or *GBC 2000* – the emphasis being one of refinement and automation. Such developments may be of less interest to those countries experienced in building environmental assessment and who are in the process of introducing methods that involve a host of new considerations. The process and *GBTool*, however, maintains considerable interest by those countries in the early stages of developing domestic methods, and the education role between the experienced and inexperienced countries – with the GBC Framework and *GBTool* and the vehicle may assume greater importance.

The *Green Building Challenge* and *GBTool* has retained several important qualities, including:

- Exposure of users to a wide range of performance issues.
- Transparency of algorithms and relationships (e.g., weights not hidden).

- Usefulness of being forced to think about what are appropriate weights.
- Usefulness of being forced to consider the meaning and value of industry-minimum benchmarks.
- Ability to make all values in the system relevant to your region and building type.

The key disadvantages are clearly the extra time, effort and cost involved in doing all the above and ambiguities (but also reflecting inherent ambiguities in some performance issues).

The field of building environmental assessment has matured enormously over the past six years and the GBC process has been instrumental in those advances. It seems important that *GBTool* – as a tool for testing new ideas should reflect on these advances that have been, and continue to be made in the domestic methods of the experienced countries. For example, the proposed *Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)*[1] in Japan has fundamentally different conceptual underpinnings to other existing methods, and NABERS[2] in Australia has rejected the use of weightings because they are likely to change over the life of a building and there remains considerable uncertainty of the basis on which relative weights are derived.

7.1 Future of Green Building Challenge

The *Green Building Challenge* has gone through three two-year cycles and has been a central component in the major international conferences over that period. Two significant changes have occurred over this period:

- Although a core group of countries have participated in all three rounds, the overall mix of the participating countries has changed from those experienced in building environmental issues and assessment to those who are less experienced.
- GBC is now positioned under the umbrella of the *International Initiative for a Sustainable Built Environment (iiSBE)* that has a broader mandate than the initial intentions and framing of GBC.

The next major conference will be SB 2005 in Tokyo, Japan. This is a three-year interval rather than the 2 years that separated the three previous rounds. Given the rapid pace of development of building environmental issues and building environmental assessment, one can imagine the intellectual/experience context will be qualitatively different in 2005.

The question as to whether GBC can continue to provide the central and leadership role at SB 2005 that it has in the past is not clear cut:

- The most significant contribution of GBC has been to raise the profile of building environmental assessment both within the participating countries and internationally.

---

[1] Murakami, S., *Comprehensive Assessment System for Building Environmental Efficiency,* Japan Sustainable Building Consortium, 2002

[2] Vale, R., Vale, B., and R. Fay, *NABERS, The National Australian Buildings Environmental Rating System,* Final Draft Version, 14 December 2001

Given the widespread awareness and use of building environmental assessment methods, this function is now less significant within many countries.

- GBC and *GBTool* were initially positioned as a "research and development" exercise to test new ideas. Given the increasing sophistication and maturation of building environmental assessment within the broader building research community GBC's role here is also becoming less potent. There has been a significant increase in PhD theses and other specific funded research into a variety of aspects of building environmental assessment and it will difficult for the voluntary basis by IFC members to compete with these in terms of sustained effort. The "research" role of GBC is now less significant.
- As a development exercise, 6 years would seem sufficient to have refined a product. Indeed, the three rounds of GBC have led to the creation and refinement of *GBTool.* Though several issues remain unresolved (e.g., the transportation module), it would be difficult to justify a fourth round of further development.
- Although the most recent version of *GBTool* can account for mixed-use facilities, GBC has been primarily directed at the *environmental* performance of *individual* buildings. Performance is increasingly being framed under the umbrella of sustainability which broadens the scope beyond individual buildings and environmental considerations. To maintain potency, this would require GBC to make this conceptual shift.
- A major strength of the GBC is that it tests ideas on a range of case-study buildings from a variety of different cultural and regional contexts. At the three major conferences, the attraction of the GBC session has been equally split between the research community interested in the performance assessment and the design profession interested in the technical advances demonstrated in the case-study buildings. This role of bringing the two communities together is still important.
- The cost and effort for national teams to participate in GBC is considerable and has been increasingly difficult to justify. Simply continuing to undertake refinement and testing of a generic tool will not maintain the engagement and commitment of many National Teams. It seems important to make a clear strategic decision change the process rather than having it simply fade.

