Green Building Challenge 2002

GBTool User Manual

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NRCan **iiSBE**

International Initiative for a Sustainable Built Environment

Members of the International Framework Committee

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Preface

Green Building Challenge Process

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 goals of the *Green Building Challenge* process are:

- To advance the state-of-the-art in building environmental performance assessment methodologies.
- To maintain a watching brief on sustainability issues to ascertain their relevance to "green" building in general, and to the content and structuring of building environmental assessment methods in particular.
- Sponsor conferences that promote exchange between the building environmental research community and building practitioners and showcase the performance assessments of environmentally progressive buildings.

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.

SB2002/GBC2002

Green Building Challenge 2002 is a continuation of the *GBC '98* and *GBC 2000* process. This current round will culminate in the presentation of the assessed buildings at the *Sustainable Building 2002 Conference (SB 2002)* in Oslo, Norway, September 23-25th 2002.

As of writing, 21 national teams will participate in GBC 2002:

- Australia
- Austria
- Brazil
- Canada
- Chile
- PR China
- Finland
- France
- Greece
- Hong Kong
- Israel
- Italy
- Japan
- Korea
- Norway
- Poland
- South Africa
- Spain
- Sweden
- United States of America
- Wales

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 allow users 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 are free to draw from it in whole or part for use in the creation of assessment tools.

GBTool consists of a single *Microsoft Excel™* workbook. The first two worksheets, Intro and ID, are intended for all users. Other 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.

A Trnspt (Transport) worksheet has also been developed, but it is currently hidden, until such time as detailed requirements and algorithms have been developed for commuting transport projections.

This manual provides an overview of *GBTool* – the building environmental assessment tool that will be used in current round of building assessments. It consists of Six (6) Parts:

Part One: Key Features of *GBTool*

Part Two: GBTool Worksheets – Section 1: Descriptions of Worksheets 1-5 in *GBTool*

Part Three: GBTool Worksheets – Section 2: Descriptions of Worksheets 6-13 in *GBTool*

Part Four: GBTool *Assess* Worksheet – Section 3: Descriptions of Worksheet 14 in *GBTool*

Part Five: GBTool Worksheets – Section 4: Descriptions of Worksheet 15-17 in *GBTool*

Part Six: Glossary of Terms

This manual should be used in conjunction with the *Management Overview of the GBC 2002 Building Assessment Process* document that provides building assessment Team Leaders with step by step guidance through the assessment process (downloadable from the *iisbe* web-site site (http://iisbe.org)).

Part One:

Key Features of GBTool

1.0 INTRODUCTION

GBTool provides approximate assessments of a broad range of potential environmental performance parameters, all related to performance benchmarks that are relevant to the region and building occupancy. Although *GBTool* performs various internal calculations, it is primarily designed to act as a framework for scoring and weighting, using data that is generated in external models that perform detailed studies or from other similar sources.

GBTool is implemented in Excel 2000, and three versions are available on the *iisbe* web-site site (http://iisbe.org):

- A "Dummy" variant contains fictional but reasonable input data for a hypothetical Canadian building consisting of a major renovation component as well as new construction. The Dummy variant includes multi-unit residential, office and retail facilities, and is intended to illustrate the way the system works.
- An "Empty" version contains no data and is intended for insertion of new design values by the national teams.
- A “Reference back-up” version to enable National Teams to reestablish information should any cells in the case-study version be inadvertently deleted or overridden during the inputting process.

1.1 ASSESSMENT FRAMEWORK

The environmental performance assessment framework in *GBTool* is structured hierarchically in four (4) levels, with the higher levels logically derived from the weighted aggregation of the lower ones:

- Performance Issues
- Performance Categories
- Performance Criteria
- Performance Sub-criteria

This *nesting* principle enables building performance to be *described* at successively detailed levels.

1.1.1 Performance Issues

Assessment of green performance is made in seven (7) general *Performance Issues:*

- Resource Consumption
- Loadings
- Indoor Environmental Quality
- Quality of Service
- Economics
- Pre-Operations Management
- Commuting Transportation (not yet operational)

1.1.2 Performance Categories

Each *Performance Issue* comprises of several *Performance Categories*. The *Performance Categories* are the principal performance characteristics that collectively define the overall performance of a case-study building. It is anticipated that the *Performance Categories* will remain valid across a broad range of building types and for the next five years or so. The *Performance Categories* form the most direct means of communicating the results of a *GBC 2002* assessment. Criteria and sub-criteria in these performance issues are scored using the –2 to +5 assessment scale.

1.1.3 Performance Sub-Criteria and Criteria

- The third level of assessment parameters are collectively called *Performance Criteria*. In many cases, these constitute the lowest level of assessment, but in some cases (especially in IEQ), they are derived through the aggregation of several *Performance Sub-criteria*. In some cases, the constituent sub-criteria are all expressed in the same units, making it relatively easy to derived relative weightings in deriving the Performance Criteria score. In other cases, a *Performance Criterion* may be composed of several *Sub-criteria* with different performance indicators and units of measure, requiring greater judgement in deriving the weightings.
- *Performance Sub-criteria* represent the basic building block (e.g., lowest level of description) of the overall assessment framework.
- *Performance Criteria and Sub-criteria* represent distinct aspects of building performance and are specific and logical sub-sets of the *Performance Categories*. Unlike the *Performance Categories* which are generic and broadly applicable, *Performance Criteria* and *sub-criteria* are much more building- and region-specific. Moreover, their inclusion in the assessment framework is affected by a host of practical issues in their assessment.

1.2 SCORING

Scoring is made at the *Sub-criterion* and *Criterion* level. All performance criteria and sub-criteria are set within performance scales ranging from –2 to +5. Performance scores are presented in a consistent manner all relative to an explicitly declared benchmark- the zero (0) on the performance scale. The performance scales are:

- *0: Minimum acceptable performance* for the relevant occupancies within the region, as defined by regulations or, where there are no relevant regulations, by industry consensus.
- *5: Demanding Performance:* Represents a performance target that is considerably in advance of current practice. National teams are responsible for defining what this performance target represents but it should be one that is potentially achievable with current technologies, based on reasonable extrapolation from current practices, but without consideration of cost effectiveness.
- *-2: Unsatisfactory Performance:* Performance that is clearly inferior to accepted industry norms. This is unlikely to occur in cases where the Benchmark represents a code requirement, but could occur in performance areas not covered by regulation, and especially in retrofit projects where it is not possible to achieve currently accepted performance levels for new buildings.
- *1-4: Intermediate Performance Levels:* Represent varying degrees of performance between the primary benchmarks:
  - A score of one (1) represent a *moderate* improvement over the *Industry Benchmark* performance, e.g., “good practice” within the region.
  - A score of three (3) represent a *significant* improvement over the *Benchmark* performance and is understood to represent “best current practice” within the region.

1.2.1 Numerical Scales

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.

This process differs from the previous versions of *GBTool* where the scales were inputted directly and all expressed as percentage reductions or increases relative to the benchmark.

1.2.2 Qualitative Scales

The performance scales for those criteria and sub-criteria that are described qualitatively are described as a series of written descriptor that convey the features of requirements necessary to achieve the respective scores.

1.3 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.

National Teams are 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.

1.3.1 Selecting Performance Issues

Resource Consumption, Loadings and Indoor Environmental Quality represent core requirements within the GBC process and must be assessed in all *GBC 2002* projects.

National Teams are encouraged to complete the remaining three performance issues – Quality of Service; Economics and Pre-Operations Management – but their completion is optional in *GBC 2002.* The Commuting Transportation worksheet is hidden until suitable algorithms are developed.

1.3.2 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. The following points are of importance:

- In all cases, users are asked to define the zero (0) score level for each parameter. In all cases where a numerical value is appropriate, these values are entered on the Bmark worksheet.
- In cases where text statements are used to determine values, users should establish the zero (0) value by ensuring that the text statement proposed on the Assess worksheet in *GBTool* is appropriate or, where it is not, these statements should be modified as needed.
- Modifiable text scales are coloured in yellow.
- In most cases of numerically-based parameters, the values of the highest performance levels (5) have been indirectly determined by the *GBTool* developers through the establishment of a *Scale Interval* value (see *Assess* worksheet) that is used to determine the interval between each number on the scale.
- Where a clear and logical case exist for the (5) value, such as a 0 (zero) level of consumption for potable water consumption in R3 or, conversely, for the zero (0) value given a (-2) score in R4; then the scale intervals have been established in this way.
- In a few cases (R1.1, R1.2, L1.1 and L1.2), users are asked to define the both the zero (0) and (5) levels of performance directly on the *Bmark* worksheet.

1.3.3 Customizing the Weightings

Some flexibility is permitted in customizing the weighting:

- Weightings at the sub-criteria and criteria level are fixed. The principle followed is that Criteria or Sub-criteria are evenly weighted, e.g., if there are four sub-criteria, then each is weighted at 25%. Where deviations are made, the logic used to determine the weights are shown in the form of notes in the margin of the *Weight* worksheet. Generally, the reasons for deviations include certain proportions of residential v. non-residential occupancy areas that may affect the weight of a parameter that is or is not applicable mainly to one of these uses; or the relative areas of mechanically conditioned occupancies. In a few cases, weights of Criteria or Sub-criteria are adjusted because of the presence or absence of a certain condition (e.g. presence of Radon, the use of a ground-source heat pump), or another contextual condition (see for example C11, C12, C17, C12, C20 and C23 to C26 in the *Cntxt* worksheet).

- Weightings at the *Category* and *Issue* levels are established by the National Teams. We take the position that the highest level *Issue* weights (see *Vote* worksheet) are not amenable to an objective determination, and teams are therefore invited to either use the GBC defaults or to use their own weights, while indicating their reasons for doing so. With regard to *Category* weights, these should be determined by objective means, but we have not yet determined a satisfactory way of doing so. We have therefore, as an interim step, provided space for up to six team members to vote on these weights. It is important to note that persons casting these votes should have expertise in the relevant Issue area, which implies that the team members voting may be different for each group of *Category* votes.

If a National team elects to only complete the three *core* Performance Issues, then weightings for the remaining four should be set to zero.

1.3.4 Non-Applicable Criteria

Several *Performance Sub-criteria* and *Criteria* may not be applicable in some instances. If a Sub-criterion/Criterion is declared *non-applicable*, it will be identified as such in the assessment and assigned a weighting of zero. National Teams must provide a rationale as to this decision. The use of the *Non-Applicability* designation has a considerable influence on the aggregated score, and it is important that the designation be used appropriately:

- In those countries where environmental standards are more demanding, what had been designated as the best performance (i.e., 5) in the general scale, was typical practice regionally. This raised the question whether a rating of *non-applicabl*e (since every other building in the region would meet this performance) or 5 should be assigned.
- The designating a criterion as *Non-Applicable* applies only in those circumstances where the performance issue is not pertinent to the case-study project, and not where technical difficulties are incurred performing an evaluation (e.g., missing data).

1.4 USING GBTool

As with any comprehensive building environmental assessment, *GBTool* requires considerable amounts of information to be gathered about the building and the context in which it sits. Since one of the primary objectives of GBC is to explore difference aspects of environmental assessment, *GBTool* moves into areas that are relatively uncharted and, as such, it is not always evident what kinds of information may ultimately prove important or insignificant. That stated, every attempt has been made to use internal algorithms and links to minimize the amount of effort required to undertake an assessment without losing transparency in the process.

1.4.1 Building Types

The performance criteria addressed in *GBTool* are generic and applicable to a broad range of building types. The presence of a residential use is determined by an on/off selection; two others are selected through a drop-down menu and cover six common uses, while the last occupancy option is totally open to a user selection, and is marked yellow for text input. The occupancy selections made by the user are automatically copied to appropriate locations in the *Bmark, Arch* and *Tech* worksheets. It is important to note that this flexibility will only produce meaningful results if Benchmarks appropriate to each occupancy specified are entered on the Bmark sheet.

The Dummy version includes an example of a mixed-use building that contains a residential, office and local retail uses, but the system allows the specification of as few as one or as many as four occupancies.

For GBC 2002, all case-study buildings should ideally be *completed* projects or, if not, certainly sufficiently developed to facilitate a complete assessment (e.g. working drawings and specifications complete). It is also anticipated that all the case-study buildings will have been pre-screened to ensure that data on important functional and other performance requirements are available. For users not participating in GBC 2002, GBTool can, of course, be used for projects as an earlier stage of design, bujt the trade-off is that results will be less definitive.

GBTool can handle both new building and renovation projects. In the case of renovations, Block 1 (see *Area* and other worksheets) is reserved to identify its characteristics. The Dummy file version shows an example of an existing building in Block 1.

1.4.2 Inputting Data

The various sections of *GBTool* data sheets have been colour coded to identify what must be completed by the user and what should be untouched:

- *Light Yellow:* Here users are required to enter *text.*
- *Light turquoise:* Users are required to enter a numerical figure
- *Light Blue:* Users are required to select a text statement or numerical figure from a click-down boxes
- *Grey:* The results of a calculation made within GBTool, or an information statement, and are not to be altered by users.

Note that colours appear different on various monitors, and you may therefore want to adjust the colours to suit (on Windows machines, go to Tools>Options>Colors in Excel and, after selecting the colour being used, modify it to suit.

1.4.3 Units

Standard SI units are used throughout *GBTool.* Imperial values must be converted prior to entering values. Two unfamiliar units are included in *GBTool* to normalize performance values for occupancy:

- kaph = thousand annual person-hours of occupancy
- maph = million annual person-hours of occupancy

These are calculated according to more familiar inputs provided by users, including hours per day and days per year of operation, and the number of typical occupants.

1.4.4 Hiding Information

GBTool provides a comprehensive description of building environmental performance and includes many “built-in” options such as handling up to 4 blocks, up to 4 occupancies etc.):

- To hide things you don’t need, go to the Views menu, then to the Custom Views sub-menu, and pick a more manageable version. In doing this, the data do not disappear, but are only hidden.
- To see everything, use the “All shown” option.

We suggest that Design teams who may be providing input on the characteristics of the case-study projects should be given a copy (separately named) of the file showing only one of the "designer view" options, so that they are not influenced by the benchmarks or Weights that have been assigned, or by the Results.

1.4.5 Printing GBTool

It may be useful to print out sections of *GBTool* to facilitate discussion within the National Team and assist in the gathering of information:

- Printing formats are based on the "All shown" setting, and result in 103 pages
- Printing the Benchmarking option generates 27 pages
- Printing the Assessment option generates 52 pages
- Printing the Designer 2 blocks and 3 occupancies generates 49 pages

1.5 GBTOOL WITHIN THE OVERALL ASSESSMENT PROCESS

Experience in GBC and the available expertise and financial resources will invariably dictate the approach that National Teams use in the assessment process. The following represent some guidelines that may be of assistance to those countries entering GBC.

1.5.1 Introducing GBTool to Assessment and Design Teams

GBTool is the focus of a GBC assessment and how it is introduced and used within the overall assessment process will again be dictated by the experience of the Assessment Teams. Experience has shown that:

- *GBTool* is best introduced to the assessment and design teams using an example with both hard and soft copies.
- Even though the design team will only be responsible for providing building design information, demonstrating the full version of *GBTool* will assist them in understanding the reasons for many of the inputs and especially the “fuzzy” qualitative areas of the assessment.

The Assessment Leader or designate:

- Must have good working knowledge of most of the terms and criteria used in *GBTool* and how they are used in the input and assessment process and a thorough knowledge of the content and requirements of all *GBTool* screens.
- Must have a good working knowledge of the benchmarking process and of the extent of work needed to establish benchmarks. This will require some preliminary investigation before the initial meeting to define local and/or regional practices, codes and regulations, and the regional climatic variations and to be familiar with the project background.
- Must be knowledgeable enough to see and comprehend the extent of incoming work, but not necessary all the details, which can be left for the specialists. The whole issue of "what should be done, when and by whom" should be resolved during the first meeting.
- Should distribute *GBTool* printouts among the participants and then guide them through the following steps:
  - Explain the data input screens – "what and how" shown on the Dummy file example. Some sheets will require special attention such as the one related to Building Blocks.
  - Define roles and responsibilities for completing the Data Input screens for the building being assessed - in simple terms: "who does what". This should include the preliminary schedule for all data input, so that the date of final approach in the assessment could be easily determined.
  - Decide on the extent of simulation work, the software used, and the standard expected. That should be discussed with the energy simulator present or as part of a conference call. This issue should be determined with all participants present.
  - Discuss embodied energy in a similar way – the extent of work, the software used and the budget. The need for both energy assessments properly conducted should be emphasized as they will create a main perception of sustainability.
- Should discuss all procedures used later by the assessment team including the way data will be used in *GBTool*, the application of the weighting and how the scoring will affect the final assessment.

1.5.2 Key Components of GBC Assessment

Figure 1 shows the key components in a GBC Assessment.

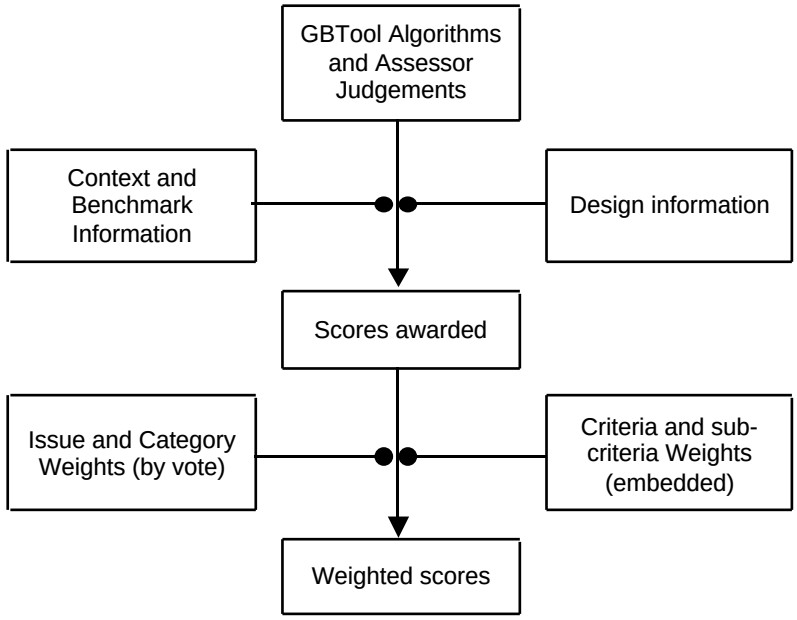


Figure 1: Key Components of GBC Assessment

There are two different inputs to *GBTool* that determine the scores achievable for each sub-criterion and criterion*:*

- *Context and Benchmarks information* to assist and facilitate an assessment is provided and inputted to *GBTool* by the Assessment Team. Benchmarks should be prepared by a third party designated earlier in the process. However, this may also be accomplished with the assistance of the Design Team (particularly in the case of large mixed use buildings, major retrofits or when the building is not of typical use) who can provide information on paper and later entered by the Assessment Team.
- *Design Information* about the physical and operational characteristics of the case-study building is logically provided by the design team:
  - The Design Team enter only building description data to *GBTool* and later hand it over to the Assessment Team.
  - Teams may choose to create a separate Design Input version of *GBTool* that only includes sections related to this part of the input process. The assessors will copy to it (or import, if possible).
  - In any case, a final file is created with all inputs from designers and assessors and it is up to the Leader to decide the appropriate strategy.

The weights applied to the scores in order to derive the final performance profile include:

- Default weightings values of sub-criteria and criteria are included within *GBTool*.
- Weightings for the performance categories and issues are the responsibility of the Assessment Team who are required to assemble experts in the respective performance areas to determine appropriate values.

1.5.3 Assessment

The Assessment Leader must be prepared to verify that the information is correctly inputted into *GBTool.* In particular, the Assessment Leader should review:

- Benchmarks, which should be delivered established and checked BEFORE the energy simulation starts, to eliminate any misunderstandings or omissions.
- Consistency in the data set provided by the Design Team and its time scheduling so the project is always on track and that timing of all parties involved is in order. There could be two approaches to the correlation of data input and the work on simulations:
  - All input data is provided in *GBTool* and only then the next steps are conducted – recommended, if possible, with small projects
  - Only a partial input work is provided to proceed with energy simulation and the embodied energy calculations while the Design Team works on other “non-vital” issues – recommended with large projects due to the time constraints.
- Once the simulation is performed and a final copy of the GBTool from simulators is obtained, the Building Assessment Team should conduct a last verification (a sanity check) of data input and of the simulation results.
- The assessment process can begin once the following information has been inputted into *GBTool:*
  - Context information
  - Weighting of Issues and Categories
  - All benchmarks
  - All characteristics of the design required in the "designer set" of worksheets
  - Operating energy and embodied energy results
- When this has been completed, the Building Assessment Team should meet for at least one, and possible two full days to review all the inputs to *GBTool*, make the final assessment and provide supporting comments. Approximately 45 Scorings must be performed manually by the assessment Team and approximately 100 Assessor’s Comments added.

Part Two

GBTool Worksheets – Introduction and Section 1

2.0 INTRODUCTION

Introduction and Section 1 worksheets of *GBTool* is primarily concerned with defining the contextual information.

The *Introduction* contains Two (2) specific worksheets:

- Intro (Introduction)
- ID (Project Identification)

Section 1 contains Four (4) specific worksheets:

- Cntxt (Context)
- Vote
- EnGen (Energy Generation)
- Bmark (Benchmark)

The Vote and Bmark worksheets should be completed by persons who are NOT linked to the design or by persons who are undertaking the assessment. This is necessary to maintain an unbiased basis for the case-study assessments. As previously stated, it is also recommended that persons providing input on the characteristics of the case-study building should be given a copy (separately named) of the file showing only one of the "designer view" options, so that they are not influenced by the benchmarks or Weights that have been assigned, or by the Results.

2.1 INTRO

The *Introductory* worksheet (Intro) provides a brief overview of *GBTool* Worksheets and lists the members of the International Framework Committee (IFC).

2.2 ID

The *Project Identification* (ID) worksheet provides basic information on building name, location and team submitting data. A separate *GBTool* file is necessary for each project.

The worksheet specifically asks the user to identify:

- Up to a maximum of four major occupancy types in the building.
- If the building is new, renovation or mixed
- If the building is currently in design or construction
- Which hemisphere the project is located. This designation changes orientations throughout *GBTool* from North to South or vice versa.

A critical input to this sheet is the anticipated life span of the building. Although the life span of the benchmark and case-study building can vary, the same value will be used in the *GBC2002* assessments.

2.3 CNTXT

The physical and environmental context of the case-study building issue influences the relative importance of many performance criteria.

Information reported in the *Context* (Cntxt) worksheet characterizes the micro-urban neighbourhood. It provides assessors with a better understanding of relevant local issues to establish meaningful weights and inform the establishment of benchmarks. For example, an area that is characterized as having a shortage of water may lead the assessor to set a low benchmark for water consumption. The key characteristics of the Context Worksheet are:

- It contains 35 rows, covering the density, climatic, air quality, ecological, natural, infrastructure and transportation infrastructure, and organized as to whether they are relevant at the urban, neighborhood or site scale. These are highlighted in light blue.

- The majority of the input is handled through drop-down menus that offer a range of possible conditions from which to select.
- Some fields are tied to the Weights worksheet. The "link" column identifies which performance criteria or sub-criteria may be influenced by the information reported in this context sheet. Most are used to provide information statements in the Bmark worksheet.

2.4 VOTE

The *Vote* worksheet is one of the key worksheets in the system. *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.*

The weightings at the two lowest levels (sub-criteria and criteria) are *fixed* within *GBTool:*

- Many of the weights for Criteria and Sub-criteria are developed through the use of formulae that take into account relative areas of occupancies or mechanically cooled spaces. These are explained in comment boxes.
- Others are determined by total building size or, for example, the presence of Radon, ambient noise characteristics etc.

The weightings at the upper levels (category and issue) are determined by the National Teams, and these are set on the vote worksheet. It has two distinct sections:

- Vote for relative importance of Major Issue Areas
- Vote for relative importance of Categories within Major Issue Areas

In both cases:

- National-Team members are asked to allocate points to indicate their relative importance.
- 100 points are available for allocation within each category, and these will be automatically averaged for insertion as percentage values in the Weight worksheet.
- Error messages will appear if points do not add up to 100, prompting one to modify or remove excess points.

In the absence of a consistent methodology, it is 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.

2.4.1 Vote for relative importance of Major Issue Areas

This section enables national Teams to declare weightings of the major performance issues. This provides both an explicit indication of priorities and also forms the basis of deriving a final building score:

- *GBTool* includes a set of default weightings across the seven performance issues. However, National Teams are expected to review and customize these default weightings to reflect regional and national priorities.
- National Teams may opt to apply weightings across all seven-performance issues.
- Weights must be assigned to the three core performance issues: Resource Consumption. Loadings and Indoor Environmental Quality.

2.4.2 Vote for relative importance of Categories within Major Issue Areas

This section enables national Teams to declare weightings of the categories within the major performance issues. Weightings should ideally be based on data that indicates the relative importance of each Category in having an impact on ecological systems or human health and productivity over the life cycle of the building. In

the current absence of reliable methods to determine such impacts, experts in the respective performance areas should determine these weightings, using their expert knowledge. In all cases, it should be noted that Category weightings should be based on the general case of the particular occupancy types within the region in question, and should not be based on the particular characteristics of the Case-study building, except where noted. Weightings for specific Categories should be carried out as follows:

- *Resource Consumption and Loadings:* Basis for weighting should be potential short- and long-term effect on ecological systems and human health; predicted by experts in the field.
- *Indoor Environmental Quality:* Basis for weighting should be potential short- and long-term effect on human health and productivity; predicted by experts in the field.
- *Service Quality:* The relative weights of Categories may be affected by the area breakdown by occupancy in the design.
- *Economics:* Values for Economics are allocated automatically, since there is only one Category
- *Pre-Operations Management:* The weighting may be dependent on the relative size of the building.
- *Commuting Transport:* This worksheet is currently hidden, until such time as appropriate algorithms can be developed.

Each National Team can decide on the appropriate way to develop weightings to complete the Vote Worksheet. The worksheet permits up to 6 persons may enter votes. For each, a message appears showing if overall weightings greater more or less than 100%. Alternatively, experts may discuss the issues and collectively arrive at an appropriate set of category weightings and enter a single set. It is important to note that persons casting these votes should have expertise in the relevant Issue area, which implies that the team members voting may be different for each group of *Category* votes. Weighting values for Issues and Categories provided by the individual voters are averaged and transferred automatically to the Weight worksheet.

2.5 ENGEN

The *Energy Generation and Consumption Report* (EnGen) worksheet provides users with tables to enter emission values for fuels and electricity production relevant to their regions. The results, based on fuel mixes for base loads, are used to determine air emissions due to energy consumption. These are subsequently summarized in the Report worksheet.

The key inputs on this worksheet cover:

- Primary energy and environmental factors for fuel used for on-site heating or cooling and fuel used for off-site generation of electricity.
- Electricity power generation base load mix: the percentage breakdown of the primary fuels used for electrical power generation in the region.
- Primary energy and environmental factors for fuel mix used in Benchmark: converts the delivered energy for the benchmark to primary energy values and generates appropriate emission values.
- Primary energy and environmental factors for fuel mix used in the case-study design: converts the delivered energy for the case-study building to primary energy values and generates appropriate emission values.

The information required to complete this worksheet is typically available from regional utilities or relevant government agencies. If this is not available, National Teams should use the default values provided in *GBTool* but indicate that this has been done (note, however, that the default values are incomplete). The results are summarized at the bottom of this worksheet as:

- Total electrical primary energy used in the case-study design, annual basis, GJ
- Total primary non-renewable fuels used for Design on-site and for generation of electricity, annual basis, GJ
- Total emissions generated from fuel used on site and electrical consumption in the case-study design, annual basis, kg.

2.6 BMARK

The Benchmark (Bmark) worksheet is designed to allow the entry of benchmark performance values that are appropriate to the region and occupancy types included in the building. The intent of the benchmarks is to provide a meaningful basis to assess performance values of the case-study project. In defining appropriate benchmarks:

- Quantifiable issues (energy use, water use etc.,) are assumed to be either minimum code requirements or typical practice, depending on access to reliable data. In either case there must be a clear description and rationale of the choice.
- For many of the qualitative criteria considerable judgement will be required. The default benchmarks for these are simply a declaration of what would be considered to be a typical condition or typical practice for the building type in the region. These are entered in the yellow comment boxes and will be consulted by the sub-group carrying out the scoring.

Benchmarks in *GBTool* are the basis for assigning scores for performance of the case-study projects, so they are of considerable importance:

- They should be equivalent to the minimum acceptable industry practice in the region, for this type and class of building. In many cases, there may be a regulation that is applicable, but in other cases the assessment team must make a determination based on local industry practices. This may require assembling a panel of regional experts.
- Some of these benchmarks are context dependent.

The benchmark worksheet groups the information into the following categories:

- General building design benchmarks
- Benchmarks for Materials, including a simple method for approximating the benchmark initial embodied energy of the building structure.
- Embodied Energy Benchmarks
- General Benchmarks by Occupancy Type
- Benchmarks for Natural Ventilation Systems
- Benchmarks for Mechanical Systems
- Benchmarks for Refrigerants in Mechanical Systems
- Benchmarks for Mechanical Ventilation Systems by Occupancy Type
- Occupant Density and Water Consumption Benchmarks for Residential occupancies
- Benchmarks for Building Water Use for Non-Residential Occupancy Types

Part Three

GBTool Worksheets – Section 2: Design Data

3.0 INTRODUCTION

Section Two of *GBTool* contains seven (7) worksheets:

- Arch
- Area
- Tech
- Matrl (Material)
- Ops (Operations)
- LCC (Life-cycle Costing)
- Trnsprt (Commuting Transport - currently hidden)

These worksheets are intended to be completed by a team of persons who are knowledgeable about the design. In most cases, this will be a mix of the architects and engineers who designed the building.

3.1 ARCH

The Architectural Systems worksheet (Arch) permits user entry of the basic occupancies in the case-study building, as well as descriptions of a number of other architectural features and elements. Equivalent values for the benchmark are imported directly from the Bmark worksheet.

The input is organized under the following headings:

- Site and Building Development Data
- Materials: Reducing, Reusing and Recycling
- Daylight, sunshine and shading
- Estimated Average Daylight Factor for sample typical space automatically calculated within the worksheet, based on method developed by Lawrence Berkeley National Laboratory.

3.2 AREA

The Area worksheet enables input of data on the number of stories, functional area requirements, gross areas, net areas, wall areas and glazing area and characteristics. These data are used for many subsequent calculations in other worksheets and must be completed. A specific example is the relative areas of various occupancy types, which influence several weights at the Criterion and Sub-Criterion level in the Weight worksheet.

The Area worksheet allows for up to four separate blocks to be designated, as previously identified on the *ID* worksheet:

- Although each block can have a different occupancy or a mix of occupancies, there is a minimum of one and a maximum of four occupancy types for each project.
- In the case of the re-use of an existing structure to serve as part of a new building, the re-used structure is to be described in Block 1. Where the building is all new construction, begin describing the blocks in Block 1.
- When occupancy types are specified, all the Benchmarks, areas and other values in the system must be entered accordingly. The occupancies specified then become headings for data entry in the *Bmark* and *Tech* worksheets.

This worksheet is divided into 7 parts, each of which allows entries to be made for each of up to four building blocks:

- Part 1: Functional Area Allocations
- Part 2: Number and Type of Floors
- Part 3: Gross Floor Areas and Volumes, and Roof Areas (includes user-selectable floor and roof type descriptions from a pick list)
- Part 4: Net Floor Areas and Volumes

- Part 5: Total Exterior Wall Areas Above Grade
- Part 6: Exterior Fenestration and Vent Areas and Characteristics (includes user-selectable window types from a pick-list)
- Part 7: Exterior Solid Wall Areas and Characteristics (includes user-selectable wall types from a pick-list)

The definitions used on this spreadsheet are as follows:

- *Primary area:* the area related to the main function of the occupancy.
- *Support area:* includes staff areas, lobbies, cafeterias and other functional areas used by occupants, the public or staff, as well as stairs, public washrooms, elevators, storage, and any other area located within the heated or cooled area.
- *Net building area:* All normally occupied spaces bounded by the inner wall surface, including common and circulation areas, but excluding structure, garages and ancillary support functions/areas such as mechanical/electrical spaces.
- *Gross floor area:* Entire area within the inside perimeter of the exterior walls.

The Benchmark building has an assumed footprint with a 2:1 ratio of exterior wall lengths, and with the long axis in an East-West orientation.

3.3 TECH

The Technical Systems and Energy Consumption (Tech) worksheet provides space for the characterization of technical systems in the building, including HVAC, lighting and control systems. It also provides entries for the energy consumption of the case-study building. The information is organized in the following sections:

- General description of ventilation, heating and cooling systems
- General description of ventilation, heating and cooling systems
- Mechanical HVAC description
- Identification of Refrigerant Types and Amounts
- Electrical, Lighting, Control Systems, Acoustics and Plumbing
- Water Consumption Calculations
- Sanitary and storm waste water management systems
- Energy strategies and general HVAC description
- Annual Consumption of Energy by End Use (from simulation results)
- Annual Consumption of Delivered Energy, accounting for production of on-site energy
- Approximate embodied energy calculations, with the option to either input values obtained from an independent embodied energy analysis or using simplified method within *GBTool.*

3.4 MATRL

The Material worksheet provides a table to capture weight and volume data on some major groups of materials. It also allows estimates to be made of the percentage of these material groups that conform to various environmental requirements. Information is organized in three sections:

- Materials re-used from existing structure(s) on the site covering: structural and exterior wall/roof materials.
- Materials imported from off-site sources covering: structural materials, envelope materials, window systems and interior finishes.

The Total of the Materials re-used from existing structure(s) on the site and those imported from off-site sources is summarized at the end of this worksheet:

- The amounts of materials from the existing structure re-used in case-study design or recycled off-site, both expressed as a percentage of the total.

- The percentage of the amount of material in the case-study building that is:
  - Locally produced
  - Derived from a renewable source off-site
  - Reused from projects off-site
  - Recycled in off-site materials

- Low in VOC emissions

Mechanical, electrical, plumbing and vertical transportation systems are not included in this analysis.

3.5 OPS

The Ops worksheet is intended to describe various features related to the future operation and management of the building, including space allocations, numbers of occupants, hours of operations etc. Information is organized in three sections:

- Building Occupancy: for up to four possible occupancies (previously defined in *ID* worksheet)
- Building Operations: for up to four possible occupancies (previously defined in *ID* worksheet)
- Construction Process and Pre-Operations Management Plans: These are written descriptions for subsequent reference by the Scoring sub-team.

3.6 LCC

The LCC worksheet is only partially complete. The intent is to provide a full basis for the calculation of life cycle costing, but data on replacement materials and components are not yet available. As it stands, this is an extremely crude LCC estimate, taking into account only capital costs, estimated design life and Present Value of total O&M costs. Discount rate and costs of replacements is not active.

3.7 TRNSPT (Hidden)

The Trnsprt (Transport) sheet is under development and is therefore hidden. When complete, it will provide inputs and algorithms to allow a crude estimate to be made of the commuting transport that is likely to be generated by the building. Commuting transport is defined as trips undertaken to work or to shopping to or from a residential building.

Part Four

The GBTool *Assess* Worksheet – Section 3

The *Assessment* worksheet (Assess) is the key worksheet in *GBTool.* It 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.

The Assess worksheet is intended to be completed by a team of persons who have reviewed all other worksheets and who have the skills required to assess various specialized aspects of building performance, but who are not associated with the case-study project. The coding for this worksheet is:

- *Grey boxes:* These are calculated automatically within *GBTool*.
- *Yellow scoring boxes:* These require the intervention of team members to pass judgement, since they are not amenable to calculation. Enough information should be available in the Context, Arch and Tech worksheets to enable the assigning of meaningful scores.
- *Purple scoring boxes:* For entry of scores for parameters that are text-based.
- Any parameters that have been weighted at 0 do not require a score to be assigned.

The worksheet can be opened and viewed at four levels of detail by clicking on the appropriate box on the upper left corner:

- Level 1: Performance *Issues*
- Level 2: Performance *Categories*
- Level 3: Performance *Criteria*
- Level 4: Performance *Sub-criteria*

DETAILED DESCRIPTION OF ALL ASSESSMENT PARAMETERS

RESOURCE CONSUMPTION

R1 Net life-cycle use of primary energy

This category has two performance criteria:

R1.1 Primary energy embodied in materials, annualized over life cycle

R1.2 Net primary non-renewable energy used for building operations over the life cycle

R1.1 Primary energy embodied in materials, annualized over life cycle

This criterion assesses the primary energy embodied in materials of the case-study building annualized over the life cycle.

Performance Measure: Embodied energy of the in the case-study building annualized over the life-cycle: MJ/m^2/year

- Area is the gross building area

Assessment Notes:

- The data necessary to make embodied energy assessments is currently neither comprehensive nor consistent nor is there a consensus of what are reasonable benchmark or target performance levels. It is anticipated that assessments of this criterion will be relatively crude, and it is important to report on the overall level of confidence of the results to provide a more valid interpretation of the final result.
- Data can be obtained from an embodied energy calculation program such as *Athena* or *Eco-Quantum*, or from data on performance of building stock, using similar buildings constructed within the last 5 years.
- In the absence of a detailed embodied energy analysis, an approximate estimation can be made in the Tech Worksheet (Rows T154-T165).

- There are several options are possible conditions that apply to this assessment:
  1. *If an analysis is made of initial embodied energy:* National teams should ideally make a detailed assessment of the initial embodied energy for the case-study building. The benchmark can be determined undertaking the embodied energy for an equivalent "typical" building, from regional or national databases on typical buildings or, if this is not possible, using default values given in Tech worksheet.
  2. *If an analysis is NOT made of initial embodied energy:* National Teams can use the default values included in the Tech worksheet, for BOTH the case-study building and the benchmark.
  3. *If there is an existing building on site that is demolished:* Here, an estimate must be made of the embodied energy of this building and added to the initial embodied energy of the new facility, i.e., the demolition of an existing building is penalized.
  4. *If the existing building is to be refurbished:* Here, the initial embodied energy is the difference between that of the new materials, components and systems added and that removed during the refurbishment. This is important to give appropriate credit for retaining an existing building. An estimate is provided in the *Matrl* worksheet, which estimates the Benchmark value on the basis of all-new construction, while netting out structures and materials re-used from the site.

R 1.2 Net primary non-renewable energy used for building operations over the life cycle

This criterion assesses the annual primary non-renewable operating energy of the case-study building. The economic and political implications associated with a dependence on fossil fuels together with the increasing environmental impacts from combustion are widely recognized. Reducing the amount of non-renewable energy needed to operate buildings is a critical green performance issue.

Performance Measure: Primary energy use normalized for area and annual occupancy: MJ/m^2/year

- Area is the net usable building area

Assessment Notes:

- The assessment must include:
  - Annual Heating, Ventilation and Air Conditioning (HVAC) energy consumption.
  - Annual site lighting energy consumption.
  - Annual building lighting energy consumption.
  - Annual plug load (tenant equipment) energy consumption.
  - Annual other building system energy consumption (conveyance, refrigeration etc.)
  - Annual service hot water energy consumption.
- Unless a specific attempt has been made to address plug load energy consumption, the case-study building and benchmark are assumed to have the same plug load characteristics. The intent is to remove the impacts of non-building energy use factors beyond the control of the building designers.
- Values must be supported by computer simulation or prediction tool:
  - The prediction or simulation tool used should be a recognized program within the case-study country and endorsed by the National Team.
  - Hourly simulation methods using hourly weather data are preferred.
  - Computer modeling is to be of a high level of rigor, including detailed HVAC zoning and control, and provide a clear disaggregation of the energy end-uses.
- Values of the annual consumption of delivered energy, accounting for production of on-site energy are entered into the *Tech* Worksheet (Rows T130-T137).
- Assessments of operating energy performance are based on *primary non-renewable* energy values, i.e., accounting for the energy to produce and deliver it to the case-study building, with an explicit declaration of the factors used to derive *primary* energy from delivered energy, all based on fuels from non-renewable sources. The transformation of delivered energy to primary non-renewable energy values is handled automatically within the EnGen Worksheet.

R2 Use of land and change in quality of land

This performance category evaluates the effectiveness of the use of land by the case-study building and the measures taken to restore, maintain or enhance its ecological productivity. Preservation and maintenance of the integrity of biologically productive land by curbing the encroachment of building development is an essential prerequisite of environmental sustainability. The continued encroachment and degradation of biologically productive land through urbanization not only diminishes its ability to produce essential resources but also its ability to recover from such abuses.

This category consists of four (4) performance criteria, one dealing with the amount of land used in the development and the others with any change in value:

R2.1 Net area of land used for building and related development purposes

R2.2 Change in ecological value of the site

R2.3 Change in agricultural value of the site

R2.4 Change in recreational value of the site

Only R2.1 and R2.2 are assessed in *GBC 2002.*

R2.1 Net area of land used for building and related development purposes

This criterion essentially assesses the area of land that is used per occupant in the case-study building and related development. The amount of land used for building footprint and related development is an important factor contributing to a reduction of the natural filtration of water contributing to the groundwater reservoir and therefore damaging the local hydrology of most urban site, and the biodiversity and effectiveness of local ecology.

Performance Measure: The amount of land used for building footprint, on-site surface parking and access roads relative to the net building area: m^2 land per m^2 net area

Assessment Notes:

- Given the widely differing possible sites (urban, rural, high and low density situations, etc), it is extremely difficult to find a simple, effective measure to evaluate the efficiency of land use by the case-study building, particularly when assessments are made relative to "typical practice."
- The net area of land covers the building footprint, onsite surface parking and access roads and areas of the site that are deemed to offer significant ecological benefit. Areas of roof offering significant ecological benefit can be subtracted from this value.
- Information is inputted into the *Arch* worksheet.
- The necessary information can be directly extracted from site plans showing the building footprint, onsite surface parking and access roads and areas of the site that are deemed to offer significant ecological benefit.

R2.2 Change in ecological value of the site

This criterion assesses the ecological characteristics of the site immediately prior to and after the development of the case-study building. The amount and type of vegetation retained or introduced into the development is a critical part of the preservation, restoration and maintenance of site ecology.

Performance Measure: The presence or absence of design features that demonstrate that the site ecology has been disturbed, retained or improved.

Assessment Notes:

- The opportunities for making significant performance improvements for this criterion are context specific with obvious differences between buildings with small footprints on dense urban sites and expansive, low-rise facilities in more sub-urban or natural settings.
- There are no clear rules or directives for identifying conformance with the issues relevant to this criterion and considerable judgment will be required on the part of the assessment team.