These developments suggests that the *Green Building Challenge* can still play a valuable international role but qualitatively different from that in the past:

- International collaboration is always a valuable endeavour. An enormously important role within the GBC process has been the engaging of countries who are in the relatively early stages of developing expertise in building environmental issues and assessment methods. International collaboration is a primary mission of iiSBE and, given that the GBC process is widely known, it would seem appropriate that it remains a key vehicle to fulfil this role.
- Explicitly facilitating the exchange of knowledge and experience with building environmental assessment between countries is probably more important than the research and development role that GBC has targeted in previous rounds.

In sum, GBC would need to be broadened to maintain continued interest and value. Given the increasing use and experience of domestic building environmental assessment methods, these could and should be legitimately used within the GBC showcase of international case-study projects. However, they would have to be supplemented with performance measures agreed by the International Framework Committee that enable international comparability.

Appendix A: GBC 2002 Projects

Country	Primary Building Type	Project Name
France	Technical school	Lycée professionnel du Pic-Saint-Loup
Italy	MURB	Sun Space Tower
Italy	MURB	Torino 2006 Model Building
Italy	Supermarket	Green Market
Italy	Office / University	The Ship
Norway	Office	Telenor Kokstad
Norway	MURB	Pilestredet Park
Poland	MURB	Targowek Plaza
Poland	University	Old Boiler House
Spain	MURB	Vimusa-Sabadell
Spain	MURB	Iter Canarias
Sweden	MURB	Houses without heating systems
Sweden	Office	Skanska Head Office
Israel	University/college	Civil Engineering Green Building
Canada	School	Mayo School
Canada	Winery production & retail	Jackson-Triggs Winery
Canada	College	Red River College
USA	MURB	BPCA Site 18
USA	School	Clearview
USA	Retail	Big Horn
USA	Office	Chesapeake Bay
USA	Office	NOAA
Hong Kong	"public facility"	Public Laboratory Centre
Hong Kong	MURB	Parcville
Japan	Office	NEC Tamagawa Renaissance City
Japan	Office	Marunochi Building
Japan	Office	Sekisui House Kudan-minami Building
Japan	Office	Kobe Kanden Building
Japan	Office	Tokyo Gas Nakahara Building
Japan	Office	Tepco Toshima Building
Japan	University	The University of Kitakyusyu Faculty of Environmental Engineering
Japan	School	Kobe Reformed Theological Seminary
Japan	School	St. Dominic's Institute
Korea	Office	KIER Green Building
Korea	MURB	Hongeun-Dong Poong Lim Apartments
Australia	University	Arts Faculty Building
Australia	MURB	Inkerman oasis
Brazil	Office	Ufficio 2000
Chile	Office	Consalud

Figure 1: Relative National Weightings of Resource Use, Loadings and IEQ

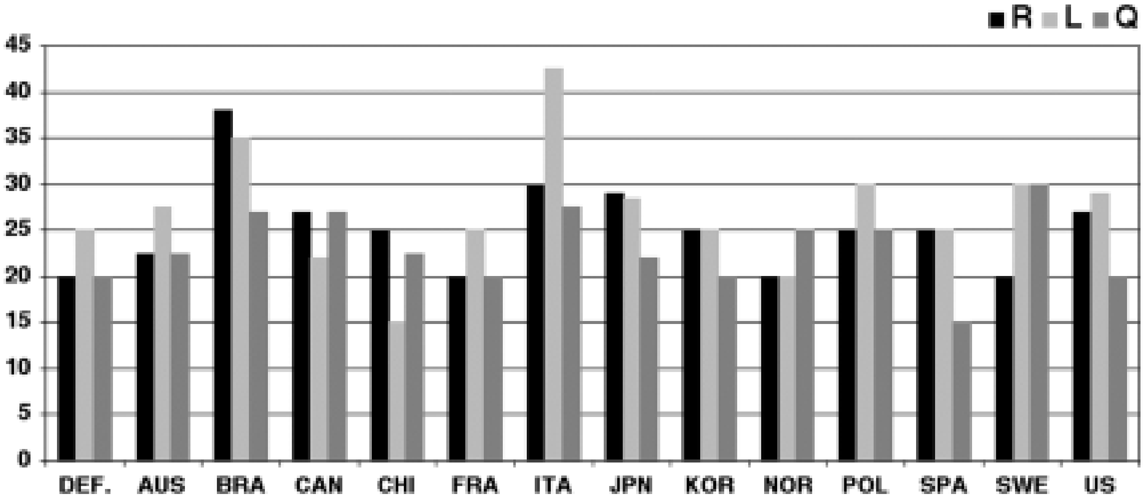


Figure 2: Relative National Weightings of Quality of Service, Economics and Management