R2.3 Change in agricultural value of the site

Not assessed in GBC 2002

R2.4 Change in recreational value of the site

Not assessed in GBC 2002

R3 Net consumption of potable water

This performance category evaluates the total annual water use of the case-study office building. The continual increase in the number and population of urban centres places considerable demand on water supplies. A reduction in water use decreases the load on both water supply and waste treatment facilities, leading to lower requirements for energy and treatment.

Performance Measure: Annual net amount of potable water per person used in the case-study building: m^3/person/year, taking into account the re-use of grey water and captured rainwater.

Assessment Notes:

- The assessment should include:
  - Potable water used for toilet flushing and urinals in public washrooms, minus any grey water re-use.
  - Potable water used for other sanitary uses, such as janitorial service facilities.
  - Potable water used for other occupant functions.
  - Potable water used for building equipment operation.
  - Commercial kitchen facilities, where applicable.
  - Landscaping irrigation (minus stored rainwater use)
- Water use data for the respective occupancies in the case-study building is inputted in the *Water Consumption Calculations* section of the *Tech* worksheet. (Rows T70-T85)
- Consumption data is derived from the specifications of water use per use of appliances; anticipated occupancy, gender mix, frequency of use of water consuming appliances; landscaping strategy and anticipated irrigation program.

R4 Re-use of existing structure or on-site materials

This category assesses the extent to which on-site material resources have been reused in the case-study building. It has three (3) criteria:

R4.1 Retention of an existing structure on the site

R4.2 Re-use of materials and components from existing structure on the site

R4.3 Off-site re-use of materials from existing structure on the site

If there are no existing structures on site that are of sufficient size or quality for the intended function, this category is *Non-Applicable*. In this case the default weightings for R4.1, R4.2 and R4.3 are reallocated. Although it would seem appropriate to transfer the weightings to R5, National Teams may want to reassess the distribution across the whole resource use categories.

R4.1 Retention of an existing structure on the site

This criterion assesses the extent to which any existing onsite building is integrated into the case-study building. Older buildings are an important part of the urban fabric, and they represent large investments of materials and labour. However, many buildings are demolished long before their useful life has ended because they no longer meet economic or fashion criteria. Retaining whole building or major elements is a primary conservation strategy for preserving urban character, reducing landfill and minimizing new material use.

Performance Measure: The proportion of the structure of an existing building on the site that is retained as part of the new building: Percent of gross floor area.

Assessment Notes:

- If applicable, evidence (e.g., annotated plans) should be provided showing extent of existing facility retained in the case-study project.
- Information relating to the proportion of the structure of an existing building on the site that is retained as part of the new building is inputted in Block 1 of the Arch worksheet.

R4.2 Off-site re-use or recycling of steel from existing structure on the site

This criterion assesses the amount of salvageable steel in an existing structure (if applicable) that has been re-used on site or recycled off-site. Steel is energy intensive in production, but has the advantage of being highly recyclable.

Performance Measure: The weight of steel taken from the part of the existing structure not re-used in the case-study building: Percentage of total weight.

Assessment Notes:

- Only applicable in the case of an existing steel-framed building on-site (see *Cntxt* worksheet).
- This assessment excludes any materials accounted for in Criterion 4.1
- The amount of salvaged steel is calculated from data inputted on the Materials worksheet.

R4.3 Off-site re-use of materials from existing structure on the site

This criterion assesses the extent to which salvageable materials in an existing structure (if applicable) have been re-used on site or recycled off-site. When buildings are renovated or demolished there are often substantial quantities of materials that are salvageable e.g., millwork, doors, architectural metals, bricks, etc., if:

- the time and effort is committed for their removal
- they are of good quality
- they are consistent with current health requirements, e.g., low toxicity.

Reuse can significantly reduce demands on limited reserves of raw feedstocks.

Performance Measure: The proportion of materials and components salvaged from existing structure(s) on the site that are re-used in the new or renovated structure: Percentage of total weight.

Assessment Notes:

- This assessment excludes any materials accounted for in Criterion 4.1
- The amount of salvaged material is calculated from data inputted on the Materials worksheet.

R5 Amount and quality of off-site materials used

This performance category covers the environmental attributes of materials in the case-study building originating off-site. It has three criteria:

R5.1 Use of salvaged materials from off-site sources

R5.2 Recycled content of materials from off-site sources

R5.3 Use of wood products that are certified or equivalent

R5.1 Use of salvaged materials from off-site sources

This criterion assesses the amount of salvaged materials and components originating from the demolition or refurbishment of buildings *off-site*.

Performance Measure: The proportion of the materials and components used in the case-study building that are salvaged from off-site sources: Percentage of total weight of materials in case-study building.

Assessment Notes:

- The amount of salvaged material is calculated from data inputted on the Materials worksheet.

R5.2 Recycled content of materials from off-site sources

This criterion covers the recycled content of the major architectural materials used in the case-study building.

Performance Measure: The proportion of architectural materials and components that have recycled content: Percentage of total weight.

Assessment Notes:

- The amount of salvaged material is calculated from data inputted on the Materials worksheet.
- Different materials and components will have different recycled contents, and this may be either post-industrial or post consumer in origin. The assessment is based on the aggregate of the material weight multiplied by their respective recycled contents.

R5.3 Use of wood products that are certified or equivalent

This criterion covers all wood products used in the building including framing, flooring, finishes and millwork.

Performance Measure: The proportion of materials of wood origin certified to conform to requirement for sustainable forestry practice guidelines: Percentage of the weight of all wood based components.

Assessment Notes:

- The amount of salvaged material is calculated from data inputted on the Materials worksheet.
- Assessment is based on wood certification documentation, including chain-of custody documentation, from manufacturer declaring conformance with an accepted certification program, and specifications and contractor submittals highlighting certified wood-based materials installed.

LOADINGS

L1 Emission of greenhouse gases from initial production and operations

This performance category assesses the life-cycle greenhouse gas emissions associated with the case-study building. There is overwhelming evidence that current increases in global warming and attendant climate change derive largely from the greenhouse gas emissions (GHGs). The principal airborne emissions associated with buildings are carbon dioxide, methane and nitrous oxide associated with the burning of fossil fuels in energy production.

As with life-cycle energy use, only the emissions associated with initial building construction and building operation will be assessed in *GBC 2002:*

L1.1 Embodied emissions of materials, annualized over the life-cycle

L1.2 GHG emissions from all energy used for building operations over the life cycle

Since building operating (primary) energy is assessed in *Criterion R1.1*, there is a clear danger of double-counting. However, the explicit assessment of airborne emissions captures the potential environmental impacts associated with the *fuels* used in energy production as distinct from the resource use issues assessed in R1.

L1.1 Embodied emissions of materials, annualized over the life-cycle

This criterion assesses the greenhouse gases emitted during the production of building materials, components and systems. Part of this emission originates from the burning of fossil fuels, and part is due to other processes during production (e.g., calcination during the cement production generates considerable quantities of CO2).

Performance Measure: Annualized greenhouse gas emissions normalized for building areas: kg $CO2_{equiv.}/m^2$ /year

- Area is the net usable building area

Assessment Notes:

- As with the data necessary to make embodied energy assessments, establishing Embodied GHGs is currently neither comprehensive nor consistent nor is there a consensus of what are reasonable benchmark or target performance levels. It is anticipated that assessments of initial GHG will be relatively crude, and it is important to report on the overall level of confidence of the results to provide a more valid interpretation of the final result.
- The amounts of greenhouse gas emissions are based on the materials inventory and energy use generated in the derivation of initial embodied energy. The additional data required for this assessment is a breakdown of the energy by fuel type and emission factors for the various fuel sources and process emissions associated with the respective materials industries.
- A complete database may not be available which give the fuel breakdown of the energy associated with the production of the various building materials and assemblies or the process emissions. Data can be obtained from programs such as *Athena* or *Eco-Quantum*, or from data on performance of building stock, using similar buildings constructed within the last 5 years.
- Should a comprehensive emissions profile not be available, an estimate can be made of the greenhouse gas emissions by:
  - Multiplying the total initial embodied energy derived in *Criterion R1* by the national or regional average CO2 for the building industry.
  - Multiplying the embodied energy by a factor that represents the ration of the GHG emission to embodied energy based on prior experience.
- Similar to the embodied energy analysis, account must be taken for any existing building on-site.

L1.2 GHG emissions from all energy used for building operations over the life cycle

This criterion assesses the greenhouse gas emissions associated with building operation. This represents the largest proportion of life-cycle emissions and is emerging as a major consideration in environmental regulation and building assessment.

Performance Measure: Annualized greenhouse gas emissions normalized for building areas: kg $CO2_{equiv.}/m^2$/year

- Area is the net usable building area

Assessment Notes:

- Operating GHG emissions are obtained by a breakdown of the energy by fuel type and multiplication by appropriate regional emission factors for the various fuel sources.
- All calculations are based on primary energy use, requiring the use of accepted regional conversions factors, and account for the major greenhouse gases: Carbon Dioxide, Nitrous Oxide and Methane.
- Operating GHG are calculated on worksheets based on the emissions factors reported by the National Teams.

L2 Emission of ozone-depleting substances

This category assesses the extent to which ozone-depleting substances have been minimized during building construction and operation. Chlorofluorocarbons (CFCs), Hydrochlorofluorocarbons (HCFCs) and halons are chemical compounds that cause damage to the earth's stratospheric ozone layer. Concerns not only stem from the gradual release of Ozone Depleting Substances (ODSs) to the atmosphere through industrial process, normal refrigeration equipment leakage, etc., but also from the threat of potential catastrophic discharge, accidental or otherwise. The ultimate safe destruction of ODS when it has outlived its usefulness in a specific application is a concern as well.

Performance Measure: Annual kg $CFC\text{-}11_{equiv.}$ normalized for area: kg $CFC\text{-}11_{equiv.}$ /m^2/year

- Area is the net usable building area

Assessment Notes:

- This criterion is assessed by first conducting an *Ozone Depleting Substance* inventory. On or off-site ODS inventories are considered to include all estimated future ODS material requirements through the life service life of the equipment. In this manner indirect credit is given for ODS containment, recovery and scavenging systems.
- Detailed inventory of all Ozone Depleting Substances, including any stockpiled inventories (on or off-site) necessary for service or future use.
- The potential hazard offered by each type of refrigerant is obtained by multiplying the quantity of each substance by its Ozone Depleting Potential (ODP), as determined by the most current information available.

L3 Emission of gases leading to acidification from building operations

This category assesses the gas emissions associated with the case-study building's operation that lead to acidification. Many air pollutants such as Oxides of Nitrogen (NOx), Oxides of Sulfur (SOx), un-burned Hydrocarbons (Methane, etc.,) and particulates emitted during the production of building materials and the burning of fossil fuels have adverse local and regional environmental impacts: urban smog and acid rain. These create health risk to humans, other species, terrestrial vegetation, and marine life. Sulfur oxides are toxic and are major contributors to acid rain.

Performance Measure: Annual kg of $SO_{2\ equiv.}$ normalized for area: kg of $SO_{2\ equiv}$ /m^2/year

- Area is the net usable building area

Assessment Notes:

- The magnitude of SO_2 emissions is directly related to amount of fuel burned that contains sulfur. This relates primarily to coal and oils, and to a less degree, natural gas. Usually, this will be linked to the combustion of such fuels off the site, in a district heating plant or an oil or coal-fired generating station.
- All calculations are based on primary energy use, requiring the use of accepted regional conversions factors, and account for the major gases: Oxides of Nitrogen (NOx) and Oxides of Sulfur (SOx).
- Operating emissions are obtained by a breakdown of the energy by fuel type and multiplication by appropriate regional emission factors for the various fuel sources.

L4 Emissions leading to photo-oxidants from building operations

This category assesses the annual emissions of gases leading to formation of photo-oxidants from annual operating emissions.

Performance Measure: Annual Grams of PCOP equivalent normalized for area: gm Ethane equiv./m^2/year
- Area is the net usable building area

Assessment Notes:

- Operating emissions are obtained by a breakdown of the energy by fuel type and multiplication by appropriate regional emission factors for the various fuel sources.
- The total emissions generated from fuel used on site and electrical consumption in Design, annual basis, Kg. are calculated on the Engen Worksheet. Photo-oxidants, ethane-equivalent kg. per year (CH4*0.007+VOC*0.337)

L5 Emissions with eutrophication potential from building operations

Not assessed in GBC2002

L6 Solid Waste

This performance category assesses the extent that solid waste has been avoided during construction and the design measures that have been included in the case-study building to support tenant-recycling programs. The volume of waste generated by building construction and activities can be considerable. Solid waste places pressure on existing landfill space and the development of new landfills is a difficult process not only do they often encounter tremendous resistance from local residents but they also occupy valuable land that could be used for other purposes. Ground and surface water contamination and soil gas generation are just two of the many environmental problems of landfills. There are three (3) criteria:

L6.1 Avoidance of solid waste from clearance of existing structures on the site

L6.2 Avoidance of solid waste resulting from construction process

L6.3 Avoidance of solid waste resulting from tenant and occupant operations

L6.1 Avoidance of solid waste from clearance of existing structures on the site

This criterion assesses the extent to which solid waste that would typically be sent to a landfill has been offset through salvaging and recycling programs.

Performance Measure: The percentage by weight of solid wastes resulting from clearance of existing structures on the site that will not be sent to a solid waste facility.

Assessment Notes:

- If there is no existing facility on the site, this criterion is non-applicable.
- If non-applicable, the weighting is reallocated to L6.2 and L6.3

L6.2 Avoidance of solid waste resulting from construction process

This criterion assesses the effectiveness of construction waste management practices.

Performance Measure: The percentage by weight of solid wastes resulting from construction of the new or renovated facility on the site that will not be sent to a solid waste facility.

Assessment Notes:

- Assessment based on:
  - A copy of the Waste Management Plan for the project highlighting recycling and salvage requirements.
  - Calculations are based on end-of-project recycling rates, salvage rates, and landfill rates demonstrating percentage of construction wastes that were recycled or salvaged.

- Although the amounts of materials recovered from any existing building are accounted for in R4.2, this criterion deals with the burden placed on landfills and deals specifically with any new construction on site.

L6.3 Avoidance of solid waste resulting from tenant and occupant operations

Solid waste generated by occupants is covered here only to the extent the issue can be affected through the design of the building. It includes four (4) sub-criteria:

L6.3.1 Area of central facility provided for sorting and storage of solid wastes

L6.3.2 Area of central facility provided for storage of organic wastes

L6.3.3 Aggregate area of facilities provided on each floor for storage of solid wastes

L6.3.4 Aggregate area of facilities provided on each floor for storage of organic wastes

L6.3.1 Area of central facility provided for sorting and storage of solid wastes

This sub-criterion assesses the provision of space for sorting and storage of solid wastes within the case-study building.

Performance Measure: Provision of central area to store and sort solid wastes likely to be generated by building and tenant operations: m^2 of facility per m^2 of occupied area

Assessment Notes:

- This sub-criterion is only applicable to buildings with a gross area greater than 500 m^2.
- Solid waste denotes waste generated from all sources in building operation that is landfilled or disposed in some other way, but not reused, recycled, or converted. Though office paper makes up the majority of the solid waste stream in offices, consumer recyclables such as glass and metal containers are also important factors.
- The benchmark is the area of storage/100m^2 of building area. Typical values weighted across the constituent occupancies by their respective areas (see bmark B49).
- The case-study area of central facility provided for sorting and storage of solid wastes is entered in Area A24.
- The input data derives directly from plans or other documentation showing the location and areas of dedicated storage facilities.

L6.3.2 Area of central facility provided for storage of organic wastes

This sub-criterion assesses the provision of a central area within the case-study building for the collection of organic wastes that are likely to be generated by building and tenant operations.

Performance Measure: Provision of central area to store organic, expressed as m^2 of facility per m^2 of occupied area.

Assessment Notes:

- It is only applicable to buildings with a gross area greater than 500 m^2.
- The input data derives directly from plans or other documentation showing the location and areas of dedicated storage facilities.

L6.3.3 Aggregate area of facilities provided on each floor for storage of solid wastes

This sub-criterion complements L6.3.1 and assesses the provision of area on each floor to store solid wastes likely to be generated by building and tenant operations.

Performance Measure: Provision of dedicated area on each floor of the case-study building to store solid wastes, expressed as m^2 of facility per m^2 of occupied area.

Assessment Notes:

- It is only applicable to buildings with a gross area greater than 500 m^2.
- The input data derives directly from plans or other documentation showing the location and areas of dedicated storage facilities.

L6.3.4 Aggregate area of facilities provided on each floor for storage of organic wastes

This sub-criterion complements L6.3.2 and assesses the provision of area on each floor to store organic wastes likely to be generated by building and tenant operations.

Performance Measure: Provision of dedicated area on each floor of the case-study building to store organic wastes, expressed as m^2 of facility per m^2 of occupied area.

Assessment Notes:

- It is only applicable to buildings with a gross area greater than 500 m^2.
- The input data derives directly from plans or other documentation showing the location and areas of dedicated storage facilities.

L7 Liquid Effluents

This category assesses the amount of liquid effluents released from the case-study building. Liquid effluents either generated from building operations or from rainwater run-off from the site, place increased loading on the community infrastructure and the subsequent loading on ecological systems.

Two (2) performance criteria are assessed:

L7.1: Storm water flows disposed of on site

L7.2: Onsite grey water reuse

L7.1 Storm water flows disposed of on site

This criterion assesses the design measures taken to control stormwater. Storm water from large paved sites and roof areas has serious impacts on local ecosystems (oil accumulation, erosion of natural water-courses and flooding of treatment facilities) and municipal systems (storm sewers sized for peak periods).

Performance Measure: The volume of storm water, per unit area, that will not require disposal by a municipal storm waste water system, per unit area: m^3/ m^2/year

Assessment Notes:

- The total storm water (m^3/year) disposed on site in holding ponds, through permeable paving, landscaping or other on-site mechanisms must be calculated using standard engineering analysis, and inputted in line T93 of the Tech Worksheet.
- A description of the actual measures that have been taken to minimize storm-water flows should be inputted in T96 of the Tech Worksheet.

L7.2 Onsite Grey Water Reuse

This criterion covers all onsite measures to reduce the amount of grey-water entering the municipal system. The removal and treatment of greywater is of significant environmental concern due to the cost, land and materials associated with the construction of required infrastructure. Another factor is the inherent advantage of biological treatment systems over chemical systems in terms of process energy requirements and reduced secondary environmental effects (from chemical wastes).

Performance Measure: The annual volume of grey water flows that will not require the use of a municipal sanitary sewer system: m^3/m^2/year.

Assessment Notes:

- This criterion is only based on the amount of grey-water reuse of the site (both for landscaping and toilet flushing. The amount of grey water re-used per year (m3/year) is inputted in T83 of the Tech Worksheet
- Maximum points are given for no connection to the municipal system.
- Documented evidence of design capability of onsite sanitary waste systems and associated approvals.

L8 Hazardous wastes resulting from renovation or demolition wastes

Not assessed in GBC 2002

L9 Environmental impacts on site and adjacent properties

This category assesses the design measures incorporated into the case-study building that reduce potential adverse impacts on neighbouring buildings or adjacent outdoor spaces. It acknowledges that the implications of building design extends beyond the boundaries of a specific site and that sustainability will require an overall urban form which is collectively responsive to natural systems and cycles. It comprises of three (3) performance criteria:

L9.1 Thermal emissions to lake water or sub-surface aquifer

L9.2 Reflectance of horizontal building surfaces and hard site areas

L9.3 Impact of construction process or landscaping erosion within or adjacent to site

L9.1 Thermal emissions to lake water or sub-surface aquifers

This criterion assesses the potential adverse effects of thermal emissions to lake water or sub-surface aquifers from using ground source heat pumps in the case-study. Technologies such as ground source heat pumps create thermal emissions that could potentially cause sufficient changes to water temperature as to limit use by adjacent properties.

Performance Measure: Qualitative assessment of the extent to which the implications of using ground source heat pumps has been explicitly considered.

Assessment Notes:

- Only applies to case-study building using ground source heat pumps and attempts to assess precautions taken to reduce thermal emissions that could potentially cause sufficient changes to water temperature that limit use by adjacent properties. If the case-study building does not employ ground source heat pumps it should be designated *Non-Applicable*.
- Judgments should be based on information submitted by HVAC consultant demonstrating that appropriate measures have been taken that maintain the thermal characteristics of lakes or sub-surface aquifers so they can be used by others.

L9.2 Reflectance of horizontal building surfaces and hard site areas

This criterion assesses the reflectance of the horizontal building surfaces and hard site areas of the case-study building. The effects of the surrounding landscape can have a profound effect on the solar heat gain, external air temperature and air quality in the vicinity of the building. The significance of the immediate surroundings in modifying the micro-climatic conditions is greatest in low-rise facilities. The choice of ground surfaces and the type and placement of trees and other vegetation provides many opportunities to positively influence the climate stress on the building and the thermal quality of the spaces surrounding buildings.

Performance Measure: The area-weighted reflectance of roof surfaces and paved site surfaces: percentage.

Assessment Notes:

- The area weighted reflectance of roof surfaces and paved site surfaces is calculated based on information inputted in the Arch worksheet.
- Assessment is made based on initial reflectance values and does not account for deterioration in reflectance through time.

L9.3 Impact of construction process or landscaping erosion within or adjacent to site

Not assessed in GBC2002

INDOOR ENVIRONMENTAL QUALITY

Indoor environmental quality embraces occupant comfort, health and well-being. Achieving a high level of indoor environmental quality can have important benefits in terms of occupant satisfaction, comfort and health. Environmental quality can translate into improved job performance, better employee relations and reduced absenteeism. For the building owner, providing a building which can deliver improved conditions can mean more satisfied tenants and a building that is easier to rent.

GBC 2002 assesses five (5) *Indoor Environment al Quality* Categories:

Q1: Air Quality and Ventilation

Q2: Thermal Comfort

Q3: Daylighting and Illumination

Q4: Noise and Acoustics

Q5: Electro-Magnetic Pollution

Many of the criteria and sub-criteria in these categories are evaluated on a feature-specific basis, i.e., the presence or absence of design features which are likely to lead to a more healthy, comfortable building interior.

Q1 Air Quality and Ventilation

This performance category covers both source control and ventilation. Source control covers all major sources of indoor air quality problems (moisture, mineral fibre, VOCs and radon). Ventilation covers both the quality and quantity of supply air reaching occupants. All criteria in this category are considered critical. The category is structured into four (4) performance criteria:

Q1.1: Moisture control

Q1.2: Pollutant control

Q1.3: Ventilation and fresh air delivery

Q1.4: Ventilation effectiveness in occupant zone of primary occupancies

Q1.1 Moisture control

This criterion assesses the type and extent of design measures taken in the case-study to minimize or eliminate indoor air quality problems from moisture, sprays and standing water. Growth of biological contaminants is regulated by the availability of moisture. Construction materials harbouring fungi are wood, cellulose, wall paper, organic insulating materials, glues, paints, mortars, textiles etc. Water systems are contaminated by bacteria, algae and yeasts. Once airborne, microbes may cause various adverse health effects. The main principle in controlling contamination is the control of moisture accumulation in a building and its HVAC systems, coupled with adequate ventilation and filtration.

This criterion covers potential moisture problems originating with the building envelope and within HVAC systems. It contains two (2) sub-criteria:

Q1.1.1: Moisture promoting mould growth inside the building

Q1.1.2: Spray in wet cooling towers and standing water in HVAC distribution systems

Q1.1.1 Control of moisture in the building envelope

This sub-criterion assesses the design measures taken to contain or reduce moisture build-up within the building envelope. Moisture can lead to both premature failure of building systems as well as microbial contamination of absorbent materials leading to sour odours and the growth of pathogenic bacteria and fungi.

Performance Measure: Presence or absence of design features that are likely to minimize the accumulation of moisture within the building envelope and related materials.

Assessment Notes:

- The issues covered in this sub-criterion relate only to the possible effects on human health such as sour odours and the growth of pathogenic bacteria and fungi. The deleterious effects on the building fabric are covered elsewhere.
- Consideration should be given to:

  - Water leakage/moisture migration through building envelope as a result of poor detailing etc.
  - Condensation on windows/wall etc.
  - Indoor sources of moisture production and inadequate moisture source control (i.e., exhaust).
  - Condensation on windows/wall etc.
  - Insufficient time for drying out of wet building construction.
- Detailed sections of critical portions of external walls showing continuity of air/vapour barrier.
- If wet construction is used, confirmation that adequate drying time was provided before the application of finish materials.
- The demands on the quality and integrity of the building envelope vary considerable with climate. Therefore National teams must used judgment to determine if the measures taken in the case-study building are appropriate to their context. In cold climates one would expect particular attention to be given to:
  - Minimization of cold condensing surfaces by the use of thermal breaks in window frames, non-conducting fasteners, insulating cladding, high thermal resistance windows, insulation of piping and ducting etc.,
  - The design of the total air barrier assembly to be continuous throughout the building envelope, structurally supported to resist wind load or pressurization without displacement and have a service life as long as the life of the building or, at a minimum, be located such that it may be serviced as necessary.
  - Incorporation of engineered weather barrier systems such as curtain walls, rain screens and drainage cavities where building form and site warrant, e.g., all buildings higher than four stories and on low buildings with little shelter from wind exposure.
- The drying of poured in place concrete is of particular concern, and interior finishes should not cover concrete surfaces until the relative humidity in the building is less than 85%.

Q1.1.2 Control of spray in wet cooling towers

This sub-criterion applies to any case where a building HVAC system incorporates a chiller, humidifier, dehumidifier, heat exchanger, air washer or any other device that may be expected to introduce moisture into the system, either by condensation or moisture injection. Wet cooling towers and evaporative condensers are potential breeding grounds for Legionella, as the temperature is ideal for growth. Wet cooling towers are typically treated using caustic and toxic chemicals, which are also hazardous.

Performance Measure: Presence or absence of design features that control the release of spray, minimize standing water in HVAC equipment and distribution system, and facilitate cleaning of the air distribution system. Design features that control standing water in HVAC equipment and distribution system.

Assessment Notes:

- This sub-criterion is *Non-Applicable*:
  - In very simple systems without cooling, heat recovery or humidification.
  - If there is no wet cooling tower.
- Confirmation by professional engineer that HVAC systems have been design and installed according to current recommendations regarding the elimination of health problems associated with moisture release and standing water.

Q1.2 Pollutant control

This criterion assesses the type and extent of design measures taken in the case-study to minimize or eliminate indoor pollutants at source. The control of indoor pollution at source should be the primary strategy for maintaining indoor air quality and the dilution of any pollutant build-up by ventilation is a necessary, but secondary consideration.

This criterion covers six (6) sub-criteria:

Q1.2.1 Mineral fibre control

Q1.2.2 VOC emissions in interior spaces

Q1.2.3 Airborne pollution migration between principal workplace areas

Q1.2.4 Radon control

Q1.2.5 Location of outdoor air supply for HVAC systems

Q1.2.6 Filtration performance in HVAC systems

Q1.2.1 Mineral fibre control

This sub-criterion assesses the extent of design measures taken to minimize the release of fibres from un-contained mineral fiber materials, particularly where exposed in ceilings used as air plenums. In particular:

- *Asbestos:* Asbestos containing materials which release fibers as they deteriorate create a long term health concern adding to risk of lung and chest cancers and other respiratory diseases. Most asbestos-containing materials such as structural fire retardants, pipe insulations and tiles were eliminated from building products in the mid-1970's and this issue is only of significance in renovation projects.

- *Mineral Fibre Duct Liners:* Three potential air quality problems have been associated with mineral fiber liners used for acoustic and thermal insulation inside HVAC ducts:

  -Fibrous liners trap dust, making air filtration and duct cleaning less effective.

  -Accumulated dust and debris will support microbial contamination if moisture is present.

  -Deteriorating fibrous liners are a source of hazardous mineral fibers.

- *Loose Mineral Fibre:* Manmade mineral fiber materials used for applications other than duct liners that are exposed to the building interior or to air handling systems are also potential sources of hazardous fibers. Structural fire retardant treatments and exposed acoustic or thermal insulation in suspended ceilings used as plenums are common examples.

Performance Measure: Presence or absence of design features that control the release of mineral fibres into the ventilation air path.

Assessment Notes:

- This criterion deals only with mineral fibres associated with duct liners and structural fire retardant treatments and exposed insulations used in plenums.
- Assessments should be based on detailed specifications on any duct liners and structural fire retardant treatments and exposed insulation used in plenums.

Q1.2.2 VOC emissions in interior spaces

This sub-criterion assesses the extent of measures to eliminate or control the emission of volatile organic compounds (VOCs) from materials based on polymers, or containing solvents or plasticizers. Because finishing materials are those directly enclosing an occupied space, their selection is critical from an indoor air quality standpoint:

- *Paints:* Interior paints are sources of serious exposure to trades and building occupants throughout their curing period. This period may be several weeks in length and extend well into the occupancy period of a new or renovated office building.
- *Adhesives:* Solvent based adhesives are environmental hazards and are toxic to handle. Both the solutions used to clean up solvent-based adhesives, as well as the unused adhesive itself, are hazardous wastes. Low VOC emission adhesives contain virtually no aromatic solvents, do not have strong odours, are safer to install, and have less environmental impact during manufacturing and disposal.
- *Floor Coverings:* Floor coverings are important sources of volatile organic compounds, dust, and fibre release due to their large surface area. They have both short and long term consequences. The interaction of indoor air pollutants with interior surfaces is an important indoor air quality problem. A surface can act as a sink by absorbing VOCs emitted from another material, and later desorbing that VOC into the space. Surfaces with the highest accessible surface per unit area such as acoustic tile, carpet and upholstery fabric have the highest sink capacity.
- *Maintenance:* VOC emissions from maintenance supplies (cleaners, waxes, carpet cleaning and pesticides etc.,) are a continuous concern, emphasizing the importance of the selection of low maintenance finish materials.

Performance Measure: The proportion, by weight, of interior finish materials specified that conform to VOC emissions standards of a recognized certification agency: percentage.

Assessment Notes:

- Assessments should be based on detailed specifications on the VOC emissions of finish materials and adhesives used in the primary occupied areas.
- The percentage of the area of interior finishes with low VOC emissions are inputted directly into the Matrl worksheet.

Q1.2.3 Airborne pollution migration between principal workplace areas

This sub-criterion assesses the extent of measures taken to eliminate or minimize the migration of airborne pollutants between Printing shops, graphics departments, printers photocopiers. Though fire code and health and safety regulations govern this matter, compliance may not prevent comfort complaints or produce “fail safe” conditions.

Performance Measure: Presence or absence of design features that control and separate sources of pollution from other occupied areas.

Assessment Notes:

- Assessment is based on plans showing the locations of potential sources of indoor air pollution and details of architectural and system measures taken to minimize contamination of adjacent or other occupied spaces.

Q1.2.4 Radon control measures

This sub-criterion assesses the extent of measures taken within the case-study building to minimize the entry of radon.

Performance Measure: Presence or absence of design features that control the entry of radon gas into the occupied areas of the case-study building.

Assessment Notes:

- It is only applicable to regions where radon is known to be present. In other cases, this sub-criterion should be weighted zero.
- Assessment is based on information showing whether the building is located in a geological zone with known radon concentrations. If so, design details showing that testing soil for radon has been undertaken and the mitigation measures taken to control migration.

Q1.2.5 Location of outdoor air supply for HVAC systems

This sub-criterion assesses whether the air intakes for the case-study building are located to draw on the best possible outdoor air. Many indoor air quality problems begin by the introduction of poor air from the outside. There are two issues:

- Poor air quality at site: Some sites may be located where they are relatively free from urban and industrial pollution. Others, however, are not and may require extraordinary filtration of outdoor air.
- Poor intake air quality may occur as a result of locating supply intakes in locations of poor quality such as too close to ventilation exhausts or adjacent vehicular access.

This sub-criterion is concerned with the latter, i.e., for a given site condition, have efforts been made to introduce the best quality air available.

Performance Measure: Combination of two factors: the height of air intakes above ground level and the distance between intakes and exhausts or sources of polluted air.

Assessment Notes:

- Data required to perform this assessment can be derived from plans and sections showing location of all air supplies to the building and potential sources of outdoor pollution adjacent the case-study building.

- The assessment is based on the arithmetic average of the height of air intakes above ground level and the distance between intakes and exhausts or sources of polluted air relative to the equivalent benchmark values.
- The following design features are important:
  - Adequately isolating building air intakes both vertically and horizontally from sources of vehicle exhaust, cooling tower spray, combustion gases, laboratory exhausts and other hazardous air contaminants.
  - Adequately isolating building air intakes both vertically and horizontally from sources of nuisance air contaminants such as garbage collection areas and plumbing.
  - Adequately isolating building air intakes from exhaust outlets to prevent "re-entrainment" of exhaust air.
  - Prevailing winds and airflow patterns created by the building can have a considerable impact on the air that reaches the air intakes.

Q1.2.6 Filtration performance in HVAC systems

This sub-criterion assesses the effectiveness of the HVAC filtration system at trapping particulates. HVAC systems can have some form of filtration for trapping particulates from the air stream as it returns to the HVAC plant. This is important not only to provide cleaner supply air, but also to prevent dust contamination of HVAC equipment, which is a maintenance problem and a secondary source of air pollution. However, common filtration equipment is not capable of effectively trapping smaller particulates, especially those less than 5 microns that are most inhaled and damaging to health.

Performance Measure: Percentage effectiveness of filtration system at 1.5 microns.

Assessment Notes:

- This performance sub-criterion relates to mechanically conditioned buildings. For naturally ventilated buildings this sub-criterion is designated *Non-Applicable*.
- The assessment is based on manufacturer's literature indicating results from standard testing methods will be accepted as evidence of performance.
- The units relate to measure the effectiveness of different filters will vary from country to country and assessor must make appropriate judgement to derive the performance score.

Q1.3 Ventilation and fresh air delivery

This criterion assesses the amount, quality and effectiveness of the ventilation air in the case-study building. It consists of six (6) sub-criteria:

Q1.3.1 Total outdoor air rate ventilation in mechanically conditioned areas of Multi-unit residential occupancy

Q1.3.2 Total outdoor air rate ventilation in mechanically conditioned areas of the second occupancy

Q1.3.3 Total outdoor air rate ventilation in mechanically conditioned areas of the third occupancy

Q1.3.4 Total outdoor air rate ventilation in mechanically conditioned areas of fourth occupancy

Q1.3.5 Ventilation performance in naturally ventilated areas of the building with single-sided ventilation

Q1.3.6 Ventilation performance in naturally ventilated areas of the building with cross-ventilation

This criterion does not evaluate the air quality at the site. It is concerned solely with evaluating the design efforts that have been made to introduce the best quality air available for the given conditions. Note also that the relevant weights are automatically adjusted to account for the relative areas of various occupancies.

Q1.3.1 Total outdoor air rate ventilation in mechanically conditioned areas of Multi-unit residential occupancy

This sub-criterion assesses the total outdoor air rate ventilation in mechanically conditioned areas of Multi-unit residential occupancy meets or exceeds the minimum acceptable levels set by national or regional authorities. Note that the weight of this Criterion is automatically adjusted to account for the relative area of residential occupancy in the total building, if applicable.

Performance Measure: The total outdoor air ventilation in mechanically conditioned areas of L/s per occupant

Assessment Notes:

- This applies to mechanically ventilated areas.
- Demonstration that the ventilation strategy for the building is capable of delivering appropriate quantities of outdoor air during peak occupants loads.
- For naturally ventilated buildings, the ventilation rate can be calculated on a daily average basis.
- For new office buildings occupant load will be considered as anticipated occupancy of the building when fully leased or occupied as determined for design purposes based on the occupant loads listed above or other acceptable means of calculation.
- For existing office buildings the occupant load will be considered the actual occupancy when fully leased within the current floor design.

Q1.3.2 Total outdoor air rate ventilation in mechanically conditioned areas of Occupancy Two.

As Q1.3.1, but assessment of total outdoor air rate ventilation in mechanically conditioned areas of the second user-defined occupancy, if applicable.

Q1.3.3 Total outdoor air rate ventilation in mechanically conditioned areas of Occupancy Three.

As Q1.3.1, but assessment of total outdoor air rate ventilation in mechanically conditioned areas of the third user-defined occupancy, if applicable.

Q1.3.4 Total outdoor air rate ventilation in mechanically conditioned areas of Occupancy Four.

As Q1.3.1, but assessment of total outdoor air rate ventilation in mechanically conditioned areas of a the third user-defined occupancy, if applicable.

Q1.3.5 Ventilation performance in naturally ventilated areas of the building with single-sided ventilation

This sub-criterion assesses the use and effectiveness of natural ventilation in those spaces within the case-study building only having access to natural ventilation from one side. Simply providing operable windows is insufficient in designing naturally ventilated buildings. The location, ergonomics and the extent of opening and their distribution profoundly affect performance and use.

Performance Measure: The average of the proportional decrease (or increase) in depth of ventilated space, AND, the proportional increase (or decrease) in the ratio of window area to net area, to the respective benchmarks.

Assessment Notes:

- The average score accounts for combined effects of these two design factors on natural ventilation, e.g., a room with smaller distance to window and larger opening area will score higher.
- Assessment should be based on plans and sectional drawings showing the anticipated continuous air flow paths through a typical principal work place area together with details of the operable windows, the possible extent of the opening and refinement of the control.

Q1.3.6 Ventilation performance in naturally ventilated areas of the building with cross-ventilation

This sub-criterion assesses the use and effectiveness of natural ventilation in those spaces within the case-study building only having access to cross ventilation. Simply providing operable windows is

insufficient in designing naturally ventilated buildings. The location, ergonomics and the extent of opening and their distribution profoundly affect performance and use.

Performance Measure: The average of the proportional decrease (or increase) in depth of ventilated space, AND, the proportional increase (or decrease) in the ratio of window area to net area, to the respective benchmarks.

Assessment Notes:

- The average score accounts for combined effects of these two design factors on natural ventilation, e.g., a room with smaller distance to window and larger opening area will score higher.
- Assessment should be based on plans and sectional drawings showing the anticipated continuous air flow paths through a typical principal work place area together with details of the operable windows, the possible extent of the opening and refinement of the control.

Q1.4 Ventilation effectiveness in occupant zone of primary occupancies

This criterion assesses the effectiveness of the ventilation strategy in delivering air to the breathing zone. Ventilation effectiveness accounts for the:

- Path that supply air moves through an occupied space and reaches an exhaust or return.
- Directness of delivery of ventilation air to the occupants, i.e., diffuser type and location.
- Placement of obstructions to air movement such as partitions and acoustic barriers.

Performance Measure: Different measures are used for different building types:

- For classrooms and residential projects, the primary measures are the proportion of units provided with cross ventilation.
- For office primary areas, ventilation air is supplied directly to occupants breathing zone, supply vents are capable of being relocated following major changes in office layout, and ventilation rates can be controlled for four workstations.

Assessment Notes:

- Assessment should be based on plans and sectional drawings of typical principal work place areas showing air supply and exhaust locations and any anticipated barriers to air flow at workstations.

Q2 Thermal Comfort

This performance category assesses the measures taken to ensure that an appropriate level of thermal comfort is provided within the case-study office building. Four (4) performance criteria are covered in the assessment:

Q2.1 Air temperature in primary occupancies

Q2.2 Mean radiant temperature in primary occupancies

Q2.3 Relative humidity in primary occupancies

Q2.4: Air movement in primary occupancies

Only *Q2.1: Air temperature in primary occupancies* and *Q2.3: Relative humidity in primary occupancies,* are assessed in *GBC 2000*.

Q2.1 Air temperature in primary occupancies

This criterion assesses whether the indoor air temperature within occupied spaces is consistent with user needs. Many 'green' buildings are reverting to natural conditioning, i.e., the creative use of natural lighting, thermal mass and natural ventilation to provide interior environmental conditions. This has also led to a broader range of environmental conditions than would typically be expected or tolerated in mechanically conditioned interiors.

Performance Measure: The percentage of operating hours that indoor air temperature within primary areas will be within accepted comfort ranges.

Assessment Notes:

- It is assumed that if a building incorporates a HVAC system design by a professional engineer, that it is capable of maintaining indoor air temperatures within the occupied spaces. For these circumstances, this sub-criterion is Non-Applicable. The primary concern is to assess the temperature conditions within naturally conditioned spaces, and to ascertain the extent to which they deviate from acceptable comfort ranges. The intent is to give credit to naturally conditioned buildings that successfully meet and maintain comfort conditions.
- Assessment of this criterion:
  - Should be made for critical spaces within the building, i.e., west-facing (where there maybe excessive solar gain, and north (or south in southern hemisphere) facing spaces which may be cold), using computer simulation to derive the hour-by-hour interior temperature pattern for critical times of the year.
  - Follow protocols laid out in *ASHRAE Standard 55-1992 — Thermal Environmental Conditions for Human Occupancy*, or its equivalent.
- A discussion paper on Air Temperature is included in *Appendix 1*.

Q2.2 Mean radiant temperature in principal work areas

Not assessed in GBC 2000

Q2.3 Relative humidity in primary occupancies

This criterion consists of two (2) sub-criteria:

Q2.3.1 Minimum relative humidity levels in primary occupancies during heating season

Q2.3.2 Maximum relative humidity levels in primary occupancies during cooling season

Q2.3.1 Relative humidity in primary occupancies during heating season

This sub-criterion assesses the capability of the building systems to maintain acceptable levels of Relative Humidity in primary occupancies during heating season. In cold weather, air that is drawn into buildings from the outside and then heated to room temperature often has a low relative humidity. It may be necessary to humidify the space to enhance comfort and minimize irritation of the bronchia. If the humidifier is allowed to become contaminated with microorganisms and distribute water droplets, it may itself become a health hazard. Inhalation of contaminated moisture from humidifiers can cause respiratory infections and allergenic illness.

Performance Measure: Minimum relative humidity that may be maintained during the heating season.

Assessment Notes:

- It applies to both naturally and mechanically conditioned buildings.
- Assessment should be made relative to description of HVAC systems and building envelope design with documented evidence from the mechanical consultant that the strategies have been incorporated in the case-study building to increase unacceptably low RH values during the heating season.

Q2.3.2 Relative humidity in primary occupancies during cooling season

This sub-criterion assesses the capability of the building systems to maintain acceptable levels of Relative Humidity in primary occupancies during cooling season. High humidity levels exacerbate thermal discomfort, support dust mite and fungal growth and allow airborne bacteria and viruses to survive for longer periods. This criterion applies only to areas with mechanical cooling.

Performance Measure: Maximum relative humidity that may be maintained during the cooling season in areas with mechanical cooling.

Assessment Notes:

- Interior RH conditions during the summer are temperature related, and recommended acceptable values also vary internationally.
- Assessment should be made relative to description of HVAC systems and building envelope design with documented evidence from the mechanical consultant that the strategies have been

incorporated in the case-study building to reduce unacceptably high RH values during the cooling season.