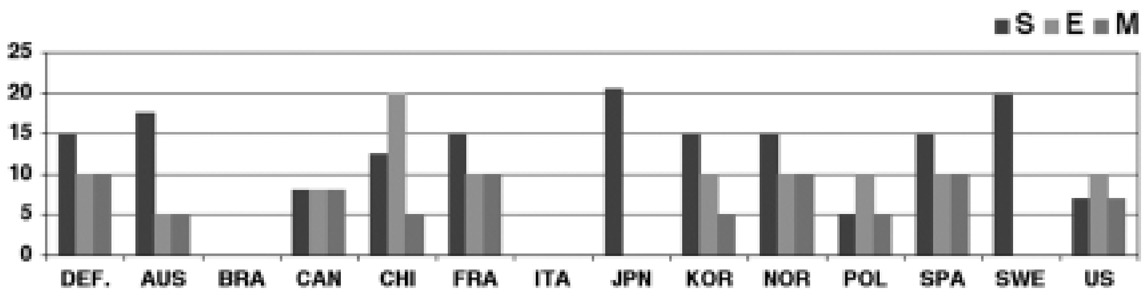


Figure 3: Weightings for the Resource Use Performance Categories (Office Building)

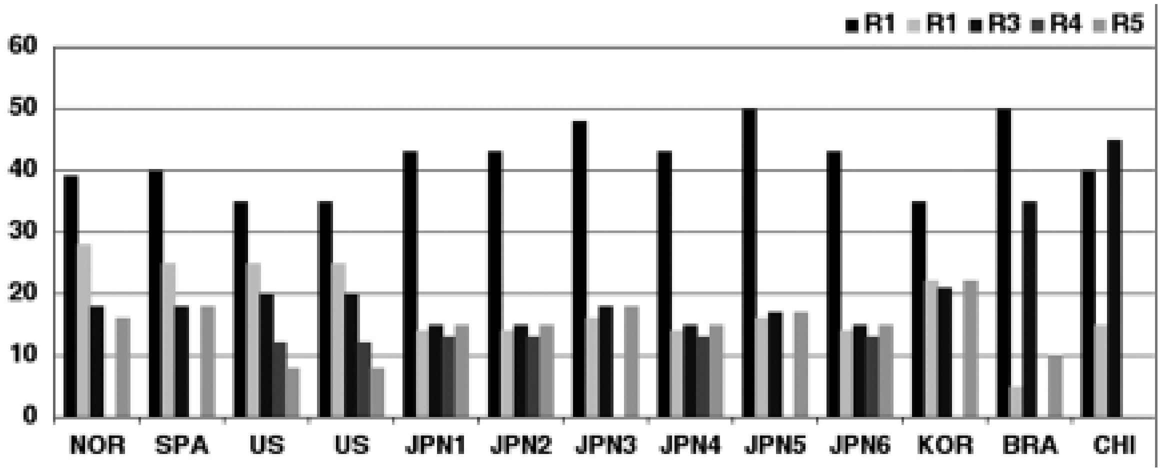
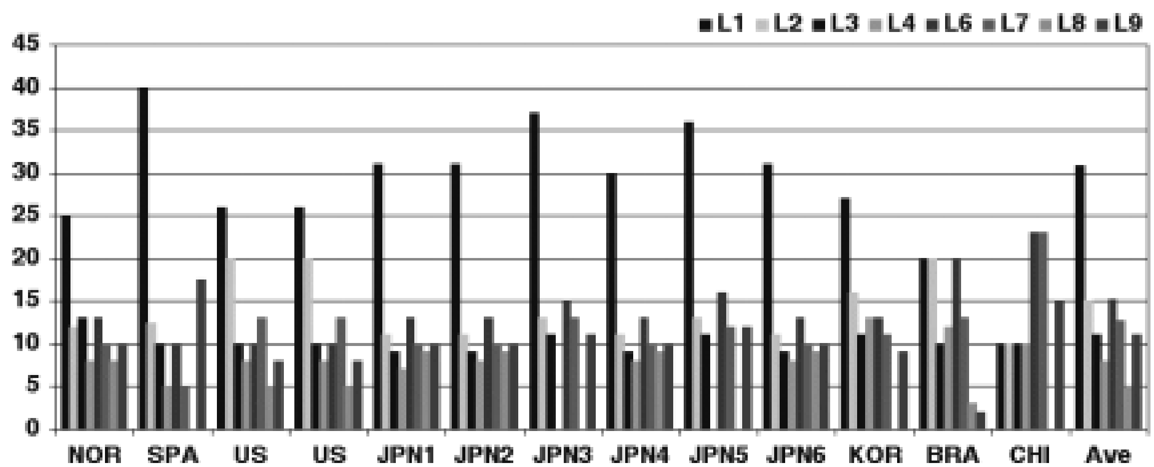