Q2.4 Air movement in primary occupancies

Not assessed in GBC 2000

Q3 Daylighting and Illumination

This performance category assesses the indoor visual quality in the primary spaces of the case-study building. It consists of three (3) criteria:

Q3.1 Provision of daylighting in primary areas of all occupancies

Q3.2 Potential glare in primary areas of all occupancies

Q3.3 Ambient illumination levels in primary areas of non-residential occupancies.

Q3.1 Provision of daylighting in primary occupancies

This criterion assesses the amount of daylight in the primary areas of the case-study building. Carefully controlled daylight is almost always a valued quality in buildings. If carefully admitted into building interiors, daylight can enhance the environmental quality. These benefits can be translated into improved occupant satisfaction and enhanced productivity. Under the right circumstances, a small amount of daylight can be as effective in increasing visual performance as larger amounts of conventional overhead electric lighting.

Performance Measure: The average Daylight Factor (%) within the 5 metre perimeter zone on the lowest typical floor of the case-study building.

Assessment Notes:

- Assessment of daylighting quality is made only on the lowest typical floor of the case-study building. The assumption is that upper floors will have greater access to daylighting than this condition:
  - For residential occupancies, the estimated Daylight Factor available in living and dining areas of typical dwelling units on the lowest typical floor.
  - For other occupancies, the estimated Daylight Factor available in a typical primary space on the lowest typical floor.
- The Daylight Factor is the ratio of indoor to outdoor horizontal illuminance, excluding direct sunlight.
- The formula included in the Arch Worksheet provides an approximation of average daylight factor in a space, assuming an overcast sky. It should only be used for spaces whose depth is no more than 2.5 times the window head height.
- Assessment should be based on sectional drawings of the lowest typical floor and calculation of daylight factor using formula included in *GBTool* or other nationally accepted method. If features such as light shelves are incorporated into the case-study project, evidence must be provided that illustrates they deliver glare-free natural lighting.

Q3.2 Potential glare in primary occupancies

This criterion assesses the potential for glare in the primary occupied spaces associated with windows. Direct and reflected glare can reduce occupant satisfaction, productivity and initiate action such as covering windows that ultimately reduce the amount of useful daylight to the building interior.

Performance Indicator: Design features that reduce the likelihood of glare.

Assessment Notes:

- The primary concern in this criterion is glare from the penetration of sunlight through south facing windows.
- The avoidance of glare (excessive contrast between light sources and illuminated surfaces) can be controlled by the reflectance of interior finishes and by reduction at source. The reflectance of walls and ceilings is largely beyond the scope of the building designers, although some encouragement for light colours can be built into tenancy agreements.

- Glare from excessive daylight is usually controlled by the installation of interior blinds or other shading devices, but this reduces the amount of daylight available. A better approach is to provide light-shelves that spread the incoming daylight in a more uniform manner and also provide more daylight in deeper parts of the interior.

Q3.3 Ambient illumination levels in primary occupancies

This criterion relates to the provision of appropriate electric lighting in the principal non-residential areas within the case-study building. It consists of two (2) sub-criteria:

Q3.3.1 The deviation of ambient illumination levels in non-residential areas from recommended levels

Q3.3.2 Minimization of lighting control system zones in non-residential occupancies

Q3.3.1 The deviation of ambient illumination levels in non-residential areas from recommended levels

This sub-criterion assesses the appropriateness of the illumination provided in the primary non-residential occupancies. The specified task illuminance needed to satisfactorily undertake tasks is a critical design choice since inadequate or excessive lighting levels for the required tasks will increase occupant eye strain and fatigue. Moreover, the specified illuminance directly influences the electric lighting system design for the interior spaces and therefore determines the energy requirements (Light Power Density in W/m^2).

Performance Measure: The deviation of designed ambient illumination levels in non-residential areas from recommended levels.

Assessment Notes:

- The assumption is that each country has recommended illuminance values for specific tasks. If these optimum values are provided, then maximum points are assigned. Deviations from the optimum, either higher or lower, are assigned lower scores.
- Assessment should be based on evidence of typical/required illuminance levels in the principal work areas and demonstration of illumination levels provided by the installed lighting strategy including lighting plan providing lamp specifications, luminaire type and distribution.

Q3.3.2 Minimization of lighting control system zones in non-residential occupancies

This sub-criterion assesses the size of the lighting control system zone in non-residential occupancies only. Smaller control zones provide the potential for greater refinement in lighting control, user control and energy efficiency.

Performance Measure: The ratio of the lighting control zones in the case-study to the benchmark: Percentage.

Assessment Notes:

- This is only applicable in non-residential occupancies.
- The percentage difference between the size of the lighting control zone in the case-study occupancy and benchmark is calculated for both the perimeter (< 5m) and interior zones (>5m). The average between these is used to score the sub-criterion.

Q4 Noise and Acoustics

Both external and internal noise sources that impact adversely on the acoustic environment within the principal work or living areas within the case-study building. It consists of three (3) performance criteria:

Q4.1: Appropriate noise attenuation through the building envelope

Q4.2: Transmission of building equipment noise to primary occupancies

Q4.3: Noise attenuation between occupancies

Q4.1 Noise attenuation through the building envelope

This criterion assesses whether building glazing system is effective in reducing the transmission of externally generated noise. Traffic, airport, rail and industrial noise is a common irritant in the workplace and is caused by poor sound isolation by building envelope elements, particularly windows. It is typically most severe on the first three floors of office buildings in dense urban areas or near major transportation or industrial noise sources. Windows designed to reduce sound transmission are readily available and are an effective remedy.

Performance Measure: Sound Transmission Class of windows (or its equivalent)

Assessment Notes:

- This criterion applies to buildings where ambient noise is considered to be a problem for occupants, i.e., on the first three floors of the building of those facades of the case-study building exposed to significant sources of external noise. For residential buildings, night-time ambient noise sources are considered, while day-time noise sources are considered for other occupancies.
- GBTool users are asked in Arch A15 to identify the building wall of the Block exposed to the highest ambient noise level. GBTool then matches information provided about the STC of the window in this wall.

Q4.2 Transmission of building equipment noise to primary occupancies

This criterion assesses the extent to noise transmission from areas containing mechanical equipment to primary occupancies has been reduced through the selection and installation of low noise equipment and isolation of mechanical equipment. HVAC mechanical noise is a common irritant in the workplace and is usually caused by worn or poorly adjusted equipment or poor sound isolation. Even moderate systems noise can be an advantage but excessively low ambient noise levels (i.e., low background noise) can lead to a loss of acoustical privacy. Noise may be amplified by vibrating sheet metal parts and carried long distances by ducts. Equipment rooms are a substantial source of noise in adjacent spaces or in ducts unless designed to appropriate noise reduction standards.

Performance Measure: Noise Criteria (NC) rating or its equivalent of all major equipment

Assessment Notes:

- Applies to mechanical noise only, i.e., noise generated by motors, fans, compressors and other moving parts. Moderate noise generated by air movement through diffusers is considered appropriate and may actually enhance conversational privacy.
- Assessment should be based on manufacturer's specification of equipment noise and design details of equipment rooms showing noise attenuation characteristics. Compliance should be in the form of specifying standard noise control for the design and installation of the HVAC equipment.

Q4.3 Noise attenuation between occupancies

This criterion assesses the measures that have been taken to reduce sound transmission between principal work areas. Noise generated within the office building by occupants, their equipment and plumbing is also a common irritant in the workplace and is usually caused by poor sound isolation in floors and walls.

Performance Measure: Number and type of design features within the case-study building that reduce sound transmission between occupancies and floors.

Assessment Notes:

- This performance criterion applies to all fixed walls and floors of office buildings that are the responsibility of the building owner.
- Assessment should be based on sections, plans and details of critical junctions between noise generating and noise sensitive spaces within the case-study building.

Q5 Electro-Magnetic Pollution

This category assesses the measures that have been taken to reduce occupant exposure to Electro-Magnetic Pollution. Although there remains scientific uncertainty about the health effects, it is prudent to adopt precautionary field management strategies and mitigation projects to reduce as much as possible the exposure of people to ELF (50/60 Hz) magnetic fields in occupied spaces.

Performance Measure: Presence or absence of design strategies to reduce the exposure to ELF magnetic fields.

Assessment Notes:

- This is an emerging performance issue and the basis for assessing it is uncertain.
- Assessment should be based primarily:

- On the physical distance of occupied spaces from major sources of magnetic fields. It is manly necessary to assess if there are occupied spaces adjacent to transformers vaults, electrical rooms, network protectors, secondary feeders, switchgears, bus bars, electrical conduits, distribution busways, electrical panels, etc., and the design has provided the greatest possible distance from them. Acceptable distances are 10 m from single overhead service; 20m from multiple overhead services and transformer (14 KV line); 40m from 115 KV line, 60m from 230 KV line and 150 m from 500 KV line.
- On the presence of “low-fields” electric and electronic appliances (that is appliances that produce low level magnetic fields while operating) in the space. To give an example like the certified MPR or TCO video terminal units.
- On the geometrical configuration of the electric power distribution system in occupied spaces. From the magnetic field emissions point of view, the best configuration is the “star” type and not the “ring” one.
- In occupied spaces adjacent to critical sources of field on the presence of a magnetic shield to reduce exposure.

QUALITY OF SERVICE

Buildings represent significant economic and environmental investments. There are a host of building characteristics that both enable a higher quality of operation and attendant services to be offered, and minimize premature obsolescence. These have indirect but significant effects on resource use, environmental loadings and indoor environmental quality.

This Section consists of six (6) Performance Categories:

S1:Flexibility and Adaptability

S2:Controllability of Systems

S3:Maintenance of Performance

S4:Privacy and access to sunlight and views

S5:Quality of Amenities and Site Development

S6:Impact on quality of service of site and adjacent properties

S1 Flexibility and Adaptability

This performance category assesses the capability of the case-study building to adapt to changing conditions. It consists of six (6) criteria:

S1.1: Ease of adapting technical building systems for changing tenant requirements

S1.2: Suitability of layout of structure and core for major changes in future uses

S1.3: Suitability of floor height for major changes in future uses

S1.4: Floor loading capacity for other uses

S1.5: Adaptability to future changes in type of energy supply

S1.6: Floor loading capacity for other uses is considered not applicable for office buildings since is not usually a problem in this building type.

S1.1 Ease of adapting technical building systems for changing occupant requirements

This criterion assesses the degree of flexibility in building systems to changing tenant requirements. Premature obsolescence often occurs when building services are either not capable of change or are too expensive to modify to meet changing requirements. Relevant weights are automatically adjusted for relevant floor areas.

There are four (4) sub-criteria covering the principal building systems:

S1.1.1: Ease of adapting HVAC systems to changing occupant requirements in non-residential uses.

S1.1.2: Ease of adapting lighting systems to changing occupant requirements in non-residential uses.

S1.1.3: Ease of installing or changing cabling or telecom systems in non-residential uses

S1.1.4: Ease of adapting interior layouts to changing occupancy requirements.

S1.1.1 Ease of adapting HVAC systems to changing occupant requirements in non-residential uses

This sub-criterion assesses flexibility of the HVAC systems, where applicable. If with a minimum of adjustment, the existing HVAC system, including HVAC delivery systems and associated control systems, can accommodate all basic types of layout from open-plan to mostly enclosed rooms (cellular layout) and also accommodate added functions such as copier or meeting rooms, then changes in layout will result in less disruption to user operations.

Performance Measure: The number and type of design measures incorporated in the HVAC design that facilitates changes that may be required by changing tenant requirements.

Assessment Notes:

- This sub-criterion is not applicable to residential buildings.

- The HVAC system is defined as including all HVAC components that may need to be modified to suit changed tenant needs, including HVAC delivery components and HVAC control systems, or their equivalents in a building with operable windows or non-mechanical cooling.
- The ease of adapting the HVAC system for changing needs is achieved by considering the following:
  - HVAC does not limit physical location or size of rooms.
  - HVAC provides sufficient conditioning capacity for foreseeable occupancy needs.
  - HVAC system is sufficiently diversified to accommodate operable windows.
  - HVAC flow of air is not affected by relocation of screens, walls or furniture.
  - HVAC adjustments and upgrades can be performed during fit-out or re-fit for a low cost.
  - HVAC system can respond and effectively condition local spaces with little lead-time.
  - All rooms have the potential to be equally serviced (e.g., allowing storerooms to be converted to habitable space, etc.).
  - HVAC system provides automatic response to user action, e.g. if windows are opened.
- Assessment should be based on documented evidence that the HVAC system is sufficiently flexible to meet a variety of possible tenant needs.

S1.1.2 Ease of adapting lighting systems to changing occupant requirements in non-residential uses

This sub-criterion assesses whether an acceptable level of flexibility has been provided within the lighting layout, luminaire type and control system to facilitate adaptation following changes in use within the primary occupied spaces of non-residential uses. The type, location, wiring and control of the ambient lighting system limits the ability to change the configuration of office spaces, such as from open-plan to cellular, or to add or delete other functions such as copier rooms or meeting rooms. A flexible lighting system will permit easy and rapid changes required for minor changes in layout, and will also permit the relatively economical and rapid alteration of lighting patterns and intensities that may be required for more substantial changes in office layouts or functions.

Performance Measure: The number and type of measures incorporated in the lighting layout, luminaire type and control system which facilitate changes that may be required by changing tenant requirements.

Assessment Notes:

- This sub-criterion relates only to the electric lighting system, including layout, luminaires and control systems. It is not applicable to residential buildings.
- Assessment should be based on a lighting plan that shows modularity of system, flexible conduit etc., and documented evidence that the lighting system is sufficiently flexible to meet a variety of possible tenant needs.

S1.1.3 Ease of installing or changing cabling or telecom systems in non-residential uses

This sub-criterion assesses whether a sufficient level of flexibility has been provided within the electrical and telecommunications system to readily facilitate upgrading or adaptation following changes in use within the primary occupied spaces of non-residential uses. The electrical system provides electricity for lighting, HVAC, potable water pressure, coordination and monitoring of space conditioning and security systems, telecommunications and office equipment, and elevator operations. Without sufficient capacity and flexibility, costly renovations to access and upgrade services and subsequently repair finishes may not be viable. This may then lead to the premature obsolescence of an otherwise functioning facility.

Performance Measure: The number of measures incorporated in the building that facilitates the ease with which the electrical and telecommunications system can be reconfigured.

Assessment Notes:

- Assessment should be based on sections and other design information showing the presence of raised floors, etc., and documented evidence that sufficient accommodation has been provided for telecommunications cabling to meet a variety of possible future tenant needs.

S1.1.4 Ease of adapting interior layouts to changing occupancy requirements

This sub-criterion assesses the ease with which occupants can reconfigure the interior to suit alternative uses in non-residential uses. The frequent reconfiguration of building interiors to meet changing occupant needs can be expensive, time-consuming and generate considerable waste.

Performance Measure: The number of measures incorporated in the building that facilitate the ease with which occupants can reconfigure the interior.

Assessment Notes:

- The primary emphasis of this sub-criterion is the ease or difficulty with which partitions can be relocated.

S1.2 Suitability of layout of structure and core for major changes in future uses

This criterion assesses whether the location and capacity of the building core and the structural grid have been designed to permit an acceptable level of flexibility in the planning of interior spaces and future uses. The location and capacity of the members of a structural grid dictate the amount of unusable floor area and limit the live-load capacity of each building bay. Constructing large-span bays and avoiding disproportionately large columns optimizes the flexibility of the space and increases its appeal for reuse.

Performance Measure: The presence or absence of permanent design features incorporated in the case-study building that enhance or limit flexibility and adaptability.

Assessment Notes:

- Assessment should be based on annotated plans and sections showing key design features (structural grid, location of shear walls etc.
- Specific design issues include attention given to the:
  - Absence of frequent changes of floor level.
  - Compatibility of the column spacing with standard dimensions of other interior finish components.
  - Ensuring that the column dimensions are not disproportionately large, and that column features such as pilasters, corbels, and drop panels do not limit potential interior layouts or services.
  - Complexity of the floor-plate shape and irregular column spacing does not limit the typical “usable” floor area.
  - Placement of shear walls, utility walls and fire separations acknowledges and provides for changing occupant uses.
  - Provision for expandable reception (common/public) areas for changing occupant services and traffic volumes.

S1.3 Suitability of floor height for major changes in future uses

This criterion assesses whether adequate floor-to-floor height has been provided to facilitate future reuse. The appropriate inter-storey height for future uses is the result of: the possible and perceived present and future uses of each floor-plate; adequate height for additional or new mechanical, sprinkler, potable water, and information services; and the potential to provide a distinctive, well coordinated interior.

Performance Measure: Judgments of whether the floor-to-floor height throughout a typical floor of the case-study building may limit future uses.

Assessment Notes:

- Limited floor height is often typical of residential buildings built since 1900.
- Assessment should be based on a section through typical floor showing floor to floor height and any limiting structural elements.
- Structural elements such as beams or ribs reduce the overall effective floor to ceiling height. If these are continuous over the entire floor, the floor-to-floor height refers to the height between the floor and the underside of the structural elements.

S1.4 Floor loading capacity for other uses

This criterion assesses whether loading capacity of the typical floors in the case-study building are suitable for other possible uses. Floor-plate capacity affects the building's ability to accommodate retail, storage, security, and occupancies. The future adaptability of a residential building is often limited because of insufficient floor loading capacity. Providing additional capacity and wider bays facilitates a broader range of possible occupancies and hence increases its potential for reuse or renovation. Positioning of the public circulation also tends to dictate the core structural (seismic) resistance members.

Performance Measure: Judgment on the extent to which floor loading capacity of typical floor may limit future uses

Assessment Notes:

- Assessment should be based on documented evidence of floor loading capacity of typical floors. Structural engineers design/use criteria, or report.

S1.5 Adaptability to future changes in type of energy supply

This criterion assesses the extent to which the design of the case-study building facilitates or hinders future changes to a new fuel source or to renewable energy technologies. The ability to be able to switch from one primary fuel type to another to take advantage of price, security of supply or otherwise can be an important consideration in some regions. The rapidly developing cost-effectiveness of renewable technologies, such as photovoltaics, makes it likely that many buildings will soon be actively considered for retrofits that involve such technologies.

Performance Measure: Design features which will enable the case-study building to be able to switch to another fuel or to the use of renewable energy technologies.

Assessment Notes:

- The National Teams will determine the specific aspects associated with this criterion in accordance with local/regional priorities and issues.
- Assessment should be based on annotated plans, sections, working drawings and specifications illustrating that a suitable location of sufficient area and solar exposure is available on the case-study building to house future solar systems.

S2 Controllability of Systems

The effectiveness of building services at providing appropriate heating, cooling, ventilation and lighting to various occupied zones within an office building is to a large extent dependent on to the type and sophistication of control strategy used to mediate between occupant need and system supply capacity.

This performance category contains three (3) criteria:

S2.1: Capability for partial operation of building technical systems

S2.2: Capability for control over heating and cooling systems in primary occupancies

S2.3: Level of building automation appropriate to system complexity

S2.1 Capability for partial operation of building technical systems

This criterion assesses the degree to which the building HVAC, lighting and control systems satisfy the need for part-floor and off-hours service, in non-residential buildings. Occupants in many buildings find their ability to work at odd hours (at night or on weekends) to be limited, since the HVAC and lighting control systems have not been designed to permit occupants to control their own conditions. Thus, a building user may find it impossible to switch on needed lights or ventilation to meet their specific needs. Even where this is possible (through manual controls or by occupancy sensors), the systems may have to be activated for the whole floor, or even for the whole building, to serve a single off-hours occupant. This is clearly uneconomic and wasteful of energy.

Performance Measure: The size of the control zones within the occupied areas of the case-study building, and attendant control strategies.

Assessment Notes:

- Assessment should be based on documented evidence and annotated plans provided by the design consultants that show the extent to which appropriate environmental conditions can be provided at typical workstations during partially occupied hours of operation.
- This criterion applies equally to the extent to which passive strategies in naturally conditioned office buildings are capable of providing for a range of use patterns as it does to the more conventional HVAC systems.
- Operationally, a three (3) for this criterion performance can mean:
  - The building can be operated floor-by-floor or in major sections such as wings.
  - Two to four hours lead time is required for changing operating hours or conditions.
- Operationally, a five (5) for this sub-criterion performance can mean:
  - Ventilation, temperature control, illumination and security systems can be switched on or off, and adjusted, floor by floor or by parts of a floor, either by the occupant or through occupancy sensors.
  - The air handling system is designed so that a call for ventilation for part of one floor is met by fans that service no more than one floor.
  - Control is either by the building operator (from a central station), or an occupant group (from the office floor).
  - No more than one hour lead time is required for changing operating hours or conditions.

S2.2 Capability for control over heating and cooling systems in primary occupancies

This criterion assesses the extent of control that occupants have over the over heating and cooling systems in primary occupancies**.** Effective control of the indoor environment is one of the most important factor defining the user's comfort and satisfaction. The individual occupant should have the possibility of modifying his/her environment while maintaining the entire indoor environment within acceptable limits.

Performance Measure: Degree of control that building occupants have over heating and cooling conditions.

Assessment Notes:

- This criterion applies to the level of personal control available at a typical workstation and the level of control that can be made by an individual without having a significant affect on surrounding workstations.
- Assessment should be based on design specifications and plans of typical floors showing the extent to which the various environmental factors (temperature, ventilation and lighting) can be control at individual workstations.

S2.3 Level of building automation appropriate to system complexity

This criterion assesses whether the level of sophistication of the building control strategy is consistent with the operational requirements of the case-study building. Introducing more and more energy efficient technologies and components that depend on regular management involvement and maintenance does not necessarily lead to a reduction in energy use. This is usually due to failure of occupants and operations management to fully comprehend their operation and sustain their maintenance.

Performance Measure: Number, complexity and design features of the control strategy.

Assessment Notes:

- Assessment should be based on a comprehensive review of building systems and control relative to other similar buildings of this type.
- Assessment of this criterion will require considerable judgment on the part of the assessors as to whether the design team has been successful in using simple, robust and effective control strategies.

S3 Maintenance of Performance

In the shorter term, if the intended performance level of the building is to be maintained, technical systems must be properly maintained and replaced and this, in turn, requires careful attention by designers to provide adequate clearance and access points.

Many health issues derive from inadequate maintenance of the mechanical systems. Minimizing indoor air quality problems requires that building operators have easy access to all critical parts of the ventilation distribution system. Poor maintenance also results in added costs due to shortened life-spans of equipment. Maintenance procedures can be facilitated by providing sufficient space and access to all relevant parts of the mechanical and ventilation systems in order to facilitate effective, regular maintenance.

This category consists of four (4) performance criteria:

S3.1: Protection of materials from destructive elements

S3.2: Potential to maintain performance of building systems

S3.3: Ability to maintain critical performance parameters under abnormal conditions

S3.4: Metering and monitoring of performance

S3.1 Protection of materials from destructive elements

This criterion assesses whether the design includes adequate measures to minimize the deterioration of materials in the building envelope due to the action of exterior sun, temperature variations, rain or wind, or due to the migration of moisture-laden air through defects in the envelope. The potential life-span of major components such as structure and building envelope will, to a large extent, result from the durability of its constituent materials, components, assemblies and connections between them. If service loadings are not exceeded, durability in this case depends largely on exposure to climatic and other environmental stresses.

Performance Measure: Evidence that design attention has been given to the protection of building materials, components and assemblies to the destructive actions of sun, temperature, rain or wind.

Assessment Notes:

- The significance and emphasis of this criterion is climate dependent. Judgments should be based on:
  - The presence of design strategies which are specifically included to minimize premature deterioration of the walls and roof and which are appropriate to the region, e.g., shading screens, eaves, overhangs, scuppers, etc.
  - The use of surface materials appropriate to exterior conditions;
  - The use of rain-screen design principles in joints of wall surfaces;
  - The inclusion of an air-barrier of appropriate strength, including evidence of likely structural integrity, detailing for its joints and wall/window intersections.
- Assessment should be based on details roof and wall sections, and other critical aspects such as roof overhangs showing that effective measures have been incorporated to limit water entry and migration of moisture (e.g., continuity of air/vapour barrier, exterior detailing weather membranes etc.)

S3.2 Potential to maintain performance of building systems

This criterion assesses the extent to which measures have been take to enable the case-study building to maintain performance under abnormal conditions. No designer can be expected to counter the effect of all such conditions, but the ability of the building to continue to operate under some such conditions is a measure of excellence in design.

This criterion includes three (3) sub-criteria:

S3.2.1:Access to central technical systems for maintenance and replacement

S3.2.2:Access to distributed technical systems for maintenance and replacement

S3.2.3:Access to building elements and materials for maintenance and replacement

S3.2.1 Access to central technical systems for maintenance and replacement

This sub-criterion assesses whether adequate measures have been taken to make the central or major elements of the HVAC system readily accessible for regular cleaning, maintenance and repair. The regularity and effectiveness of the maintenance of the central HVAC plant will impact directly on its performance in terms of its energy efficiency, longevity and the quality of the air eventually supplied to the occupied spaces. Inadequate thermal and lighting conditioning of spaces surrounding HVAC equipment may create a context where maintenance personnel are distracted or make rushed assessments and servicing.

Performance Measure: Sufficient space for central mechanical and electrical components and around them so that routine servicing is easy; sufficient access from the exterior to mechanical components so that they can be replaced at intervals without heroic measures.

Assessment Notes:

- This sub-criterion only applies to mechanically conditioned buildings with a central HVAC plant. For other cases, it is *Non-Applicable*
- Assessment should be based on annotated drawings indicating that adequate space and access has been provided to facilitate periodic repair and replacement (including both horizontal and vertical access).

S3.2.2 Access to distributed technical systems for maintenance and replacement

This sub-criterion assesses whether adequate measures have been taken within the design of the HVAC delivery system and its integration with the architectural elements (or the equivalent passive systems), to make it readily accessible for regular cleaning, maintenance and repair. Ductwork and other services that are embedded in structural members or concealed behind interior finishes are not readily accessible for maintenance. Without proper access, routine inspection, cleaning and maintenance is not performed resulting with a potential occupant health hazard.

Performance Measure: Design features which make it easy to access HVAC delivery systems (or the equivalent passive systems) for regular cleaning, maintenance and repair.

Assessment Notes:

- Although the issues raised above relate to mechanically conditioned buildings, this sub-criterion applies equally to passive buildings. Assessors are expected to assess if appropriate access has been provided to passive systems for regular maintenance .
- Adequate access of HVAC delivery systems can be assisted by:
  - Easily visible system gauges for monitoring.
  - Simplified, well-marked signage to clearly indicate purpose, source and destination of specific sections of the delivery system.
  - Accessible, easily demountable and adequately segmented system sections.
  - Minimization of duct run lengths and elbows, with the intent of minimizing pressure losses, reducing surface area and difficulty for ease of cleaning.
- Assessment should be based on annotated drawings indicating that adequate space and access has been provided to facilitate periodic repair and replacement (including both horizontal and vertical access).

S3.2.3 Access to building elements and materials for maintenance and replacement

This sub-criterion assesses whether adequate measures have been taken within the design of key building elements to make them readily accessible for regular cleaning, maintenance and repair. Many aspects of environmental performance are linked to regular maintenance. For example, keeping windows clean is not only an aesthetic matter, but can significantly improve daylight entry, particularly in very dirty situations such as windows close to street level in an inner city location or near a public highway.

Performance Measure: Design features which make it easy to access major building elements that require regular cleaning/maintenance.

Assessment Notes:

- The number of building elements requiring cleaning, maintenance and repair is potentially huge. As such this assessment should be directed at those that directly affect environmental performance: Ease of access for window cleaning, particularly in daylit projects.
- Assessment should be based on annotated drawings indicating access to critical building components (including both horizontal and vertical access) to facilitate periodic repair and replacement is feasible.

S3.3 Ability to maintain critical performance parameters under abnormal conditions

This criterion assesses the extent to which measures have been take to enable the case-study building to maintain performance under abnormal conditions. Buildings are designed assuming a typically and relatively predictable mode of operation. However, a variety of abnormal events can occur that will severely test the capabilities of systems to maintain conditions adequate for normal or even partial operations. Potential external events include power outages, flooding, wind conditions exceeding design assumptions, or temperature conditions beyond the maximum or minimum design temperatures.

Performance Measure: Design features that will enable the case-study building to function in the event of a major power failure or similar occurrence.

Assessment Notes:

- This criterion covers measures taken by designers such as:
  - The provision of high building mass to prolong ambient temperatures in the event of power outages, temporary disruption in fuel supplies or abnormal exterior temperatures.
  - Measures to isolate critical sections of the building or systems from damage that may occur from flooding or storm damage.
  - Redundancy in systems such as back-up power, lighting or ventilation systems, in excess of regulatory requirements.
- Assessment should be based on annotated drawings and specifications of the various building systems and controls, indicating how they perform relative to each other.

S3.4 Metering and monitoring of performance

This criterion assesses the extent to which metering and other monitoring systems have been included in the case-study building to provide performance feedback to building operators, managers and users. Comprehensive strategic environmental planning requires mechanisms that provide regular feedback to building management, operators and users on energy consumption and other resource use and impacts, and opportunities for making savings. This requires providing metering devices for all utilities and designing a system of regular feedback that permits information to be communicated to building users and regular reviews by plant operators and management to guide operation strategies, identify if targets are being met and to assess significant building retrofits. Moreover, having mechanisms for detecting leaks and having procedures that can respond to them is a critical part of environmental management.

It consists of three (3) sub-criteria:

S3.4.1:Monitoring of key system performance parameters

S3.4.2:Provision of leak detection system covering all main water and gas supplies.

S3.4.3:Provision of measures to reduce refrigerant leakage.

S3.4.1 Monitoring of key system performance parameters

This sub-criterion assesses the extent of sub-metering provided for major energy uses within the case-study building. Almost all buildings have a central meter to measure the amount of purchased energy being consumed, but relatively few provide sub-meters to monitor the energy consumed by individual occupancies. Sub-metering is an important factor in encouraging tenants and occupants to use their part of the building in a more energy-efficient manner, and studies have indicated annual energy consumption improvements as high as 30% for buildings with sub-metering.

Performance Measure: Design features that will enable monitoring of the performance of the case-study building.

Assessment Notes:

- The key requirement in this sub-criterion is the provision of sub-metering for the major energy uses provided within the case-building and provision of stand-alone monitoring read-outs or linkages to central Building Management System.

S3.4.2 Provision of leak detection system covering all main water and gas supplies

This sub-criterion assesses whether adequate provision has been made to detect water and gas leaks in the case-study building. The detection of leakage from gas systems is a matter of safety as well as efficiency, and the water leaks can damage the architectural elements as well as creating unacceptable potable water losses.

Performance Measure: Design features that will enable the detection of leaks from gas and water supply systems.

Assessment Notes:

- The key requirement in this sub-criterion is the provision of leak detection devices for gas and water supply systems, provision of separate warning system or linkages to central Building Management System.

S3.4.3 Provision of measures to reduce refrigerant leakage

This sub-criterion assesses whether design and installation procedures have been followed to minimize the release of refrigerants from HVAC system, where applicable. The prevention of the leakage of CFCs and HCFCs, either through leaks within the HVAC system or consciously during routine maintenance is a critical issue. Although Ozone Depleting Substances will eventually be banned, good design and installation practices can minimize or eliminate these leaks.

Performance Measure: Provision of systems and practices that are likely to minimize leakage of ozone depleting refrigerants.

Assessment Notes:

- Given the increased scrutiny of the use of ozone depleting refrigerants and improved design, installation and operational practices, this performance criteria is anticipated to be addressed in all new buildings. It is primarily concerned with the provision of refrigerant leak detection system for high-risk parts of HVAC plant and Provision of automatic pumps to drain refrigerants to storage tanks. If no refrigerants are used in the building, a designation of "Non- Applicable" should be used and the weighting distributed proportionally amoung the remaining sub-criteria.
- Specifications of HVAC system.

S4 Privacy and access to sunlight and views

This category assesses those aspects of the case-study building that provide occupants with contact to the exterior. It consists of three (3) criteria:

S4.1: Visual access to the exterior from primary occupancies.

S4.2: Visual privacy from the exterior in principal areas of dwelling units

S4.3: Access to direct sunlight from principal daytime living areas of dwelling units

S4.1 Visual access to the exterior from primary occupancies

This criterion assesses whether the majority of building occupants have access to distant views and visual contact with the exterior (all occupancies).

Performance Measure: The maximum distance from a workstation to the exterior: Metres.

Assessment Notes:

- Though several modifying factors affect visual access, this assessment is primarily concerned with the physical distance of workstations or living areas from the window wall that dictates the potential provided within the building for occupants to enjoy a view.
- Assessment should be based on plans and sections of typical floor showing window distribution and height, and anticipated location of workstations furthest away from window wall.

- Other information pertinent to this evaluation includes the light transmission of the glazing and anticipated types of work stations (partitions etc.)

S4.2 Visual privacy from the exterior in principal areas of dwelling units

This criterion assesses the extent to which habitable rooms in dwelling units provide privacy to occupants. Even if dwelling units are well provided with daylight and sunlight, this will be of limited attractiveness to occupants if they have to sacrifice privacy in order to take advantage of these potentials. Clearly, the ideal of a maximum of daylighting, sunlight and privacy is only available under unusual circumstances. Nevertheless, a good measure of privacy is essential if life within a dwelling unit is to be enjoyable.

Performance Measure: The minimum distance of surrounding buildings: meters

Assessment Notes:

- Occupants can make up for a lack of privacy to a certain extent through curtains and blinds, but cannot overcome a basic lack of privacy except with the sacrifice of daylight and sunlight potential during the day. The distance to the windows of occupied spaces in adjacent buildings is probably the most important factor in determining privacy.
- Assessment should be based on plans and sections of typical floor showing window distribution and height, and physical distances from windows in adjacent buildings.

S4.3 Access to direct sunlight from principal day-time living areas of dwelling units

This criterion assesses the degree to which living areas in dwelling units have access to direct sunlight.

Performance Measure: Percentage of time principal rooms receive direct sunlight.

Assessment Notes:

- Access to sunlight is defined in this criterion when one or more of the primary living spaces in the dwellings – living room, dining room or kitchen receive direct sunlight throughout the day during the winter. Practical considerations to maximize the potential include:
  - Orientation of the living area and private outdoor space of the dwelling unit so that these areas receive at least several hours of direct sunlight per day.
  - The absence of buildings or other features that could block access to sunlight.
  - Operable windows that are large enough and open in such a way that sunlight can penetrate into living areas.
- Assessment should be based on plans and sections showing the extent to which sunlight is incident on windows of the primary living spaces in the dwellings, including the effects of any external obstructions.

S5 Quality of Amenities and Site Development

This category assesses two additional attributes of site development:

S5.1 Site amenities for shade and relaxation for office workers

S5.2 Quality of parking area development

S5.1 Site amenities for shade and relaxation and play for workers and residents

This criterion assesses the extent to which designers have taken advantage of opportunities to provide site amenities for occupants, building staff and other users of the building. Creating comfortable outdoor areas to walk through or relax in is also important for a high quality street life and site development. Flexible outdoor spaces offer a variety of uses and are more likely to be used year-round. Landscape design can reduce solar heat gain and cooling requirements of buildings as well as improve the hospitality of outdoor spaces.

Performance Measure: Provision of site, landscaping and building features that are likely to provide useful site amenities.

Assessment Notes:

- This criterion covers amenities such as:
  - Provide courtyard spaces and other contained outdoor areas to provide a choice of sheltered and sunlit outdoor spaces. Canopies, arcades and trellises are three options to protect pedestrians from the elements.
  - Avoid trapping pollutants in spaces next to streets by using high tree canopies or plantings that promote air circulation.
  - Provide wider areas next to sidewalks for shaded seating and small gatherings that do not obstruct pedestrian traffic.
- Assessment should be based on annotated site plans showing location and shading effectiveness of vegetation/landscaping.

S5.2 Quality of parking area development

This criterion assesses the extent to which the design includes measures to minimize the adverse affects of on-grade parking areas. The area and type of paved surfaces can signal their use by cars, parking or pedestrians. Wherever traffic requirements allow it, surfaces can be installed that encourage non-automobile traffic, and allow stormwater infiltration. Similarly impervious pavement (concrete and asphalt) can be used only where regular car, bus or truck traffic is expected or surfaces can be matched to the need.

Performance Measure: Type and quality of design measures that minimize the adverse affects of on-grade parking areas.

Assessment Notes:

- This criterion relates to measures that minimize the adverse affects of on-grade parking areas over and above those related to stormwater retention and run-off covered in Category L7.
- Types of strategies include:
  - Using porous asphalt, paver blocks or large aggregate concrete for parking and highly used bicycle and pedestrian areas.
  - Using lattice blocks that permit grass growth for fire lanes and overflow parking.
  - Using crushed stone or brick for lightly used pedestrian paths.
  - Using recycled asphalt and recycled concrete where impervious surfaces are required,
  - Trees with a high, dense canopy integrated into “parking groves”. These provide shade for parked vehicles, and are more attractive when cars are absent.
- Assessment should be based on annotated site plans showing parking areas, surface materials, and location and shading effectiveness of vegetation/landscaping.

S6 Impact on quality of service of site and adjacent properties

S6.1 Adverse wind conditions at grade around high buildings

S6.2 Impact on access to daylight of adjacent property

S6.3 Impact on solar energy potential of adjacent property

S6.4 Noise from building affecting adjacent properties

S6.1 Adverse wind conditions at grade around high buildings

This criterion assesses the extent of measures taken to avoid adverse wind conditions around the case-study building.

Performance Measure: The presence or absence of design features, primarily height and building geometry, which are likely to minimize adverse wind affects around the case-study building.

Assessment Notes:

- It is only applicable if the building is more than 6 floors in height above ground.
- Since this performance issue is site specific, assessment are based primarily on the relative height of the case-study buildings to those surrounding it and the inclusion of design strategies to offset adverse ground wind conditions.

- Assessment should be based on information on prevailing winds, site topography, geometry of adjacent buildings; information on height and geometry of the case-study building from a review of plans and sections.

S6.2 Interference with access to daylight of adjacent property

This criterion assesses if the case-study building has provided an acceptable level of access to daylight to adjacent properties. Obscuring of a neighbouring property's view of the sky vault will limit their access to useful daylight.

Performance Measure: The angle of obstructed sky viewed from the adjacent properties. This is used as indicative of the area of sky vault providing daylight to the case-study building.

Assessment Notes:

- Daylight is defined here as the light coming from the entire skyvault and does not include direct sunlight. Daylight varies with time of day, season and the amount of cloud. It is least under overcast sky conditions and therefore this represents the most appropriate condition to assess its availability.
- Judgments of the interference of daylight on adjacent properties relate to overcast sky conditions and thereby must account for all surrounding properties.
- Consideration must be given to the reduction in daylight on existing buildings as well as potential effects on future development on adjacent properties.
- The measurement need only be made for the adjacent property most directly affected by the case-study building. In most instances this will be the one in closest to the case-study building, although other considerations such as orientation, the relative width of the affected or obstructing facades may influence this choice.
- Assessment should be based on plans and sections of case-study building and those surrounding buildings whose daylight access may be reduced.

S6.3 Impact on solar energy potential of adjacent property

This criterion assesses if the case-study office building has provided an acceptable level of access to winter sunlight on adjacent properties.

Performance Measure: Percentage of the areas of façade of adjacent buildings that are shaded by the case-study building.

Assessment Notes:

- Useful sunlight is defined here as the light coming directly from the sun during the four-hour period of maximum available sunlight in the heating season.
- Judgments of the interference of sunlight on adjacent properties relate to the southerly-facing line of a building on a property immediately to the north of the case-study building.
- Consideration must be given to the reduction in sunlight on existing buildings as well as potential effects on future development on adjacent properties.
- If the building on the adjacent property is not built as close to the property line as may be permitted by zoning laws, then use the line defined by the zoning law.
- If the building is located in the Southern Hemisphere, then North/South nomenclature in this section is reversed.
- Assessment can be made using plans and sections of case-study building and the surrounding buildings that may have their access to winter sunlight reduced.

S6.4 Noise from building affecting adjacent properties

This criterion assesses whether noise from fans and other HVAC equipment on the case-study building is contained within accepted limits.

Performance Measure: Design efforts to limit equipment noise through noise-reducing features of equipment, location of noise-producing equipment, or use of acoustic baffles or screen to reduce noise propagation.

Assessment Notes:

- The potential noise should be assessed with respect to the noise-sensitive receiver (e.g., residential building) most exposed to the noise source - usually the building closest to the case-study building unless this is screened.
- Ideally, assessments would be based on predicted or measured noise levels at critical points on adjacent properties.
- Practical and time limitations will limit this analysis and assessments will therefore be primarily based on expert judgement.
- Assessment should be based on plans and sections of case-study building showing potential sources and types of noise-generating equipment and those noise sensitive locations in adjacent buildings that may adversely affected.

ECONOMICS

There is interest within the IFC to include some measure of the cost and value issues of green building design in the *GBC Assessment Framework*.

The single category E1: Economic Performance consists of three criteria:

E1.1 Life-cycle costs

E1.2 Construction costs

E1.3 Operating and maintenance cost

These performance criteria are not scored. National Teams are required to provide a brief report on the costs of the case-study building relative to typical practice in the region.

The cost analysis should include:

- Design and soft development costs, construction costs and operating and maintenance cost.
- Assumptions regarding building life, interest rates, discount rates and other significant factors that were used in the derivation of LCC.
- A statement of how the capital cost of the case-study building compares with typical costs for similar buildings in the region.

MANAGEMENT

GBC 2002 assesses buildings assuming a standard set operational procedures and occupancy patterns. In recognition that this 'potential' performance is more likely to be realized if procedures such as commissioning are undertaken, a set of three (3) *Pre-operations Management* categories are also acknowledged*:*

M1: Construction Process Planning

M2: Performance Tuning

M3: Building Operations Planning

M1 Development of construction process quality control measures

This criterion assesses the measures taken to ensure quality control during building construction. Although considerable efforts may be made in the design to offer high building performance, this may be negated through poor construction. Quality control is critical to ensure that design intentions are fully executed, e.g., full building commissioning can embrace design and construction.

Performance Measure: Number, type and effectiveness of measures taken to ensure quality control during construction.

Assessment Notes:
Assessment should be based on the extent to which construction plans to address issues such as:

- Completeness of drawings and specifications, including location and type of air barriers.

- Measures to ensure quality control during the construction process, including exchange of information between contractors and subcontractors

M2 Performance Tuning

The performance of contemporary buildings often depends on sophisticated HVAC and automated building systems (lighting, security, fire-safety etc.) Total building commissioning – building systems, structure, envelope and finishes – can ensure that the building is appropriately tuned prior to building occupancy.