Figure 4: Weightings for the Loadings Performance Categories (Office Building)



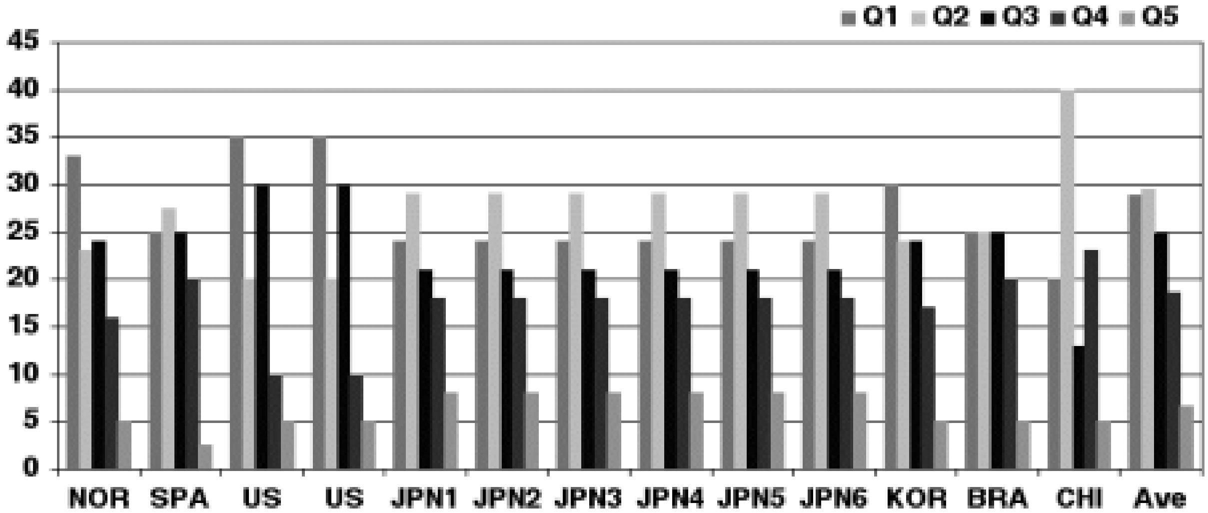


Figure 5: Weightings for the IEQ Performance Categories (Office Building)