This category includes two criteria:

M2.1: Appointment of commissioning agent and development of commissioning protocols

M2.2: Building flush-out

M2.1 Appointment of commissioning agent and development of commissioning protocols

This criterion assesses whether plans have been made to appoint a commissioning agent before the start of construction of the case-study office building and whether a recognized commissioning protocol has been recommended (or performed). Building commissioning is a critical part of the office building handover and closeout procedure. It involves testing and balancing of the installed systems to ensure correct and effective compliance with regulations and design intent. In areas with high differentials between exterior and interior temperature, testing of the air-tightness of the building envelope is recommended as a part of commissioning.

Performance Measure: Conditions regarding the engagement of services of commissioning agent.

Assessment Notes:

- This criterion only applies to buildings larger than 500 m^2
- Assessment should be based on the scope of commissioning undertaken prior to building occupancy (i.e., HVAC systems, or total building)

M2.2 Building flush-out

This criterion assesses whether an appropriate building flush-out is considered necessary and specified as a required undertaking prior to occupancy of the case-study office building. The level of volatile organic compounds from construction and interior finish materials is highest immediately after installation and declines with age. This period can be diminished by conducting a building flush-out. A building flush out is a sustained period of full ventilation, using 100% outdoor air prior to building occupancy to reduce levels of residual volatiles.

Performance Measure: Evidence of building flush-out being conducted.

Assessment Notes:

- A building flush-out is a sustained period of full ventilation, using 100% outdoor air prior to building occupancy to reduce levels of residual volatiles.
- Assessment should be based on evidence that a building flush out will be undertaken and its duration.

M3 Building Operations Planning

A clear means of communicating operations and maintenance procedures and practices is a necessary requirement for the management of building systems and this information must be kept up-to-date with changes in equipment and systems. This category includes three (3) criteria:

M3.1 Provision of as-built drawings and documentation on building systems

M3.2 Training of operating and maintenance staff

M3.3 Provision of performance incentives to tenants in leases or sales agreements

M3.1 Provision of as-built drawings and documentation on building systems

This criterion assesses whether appropriate documentation is provided for the effective operation of the office building and its systems. Information on how to operate building systems in the most efficient manner must be readily available and easy to use by both new and experienced operators to allow them to perform their jobs. This ensures consistent maintenance and operations, allowing the equipment to operate in accordance with the original intent and at peak efficiency. Comprehensive information also eases the training of staff.

Performance Measure: Comprehensiveness of operations and maintenance documentation.

Assessment Notes:

- The type of information required includes manufacturer's information on systems installed, as-built drawings, specifications, commissioning reports and, depending on the size and complexity, a custom-produced manual on effective operation and maintenance of the building.
- Assessment should be based on evidence that building operations personnel will be provided with a complete and up-to-date building systems operations and maintenance manual, that includes:
  - Detailed, step-by-step operating instructions and checklists for starting, stopping, emergency and normal operating procedures and control sequencing for all major equipment and systems.
  - Detailed, step-by-step procedures and checklists for all routine maintenance tasks.
  - A schedule of routine maintenance activities, drawn from manufacturer's recommended inspection, lubrication and maintenance frequencies, for all major equipment and systems.
  - A detailed summary of design intent, including factors which affect operations; single-line schematic drawings that show equipment, ductwork, piping and control point function and location, and desired readings for all HVAC, electrical, alarm and control systems.
  - An extensively commented listing of the current Energy Management Control System program (if any).
  - Manufacturer's performance data sheets and troubleshooting procedures.
  - Standard parts and lubrication product lists.
  - Contact information for contract and other maintenance personnel.

M3.2 Training of operating and maintenance staff

This criterion assesses whether adequate steps will be followed to ensure that operations and maintenance staff of the case-study office building will receive an acceptable initial period of comprehensive training. With the current and future rapid changes in technologies and techniques, building operations staff must be kept informed of opportunities and the "how-to" of energy conservation. A program of continual building operator training in energy efficient operations is essential in ensuring this. Operations and maintenance staff require an initial period of comprehensive training.

Performance Measure: Description of training measures for operating and maintenance staff.

Assessment Notes:

- Applicable only to buildings larger than 500 m^2 in gross area.
- Assessment should be based on the anticipated training of operations and maintenance staff including the quality, duration and numbers of personnel.

M3.3 Provision of performance incentives to tenants in leases or sales agreements

This criterion assesses the extent to which leases or equivalents maximize the potential for tenant and occupant cooperation in enabling the building to live up to its performance potential. Experience has shown that the actual performance of a building is highly dependent on tenants and occupants. In speculative buildings tenants usually install their own lighting systems, and the procurement of inefficient lighting can negate the best performance intentions of the developer and designers. Tenants may also make changes in their initial equipment specifications after a year or two, and unless the management of such changes is foreseen in the lease instruments, the results can be very negative.

Performance Measure: Comprehensiveness of tenants in leases or sales agreements

Assessment Notes:

- Not applicable to schools.
- Assessment should be based on:
  - If the lease specifies that tenants are responsible for heating, cooling and electricity payments. When combined with sub-metering, such a step can build in a healthy self-interest in high performance on the part of the tenant and occupants.
  - If leases or equivalents have been designed so that building design assumptions affecting tenants are specified, limitations and prohibitions are outlined and if incentives are provided for tenants to select and operate equipment that support high performance.

COMMUTING TRANSPORT (*This category is underdevelopment)*

Transportation affects almost every aspect of resource use, air and water quality and urban livability. Reducing the need for automobiles has major environmental benefits and is one of the most important urban planning strategies. The need to travel and the method of travel from an origin to a destination is influenced by land use patterns and the availability of transportation services. Current development patterns and transportation networks favor the private automobile. Reducing the number of personal automobile trips to and from the building both reduces overall automobile greenhouse gas emissions and local air pollution and enables reduction in number of designated parking stools. This can be encouraged by giving priority to pedestrian access and to other more efficient means of occupant transportation such as bicycling.

Part Five

GBTool Worksheets – Section 4

5.0 INTRODUCTION

Section Four of GBTool summarizes and shows results of all previous inputs and, as such, there are no user-modifiable fields. There are three (3) worksheets:

- Rprt
- Weight
- Result

5.1 RPRT

The *Summary Report* (Rprt) worksheet provides users with a summary of the key building characteristics and performance data for the benchmark and case-study buildings. Where appropriate, the results are normalized by both area and occupancy. The following building characteristics are summarized:

- Occupancy and Basic Info
- Other General Building Data
- Other General Building Data
- Normalized General Building Data
- Greenhouse Gas Equivalent calculations for operations
- Ozone Depletion Calculations for operations
- Photo-Oxidant calculations for building operations
- Annual Consumption of Delivered Energy by Fuel Type
- Annual Consumption of Primary Energy by Fuel Type
- Annual Consumption of Primary Non-Renewable Energy Sources by Fuel Type
- Annualized Consumption of Embodied Energy by Fuel Type
- Annualized Consumption of Embodied Energy plus Annual Primary Operating Energy
- Annualized Consumption of Embodied Energy plus Annual Primary Operating Energy

5.2 WEIGHT

The Weight worksheet provides a clear overview of all the weightings used in the derivation of the performance scores at different levels:

- Weighting values for Issues and Categories are transferred from the Vote worksheet
- Weighting for Criteria and Sub-criteria are also shown in this worksheet with a set of messages related to their derivation/application.
- Many of the weights for Criteria and Sub-criteria are developed through the use of formulae that take into account relative areas of occupancies or mechanically-cooled space. Others are determined by total building size or presence of Radon, ambient noise characteristics etc. All are annotated.
- There are no user-modifiable fields in this worksheet.

5.3 RESULT

The final worksheet in the series shows results of the assessments made, via scores and weights. There are two types of results shown:

- Environmental Sustainability Indicators (ESI), which are absolute numbers
- Bar-charts showing the weighted performance scores (-2 to +5) of the case-study building relative to the benchmarks (0).

5.3.1 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. Six (6) *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: Total weight of materials re-used in Design from on-site or off-site uses, kg.
- ESI-11: Total weight of new materials used in Design from off-site uses, kg.

The ESI's are shown normalized for both area and annual person-hours of occupancy.

5.3.2 Green Performance Profiles

These are a set of Bar diagrams showing the performance scores for the case study buildings:

- Category Scores within each of the seven Performance Issues. These are transferred directly from the Assess worksheet.
- Performance Issues scores. These are the weighted category scores, transferred directly from the Assess worksheet.
- Overall building score. This is the overall score for the building derived from the application of the weighting of the respective Performance Issues. It is important to note that this score includes only the weighted scores from the three core Issue areas of Resource Consumption, Loadings and IEQ.

All the diagrams show the –2 to +5 assessment scale used throughout *GBTool.*

The presentation of the results on these bar-charts is directly related to the decision on the scope of the assessment. If only the three core performance areas (Resource Consumption, Environmental Loadings and Indoor Environmental Quality) are assessed, then the weightings for the others would have been set at zero in the Vote Workshop. In this case, only the scores for the core performance areas are displayed.

Part Six

GLOSSARY OF TERMS

aph	Annual person hours of occupancy. This may be prefixed by “m” designating “million annual person hours” or “k” designating “thousand annual person hours”
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers, US
Athena	Canadian LCA - based tool for estimating the environmental consequences of material and energy use in buildings during design.
Blackwater	Water carrying human sewage.
Breathing zone	The location inside a building in the vicinity of occupant’s heads from which they inhale
Building envelope	Perimeter elements of a building, both above and below ground, that divide the external from the internal environment
Building sub-system	Complete, integrated set of parts that functions as a unit within the finished building
Building system	Collection of equipment, facilities, and software designated to perform a specific function
Building line	The closest point to the case-study building of any existing or potential buildings on the adjacent property respecting zoning, set-backs etc.
Criterion	An established precedent, rule, measure, or code upon which a decision may be based
Cultural facility	Recognized publicly accessible facility/facilities within the neighbourhood, community or town that promotes the arts (theatre, cinema, gallery etc.)
Daylight	The light coming from the entire sky-vault and does not include direct sunlight.
Daylight Factor	In most locations, natural lighting is most appropriately assessed using the *Daylight Factor* and assuming overcast sky conditions. The *Daylight Factor* is the ratio of the amount of daylight reaching a location within a building interior compared to the amount available from an unobstructed sky-vault.
Decommissioning	Process of removing a building at the end of its useful life either by demolition or deconstruction.
Delivered energy use	(Final energy use) Energy consumption measured at the final use level. For a building, energy inflow measured at the gate of the building, excluding passive solar gains and heat recovery from human activities.
Eco-Quantum	Dutch LCA--based tool for estimating the environmental consequences of material and energy use in buildings during design.
Emissions control	Any measure which reduces emissions into air, water, or soil. The most effective emissions control involves redesign of the process so less waste is produced at source.
ESI	Environmental Sustainability Indicators - a limited set of *absolute* performance measures that characterize sustainable building practices and that facilitate international comparability
Building footprint	Plan area of the building at grade

Flush-out A period of sustained high ventilation prior to building occupancy to removed outgassing from new materials and installation practices. A 'flush-out' differs from a 'bake-out' in that the latter is the provision of continuous or periodic ventilation while maintaining elevated indoor air temperatures. Concerns here are the possible warping and damage of interior finishes at these sustained temperatures (approx. 27-28C).

GHG emissions Greenhouse gases: Carbon Dioxide, Nitrous Oxide and Methane.

Gross floor area Entire area within the inside perimeter of the exterior walls

GSHP Ground Source Heat Pump

Greywater Waste-water generated from building uses other than toilets and urinals, i.e., waste water from showers, hand-basins etc.

HVAC Heating, Ventilation and Air Conditioning

Initial embodied energy The aggregate of the embodied energy required to produce the constituent building materials and elements of a building (including extraction of raw resources, manufacturing and transportation) together with the on-site energy used in their construction.

Lease Contract between the owner of real property (lessor) and another party (lessee) for the possession and use of the property for a specified term in return for rent or other income

Light Power Density The electrical load for the installed electric lighting power divided by the lit area – W/m^2

Light-shelf Device for reflecting natural light (both sunlight and daylight) deep into building interiors – typically separating the window into upper and lower portions for reflecting natural light and view respectively.

Maintainability Capability of a system or facility to be maintained to a specified level of reliability, at a specified measure of cost or economy

Mechanically conditioned Interior conditions (lighting, heating, cooling and ventilation) are provided and maintained primarily using mechanical and electrical systems

Naturally conditioned Interior conditions (lighting, heating, cooling and ventilation) are provided and maintained primarily using passive strategies (daylighting, thermal mass, natural ventilation, passive solar gain etc.)

Net building area All normally occupied spaces bounded by the inner wall surface, including common and circulation areas, but excluding structure, garages and ancillary support functions/areas such as mechanical/electrical spaces.

NC Noise Criteria standard is a frequency weighted sound pressure level using standard testing methods.

ODS Ozone Depleting Substances: Chlorofluorocarbons (CFCs), Hydrochlorofluorocarbons (HCFCs) and halons are chemical compounds which cause damage to the earth's stratospheric ozone layer.

ODP Ozone Depletion Potential: a measure established by the *United Nations Environment Program*, relating each CFC/BFC to the damage caused by CFC-11.

ODPI Ozone Depleting Potential Index: the total CFC-11 equivalent mass divided by the net leasable area of the building.

Performance criterion A quantitative (or qualitative) statement of the level of performance needed to satisfy a requirement

Potable water Water of drinking quality

Primary Energy Energy consumption measured at the natural resource level, i.e., accounting for the energy to produce and deliver it

Principal axis of building For rectilinear buildings, the axis taken through the building that constitutes the longest dimension in plan

Rain-screen Wall construction system that provides a distinct and separated exterior layer in the building envelope to eliminate the possible passage of rain.

Recreation facility A recognized publicly accessible facility that offers a range of community sports (hockey arenas, tennis courts etc.)

Retail facility Shops or shopping complex offering a range of groceries, food outlets, hardware and personal services (day care, dentist, doctors etc.) Close proximity to these will minimize the number of vehicle trips taken by building occupants to make use of these facilities and services

Reuse The use salvaged of materials, components and assemblies in new applications in their recovered condition and without reprocessing, although it is anticipated that minor repairs and cleaning would be required.

Recycled Content The percentage of post-consumer (i.e., returned and recycled after having been used by consumers). It also includes the percentage of recycled content from one industry if the waste stream used for supplies is from another industry. This is distinct from the degree of internal recycling within the industry itself.

Salvaged Materials, components and assemblies refers acquired from either any existing building on-site or from the demolition or refurbishment of other buildings.

STC Sound Transmission Class

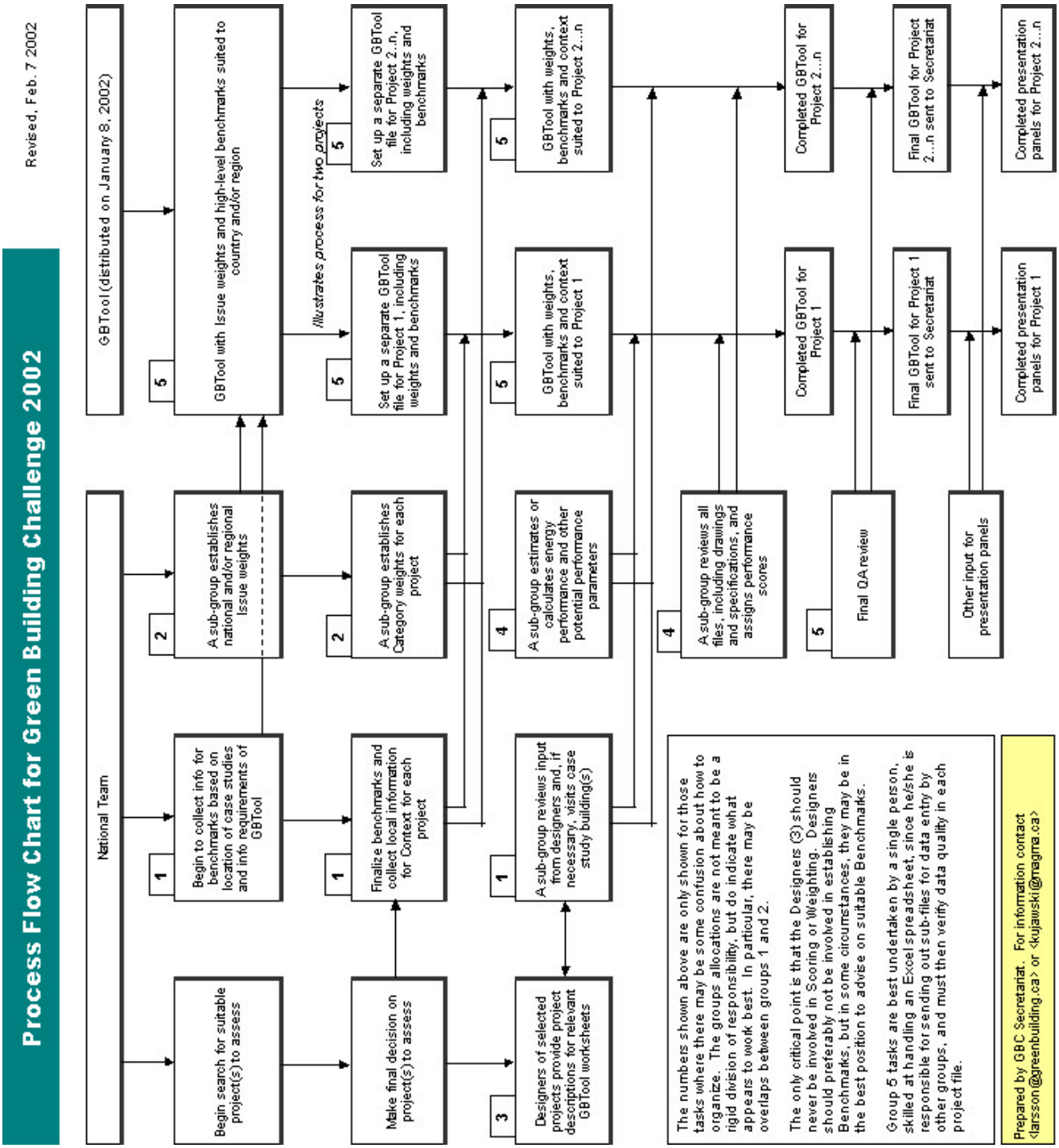
Storage area Recyclables storage refers to separate and dedicated storage for all recyclables.

Storm water Untreated urban runoff from impervious surfaces diverted to municipal storm-water system

Ventilation effectiveness The effectiveness of the supplied ventilation at meeting occupant needs as distinct from that supplied to the interior space. The ideal ventilation effectiveness is 1, where all the supplied air is delivered to the occupants.

VOCs Volatile Organic Compounds – gases with organic structures (based on the carbon atom), which are emitted from materials based on polymers or containing solvents, or plasticizers.

Walking distance The physical distance between the case-study building and the nearest point of access to a transit system or other designated significant facility, using the safest, convenient route.


Process Flow Chart for Green Building Challenge 2002
Revised, Feb. 7 2002
National Team
GBTool (distributed on January 8, 2002)
Begin search for suitable project(s) to assess
1
Begin to collect info for benchmarks based on location of case studies and info requirements of GBTool
2
A sub-group establishes national and/or regional issue weights
5
GBTool with issue weights and high-level benchmarks suited to country and/or region
Illustrates process for two projects
5
Set up a separate GBTool file for Project 2..n, including weights and benchmarks
Make final decision on project(s) to assess
1
Finalize benchmarks and collect local information for Context for each project
2
A sub-group establishes Category weights for each project
5
Set up a separate GBTool file for Project 1, including weights and benchmarks
3
Designers of selected projects provide project descriptions for relevant GBTool worksheets
1
A sub-group reviews input from designers and, if necessary, visits case study building(s)
4
A sub-group estimates or calculates energy performance and other potential performance parameters
5
GBTool with weights, benchmarks and context suited to Project 2...n
5
GBTool with weights, benchmarks and context suited to Project 1
4
A sub-group reviews all files, including drawings and specifications, and assigns performance scores
Completed GBTool for Project 2...n
Completed GBTool for Project 1
5
Final QA review
Final GBTool for Project 2...n sent to Secretariat
Final GBTool for Project 1 sent to Secretariat
Other input for presentation panels
Completed presentation panels for Project 2...n
Completed presentation panels for Project 1
The numbers shown above are only shown for those tasks where there may be some confusion about how to organize. The groups allocations are not meant to be a rigid division of responsibility, but do indicate what appears to work best. In particular, there may be overlaps between groups 1 and 2.
The only critical point is that the Designers (3) should never be involved in Scoring or Weighting. Designers should preferably not be involved in establishing Benchmarks, but in some circumstances, they may be in the best position to advise on suitable Benchmarks.
Group 5 tasks are best undertaken by a single person, skilled at handling an Excel spreadsheet, since he/she is responsible for sending out sub-files for data entry by other groups, and must then verify data quality in each project file.
Prepared by GBC Secretariat. For information contact <larsson@greenbuilding.ca> or <kujawski@magma.ca>

Appendix 2: DISCUSSION ON EVALUATING THERMAL COMFORT

(Prepared by Robert Bach, *Engineering Interface Ltd*., Toronto, Canada)

The subject of designing for and evaluating Thermal Comfort has advanced considerably over the past 10 – 20 years as a result of considerable research into the behaviour of humans. ASHRAE offers this definition:

> "Thermal Comfort is that condition of mind that expresses satisfaction with the thermal environment"

The following discussion applies to sedentary or near sedentary physical activity levels similar to office work, steady state conditions (exposure to environmental conditions for over one hour), and space conditioned by a central HVAC system. An alternative procedure is provided in the standard for naturally ventilated spaces (defined as those spaces where the occupants control their own ventilation by the use of operable windows).