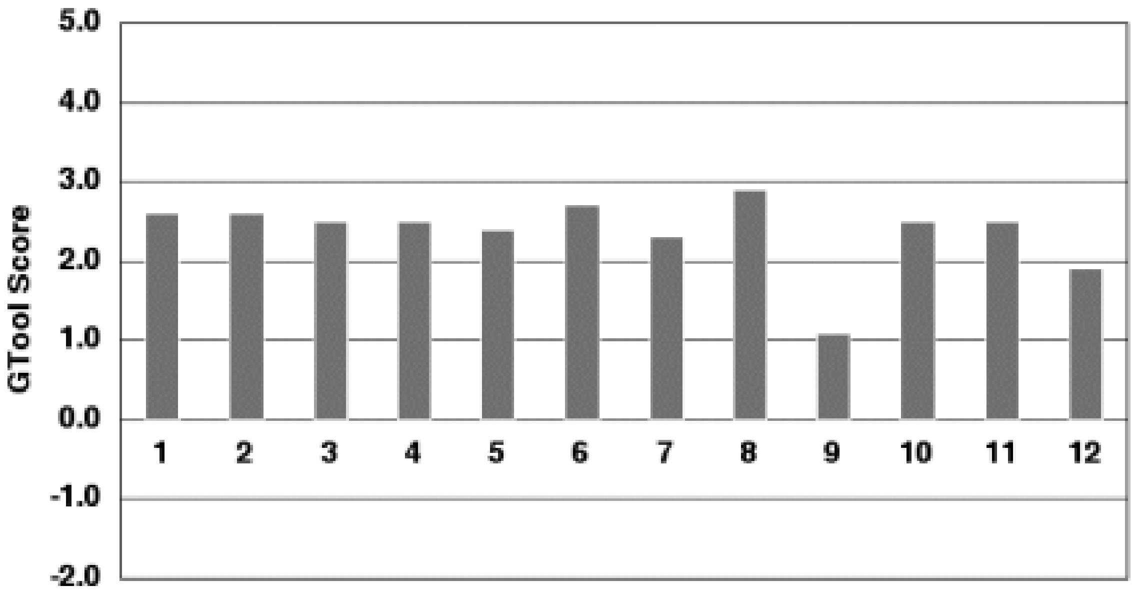


Figure 6: Overall Building Scores for *GBC 2002* Office Buildings

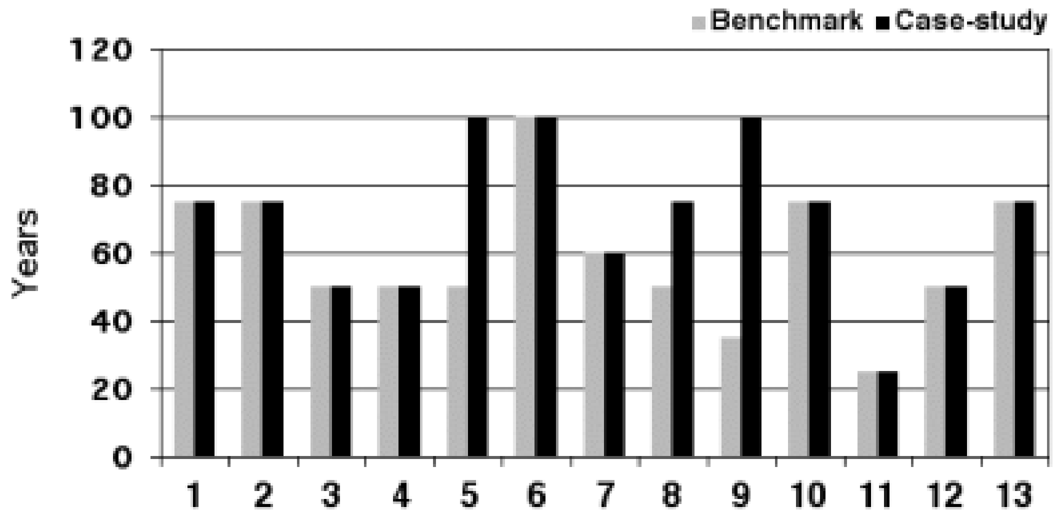


Figure 7: Benchmark and Case-study Building Life for *GBC 2002* Office Buildings

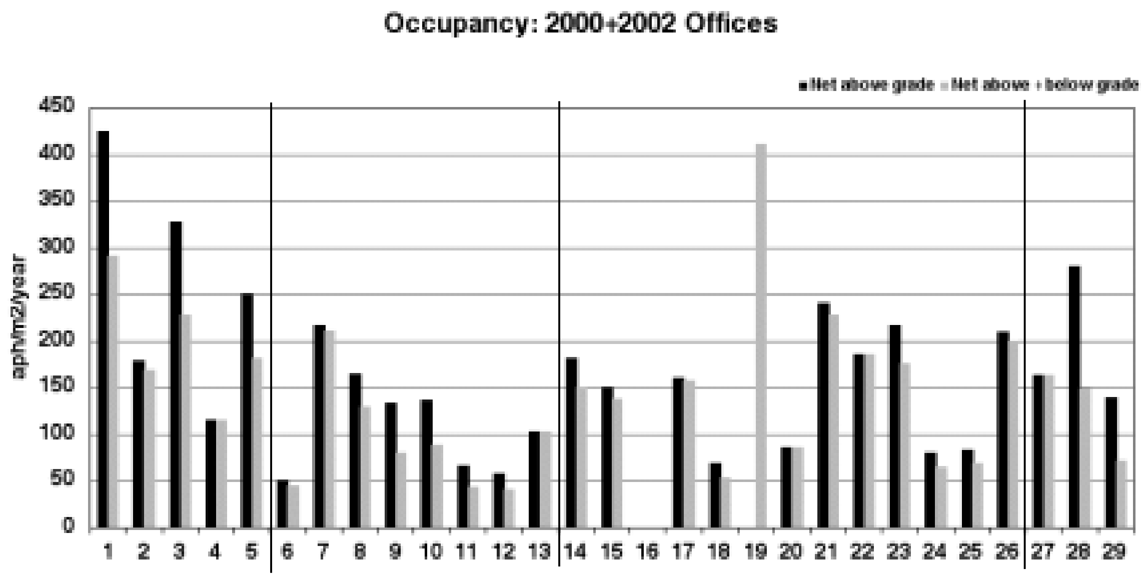


Figure 8: Annual person-hours of Occupancy for both 2000 and 2002 GBC Office Buildings

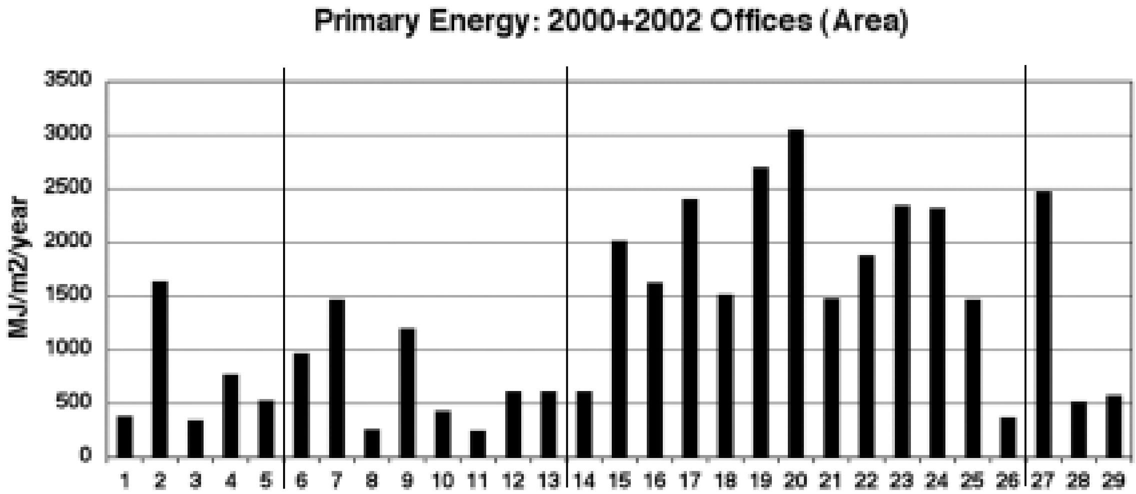


Figure 9: Primary energy normalised by area for both 2000 and 2002 GBC Office Buildings