1. Classes of Environments

Three different classes of environments with respect to thermal comfort have been defined: A, B or C. Class B is for typical applications and should be used when other information is not available. Class A is used when it is desired to adhere to higher than typical comfort standards and Class C is used when it is desired to relax the typical comfort standards.

These classes can further described through the use of a PMV-PPD index, further described below. The PMV index predicts the mean response of a large group of people according to the ASHRAE thermal sensation scale. The specific definition of each Class of space is therefore provided in terms of the per cent of occupants who will be dissatisfied with thermal comfort in the space, as shown in the following table.

Table 1 – Classes of Acceptable Thermal Environment for General Comfort

Comfort Class	Predicted Percentage of People Dissatisfied (PPD)	Predicted Mean Vote
A	< 6	-0.2 < PMV < 0.2
B	< 10	-0.7 < PMV < 0.7
C	< 15	-0.5 < PMV < 0.6

1.1. ASHRAE Thermal Sensation Scale

This scale has been developed for use by researchers in this field.

+3 hot
+2 warm
+1 slightly warm
0 neutral
-1 slightly cool
-2 cool
-3 cold

In general about a 3 KF change in temperature or a 3 kPa change in water vapor pressure is necessary to change a thermal sensation vote by one unit or temperature category.

2. Determining Acceptable Thermal Conditions in Occupied Spaces

The 6 primary factors that must be addressed when defining conditions for thermal comfort are:

1. Metabolic rate (sedentary = 1.0 met)
2. Clothing insulation (summer = 0.5 clo; winter = 0.9 - 1.0 clo)
3. Air temperature

4. Radiant temperature
5. Air speed
6. Humidity

All six of these factors may vary with time. However, this method only addresses thermal comfort in steady state.

Variables 2 – 6 may be non-uniform over an occupant's body, and this non-uniformity may be an important consideration in determining thermal comfort. Variables 1 and 2 are beyond the control of the designer, and are assumed at the levels shown for an office environment. Activities requiring a higher metabolic rate, or individuals wearing either more or less clothing than assumed, may not feel as comfortable in the environment.

2.1 Operative Temperature

For given values of humidity, air speed, metabolic rate and clothing insulation, a comfort zone may be determined. The comfort zone is defined in terms of a range of operative temperatures that provides acceptable comfort or in terms of the combinations of air temperature and mean radiant temperature that provide acceptable comfort.

ASHRAE Standard 55 provides an envelope of comfort conditions, as shown in Figure 5. Because people typically change their clothing for the seasonal weather, Standard 55 specifies summer and winter comfort zones appropriate for clothing insulation levels of 0.5 and 0.9 clo (0.078 and 0.14 $m^2 \cdot K/W$), respectively (Figure 5). The warmer and cooler temperature borders of the comfort zones are affected by humidity and coincide with lines of constant ET*. In the middle region of a zone, a typical person wearing the prescribed clothing would have a thermal sensation at or very near neutral. Near the boundary of the warmer zone, a person would feel about +0.5 warmer on the ASHRAE thermal sensation scale; near the boundary of the cooler zone, that person may have a thermal sensation of -0.5. Comfort zones for other clothing levels can be approximated by decreasing the temperature borders of the zone by 0.6 K for each 0.1 clo increase in clothing insulation and vice versa. Similarly a zone's temperatures can be decreased by 1.4 K per met increase in activity above 1.2 met.

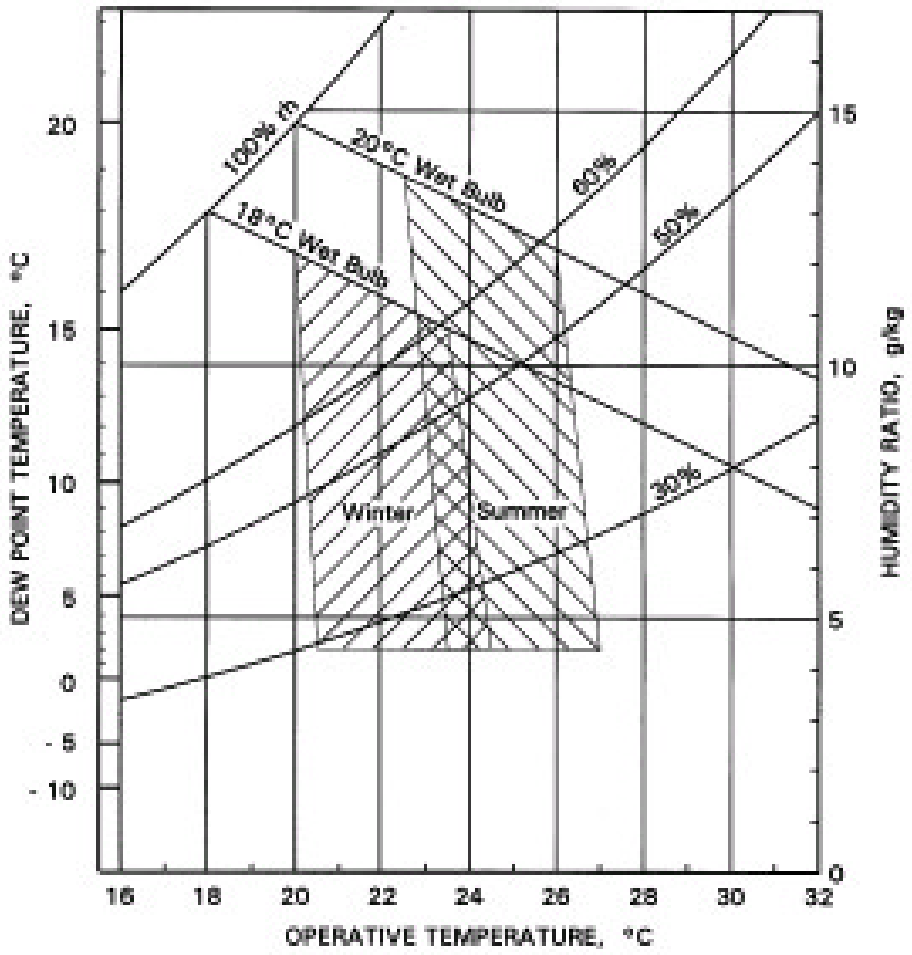


Fig. 5 ASHRAE Summer and Winter Comfort Zones
(Acceptable ranges of operative temperature and humidity for people in typical summer and winter clothing during primarily sedentary activity.)

The upper and lower humidity levels of the comfort zones are less precise. Low humidity can lead to drying of the skin and mucous surfaces. Comfort complaints about dry nose, throat, eyes, and skin occur in low-humidity conditions, typically when the dew point is less than 0°C. Liviana et al. (1988) found eye discomfort increased with time in low-humidity environments (dew point < 2°C). Green (1982) quantified that respiratory illness and absenteeism increase in winter with decreasing humidity and found that any increase in humidity from very low levels decreased absenteeism in winter. In compliance with these and other discomfort observations, ASHRAE Standard 55 recommends that the dew-point temperature of occupied spaces be not less than 2°C.

At high humidity levels, too much skin moisture tends to increase discomfort (Gagge 1937, Berglund and Cunningham 1986), particularly skin moisture that is physiological in origin (water diffusion and perspiration). At high humidity levels, thermal sensation alone is not a reliable predictor of thermal comfort (Tanabe et al. 1987). The discomfort appears to be due to the feeling of the moisture itself, increased friction between skin and clothing with skin moisture (Gwosdow et al. 1986), and other factors. To prevent warm discomfort, Nevins et al. (1975) recommended that on the warm side of the comfort zone the relative humidity not exceed 60%.

The upper humidity limits of ASHRAE *Standard* 55 were developed theoretically from limited data. However, thermal acceptability data gathered at medium and high humidity levels at summer comfort temperatures with subjects wearing 0.55 clo corroborated the shape of the upper limit and found it corresponded to an 80% thermal acceptability level (Berglund 1995).

2.2 Simplified (Graphical) Method

Provided the air speed imposed on the occupants does not exceed 0.20 m/s (40 ft/min), a space designed to maintain conditions within the seasonal envelope shown in Figure 5, above, will correspond to Class B thermal environments defined in Table 1. These envelopes are for 80% occupant acceptability, based on a 10% dissatisfaction criteria for general (whole body) thermal comfort based on the PMV-PPD index, plus an additional average 10% dissatisfaction which may occur from local thermal discomfort.

2.3 Computer Model Method

Thermal comfort and thermal sensation can be predicted by using the Predicted Mean Vote (PMV) – Predicted Percentage of People Dissatisfied (PPD) and two-node models developed by Fanger and others. Computer code for calculating PMV-PPD is provided in Standard 55 and Standard 7730.

The PMV index predicts the mean response of a large group of people according to the ASHRAE thermal sensation scale. Fanger (1970) related PMV to the imbalance between the actual heat flow from the body in a given environment and the heat flow required for optimum comfort at the specified activity.

After estimating the PMV with Fanger's method or another method, the predicted percent dissatisfied (PPD) with a condition can also be estimated, as shown in Figure 13. A PPD of 10% corresponds to the PMV range of ±0.5, and even with PMV = 0, about 5% of the people are dissatisfied.

The PMV-PPD model is widely used and accepted for design and field assessment of comfort conditions. ISO Standard 7730 includes a short computer listing that facilitates computing PMV and PPD for a wide range of parameters.

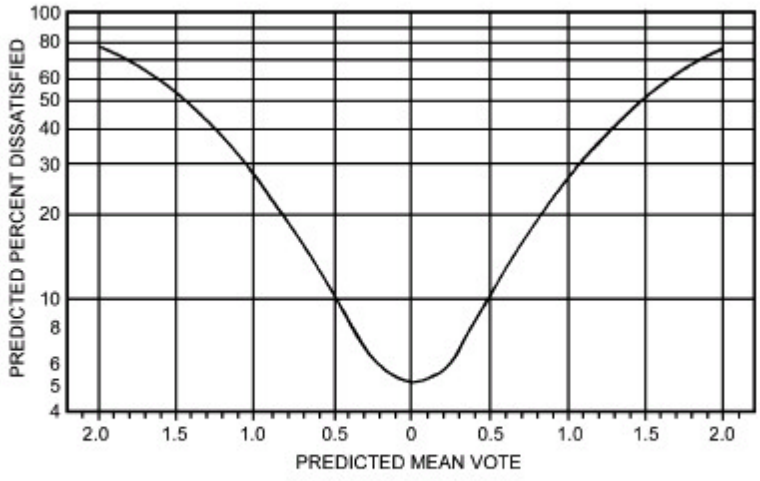


Fig. 13 Predicted Percentage of Dissatisfied (PPD) as Function of Predicted Mean Vote (PMV)

The comfort zone is defined by combinations of air temperature and mean radiant temperature for which the PMV is within the limits specified in Table 1. The PMV model is run with the air temperature and mean radiant temperature in question along with the applicable metabolic rate, clothing insulation, air speed, and humidity. If the resulting PMV value generated by the model is within the range allowed by Table 1, the conditions are within the comfort zone.

3.0 Application

3.1Local Thermal Discomfort

Table 2 specifies the expected PPD associated with each class of thermal environment for each source of thermal discomfort. The user must specify the class. The criteria for all sources of local thermal discomfort must be met simultaneously at the levels specified for an environment to meet all the requirements of that class.

Table 2: Percentage of Dissatisfied Due to Local Discomfort from Various Sources for Different Classes of Thermal Environment

Comfort Class	PPD Due to Draft	PPD Due to Vertical Air Temperature Difference	PPD Due to Warm or Cool Floors, or Warmed or Cool Buildings	PPD Due to Radiant Asymmetry
A	< 10	< 3	< 10	< 5
B	< 20	< 5	< 10	< 5
C	< 20	< 10	< 15	< 10

3.2 Radiant Temperature Asymmetry

The thermal radiation field about the body may be non-uniform due to the hot and cold surfaces and direct sunlight. This asymmetry may cause local discomfort and reduce the acceptability of the space. In general, people are more sensitive to asymmetric radiation caused by a warm ceiling than that caused by hot and cold vertical surfaces. Figure 6 gives the percentage of dissatisfied occupants as a function of the radiant temperature asymmetry caused by a warm ceiling, a cold wall, a cool ceiling, or a warm wall.

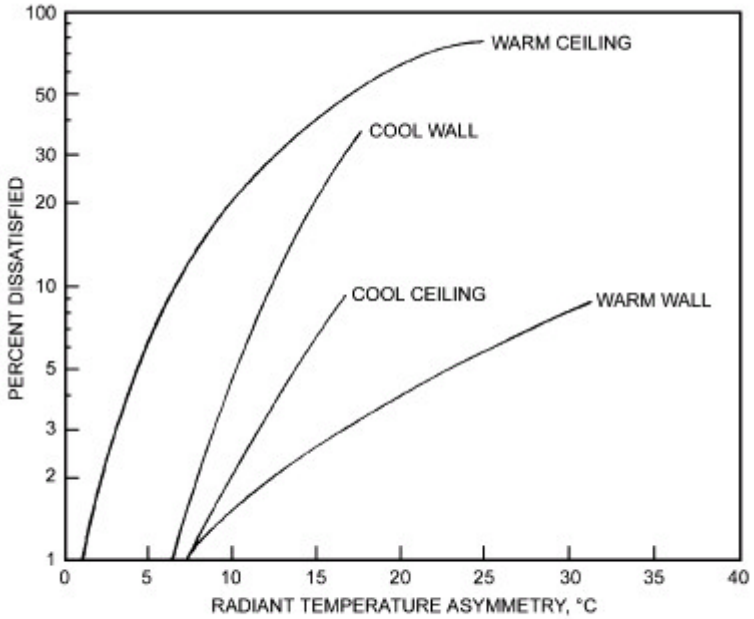


Fig. 6 Percentage of People Expressing Discomfort due to Asymmetric Radiation

The limits for radiant temperature asymmetry are specified in Table 3. Alternatively, Figure 6 may be used in conjunction with the PPD limits from Table 2 to determine the allowable radiant asymmetry.

Table 3: Allowable radiant temperature Asymmetry for the Three Classes of Thermal Environment

	Radiant Temperature Asymmetry, ^{0}C			
Comfort Class	Warm Ceiling	Cool Wall	Cool Ceiling	Warm Wall
A	< 5	< 10	< 14	< 23
B	< 5	< 10	< 14	< 23
C	< 7	< 13	< 18	< 35

3.3 Draft

Draft is the unwanted cooling of the body caused by air movement. The sensation depends on the air speed, the air temperature, the turbulence intensity, the activity,and the clothing. Sensitivity to draft is specially the greatest where the skin is not covered by clothing, especially the head region, and the leg region. These requirements are based on sensitivity to draft in the head region with airflow from behind.

Figures 7 shows the PPD as a function of mean air velocity at various temperatures. Figure 8 shows draft conditions which result in dissatisfying 15% of occupants at various turbulence intensities. On average, the turbulence intensity in a large part of the occupied zone of rooms with mixing ventilation is around 35%, and in rooms with displacement ventilation around 20%.

The values of PPD predicted must be within the limits specified in Table 2 for the selected Class.

3.4 Vertical Air Temperature Difference

This section specifies allowable differences between the air temperature at the head level and at the ankle level.

Figure 9 shows the relationship between PPD and vertical air temperature difference.

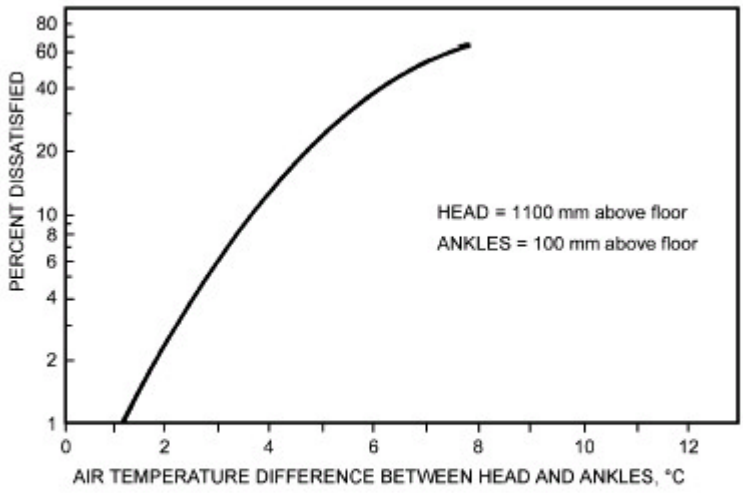


Fig. 9 Percentage of Seated People Dissatisfied as Function of Air Temperature Difference Between Head and Ankles

The allowable vertical air temperature difference can be determined from Table 2 in conjunction with Figure 9, or may be determined from Table 4.

Table 4: Allowable Vertical Air Temperature Difference for the Three Classes of Thermal Environment

Comfort Class	Vertical Air Temperature Difference, ^{0}C
A	< 2
B	< 3
C	< 4

3.5 Floor Surface Temperature

The temperature of the floor is the most important factor for foot thermal comfort for people wearing shoes. Figure 10 shows the relationship between the PPD and the floor temperature.

The allowable floor temperature limits can be determined from Table 2 in conjunction with Figure 10, or may be determined from Table 5.

Table 5: Allowable Range of the Floor Temperature for the Three Classes of Thermal Environment

Comfort Class	Range of Surface Temperature of the Floor, ^{0}C
A	19 - 29
B	19 - 29
C	17 - 31

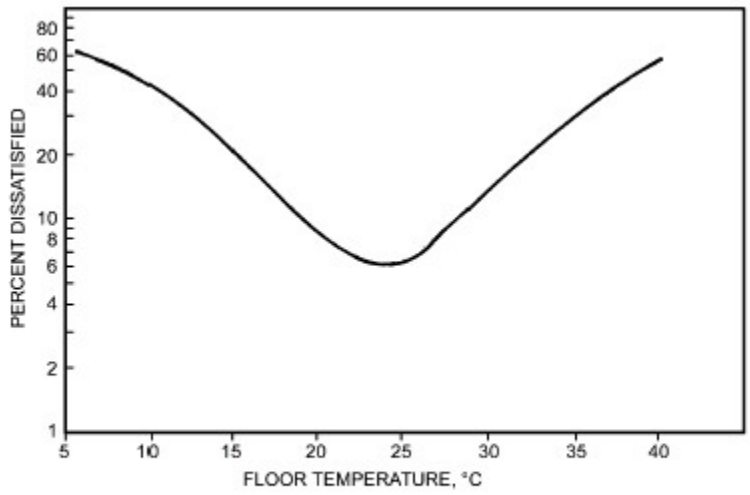


Fig. 10 Percentage of People Dissatisfied as Function of Floor Temperature

3.6 Temperature Variations with Time

Fluctuations in the air temperature and/or mean radiant temperature, not under the direct control of the individual occupant, may affect their thermal comfort.

Cyclic Variations: refers to those situations where the operative temperature repeatedly rises and falls and the period is less than 15 minutes. Table 6 specifies the maximum allowable peak-to-peak cyclic variation in operative temperature for each class of thermal environment.

Table 6: Allowable Cyclic Operative Temperature Variation

Comfort Class	Allowable Peak-to-Peak Variation in Operative Temperature, ^{0}C
A	0.8
B	1.1
C	1.4

Drifts or Ramps: refers to monotonic, non-cyclic changes in operative temperature. Generally, drifts refer to passive temperature changes of the enclosed space, and ramps refer to actively controlled temperature changes. The requirements are the same for both.

The rate of change in operative temperature during drifts or ramps may not exceed 0.6^{0}C/hr. Drifts or ramps are allowed without further restrictions provided that the operative temperature does not go above or below the comfort zone limits. However, the operative temperature may go above or below the comfort zone limits during a drift or ramp provided the drift or ramp starts inside the comfort zone at an operative temperature at least 0.6^{0}C away from the limit that is exceeded, the maximum rate of change in operative temperature does not exceed 0.6^{0}C/hr, and the limits of the comfort zone are not exceeded for more than 1.0 hour.

4. Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces

For this purpose, naturally conditioned spaces are those spaces whereby the thermal conditions of the space are regulated primarily by the occupants through opening and closing of the windows.

Field experiments have shown that occupants' thermal responses in such spaces depends in part on the outdoor climate, and differs from thermal responses in buildings with centralized HVAC systems primarily because of the different thermal experiences, availability of control, and shifts of occupant expectations.

In order for this method to apply, the space in question must meet the following criteria:

- Space must be equipped with operable windows which open to the outdoors and which can be readily opened and adjusted by the occupants of the space
- Space must have no mechanical cooling system for the space (i.e. refrigerated cooling, radiant cooling, or dessicant cooling)
- Space may have mechanical ventilation with unconditioned air, but operable windows must be the primary means of regulating conditions in the space
- Space may be provided with a heating system but this optional methods does not apply when the heating system is in operation
- Occupants must be engaged in sedentary physical activities
- Occupants must be permitted to freely adapt their clothing to the indoor and/or outdoor thermal conditions.

To meet this requirement for a PPD or 80%, the indoor operative temperature must be maintained between 31.5^0C and 17.5^0C during periods when the mean monthly outdoor temperature ranges from 10.0^0C to 33.5^0C.

No humidity or air speed limits are required when this method is used.

References

1. ANSI/ASHRAE Standard 55-1992R – "Thermal Environmental Conditions for Thermal Occupancy" (First Public Review Draft, February, 2001.

2. ASHRAE Handbook of Fundamentals, 2001, Chapter 8, "Thermal Comfort"

Consistent Documents

1. ISO Standard 7730