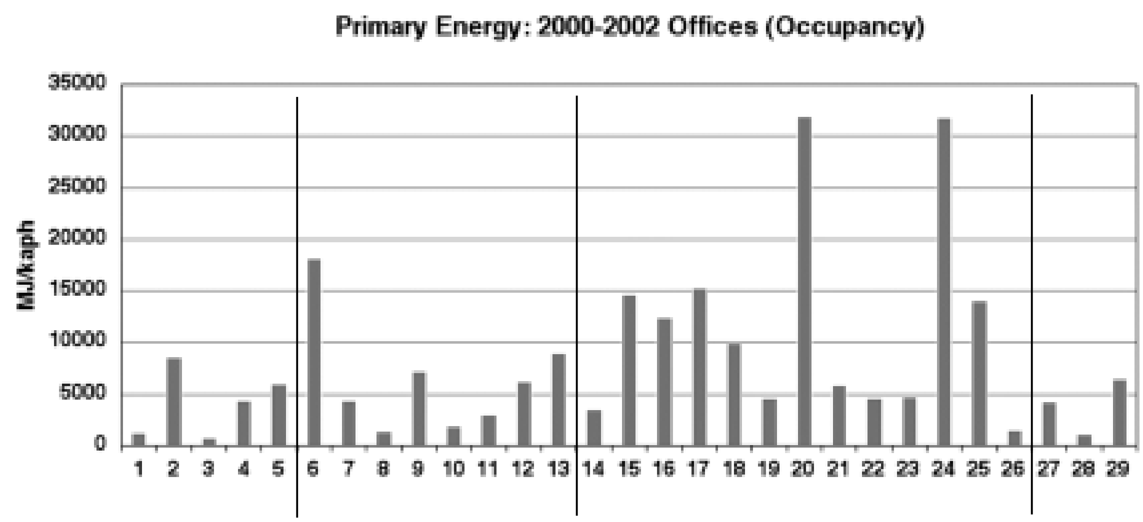


Figure 10: Primary energy normalised by occupancy for both 2000 and 2002 GBC Office Buildings

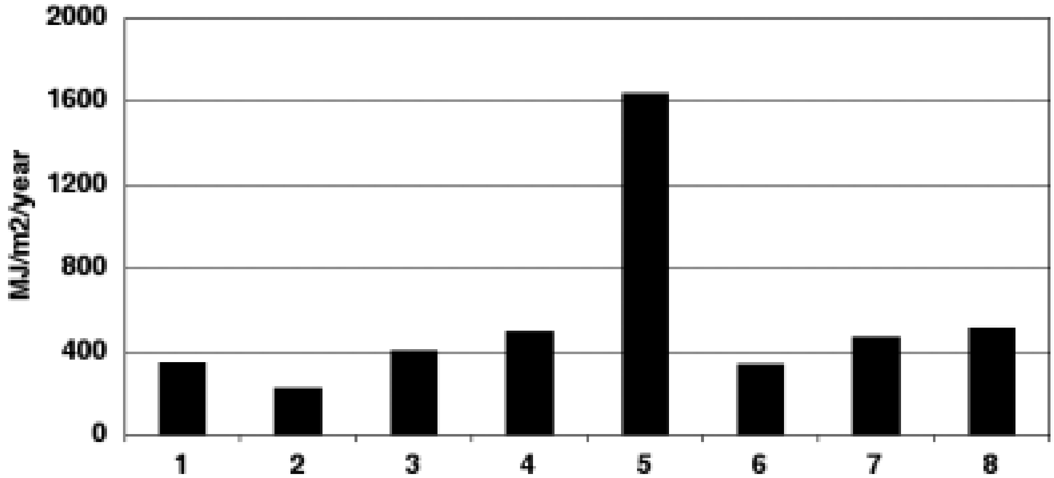


Figure 11: Delivered energy normalised by area for GBC 2002 MURBs

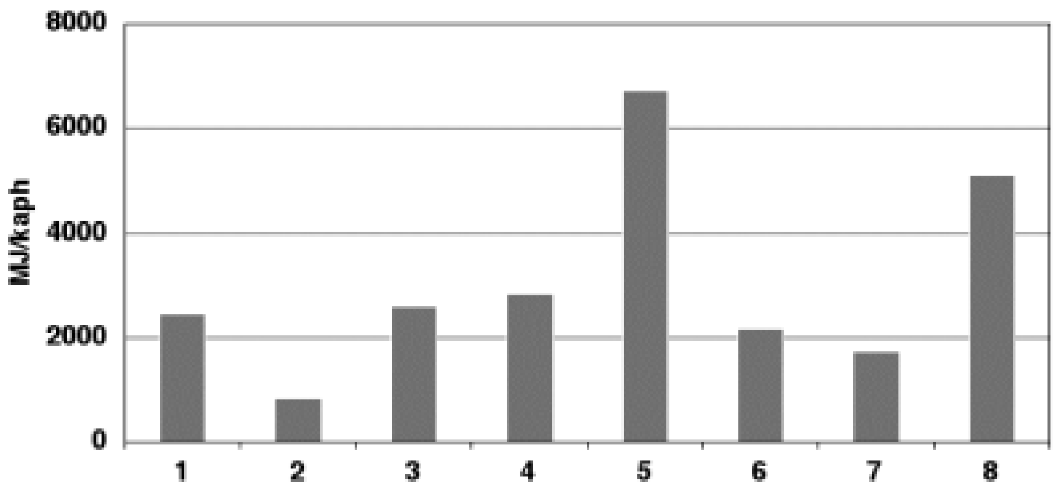


Figure 12: Delivered energy normalised by Occupancy for GBC 2002 MURBs