Client Report :

BRE Subcontract: Assessment of Sustainability Tools

Report number 15961

Prepared for :

Professor Horner
c/o University of Dundee
EPSRC

July 2004

Prepared on behalf of BRE by

Signature	
Name	Martin McCreadie
Position	Consultant
Date	

Approved on behalf of BRE

Signature	
Name	Dr Stephen L Garvin
Position	Construction Director
Date	

BRE
Kelvin Road
EAST KILBRIDE
Glasgow
G75 0RZ
Tel : 01355 576200
Fax : 01355 576210

Email : east kilbride@bre.co.uk
Website : www.bre.co.uk

Contents

Executive Summary

The SUE MoT project is part of the EPSRC's Sustainable Urban Environment research programme. SUE MoT is seeking to develop the concept of sustainability tools and to research their use in order to provide a more sustainable framework for urban development.

BRE has supported the proposal since its inception at a EPSRC workshop in Solihull in November 2001. At the project Management Executive Meeting of 26 September 2003 BRE was invited to submit a proposal for a work package to assist the project consortium achieve the scoping studies objectives. The award of a subcontract to BRE was to add value to the work of the consortium and assist in the development of the full implementation stage of the research.

The aim of the subcontract was to identify existing toolkits, metrics and models and catalogue their characteristics in a database. The tools will concentrate mainly on the environmental issues, but will where relevant take account of the economic and social aspects. The specific objectives were as follows:

- To determine suitable criteria against which to validate the available sustainability tools for the built environment.
- To evaluate a number of the sustainability tools (i.e. metrics, models and toolkits) for the urban environment.

The methodology employed to undertake the evaluation of tools involved the following:

- Development of a framework from which to evaluate the tools, this included pre-evaluation criteria and full evaluation criteria.
- Identification of suitable tools for pre and full evaluation.

The pre-evaluation resulted in 41 tools being proposed for full evaluation. From these 41 tools sufficient information could be sourced to carry out a full evaluation of 25 tools.

The following points are concluded from the work undertaken:

- The tools fell into the categories of urban planning, design, rating systems (for buildings), LCA tools and infrastructure. Of these the most developed as sustainability tools are urban planning and rating systems. The LCA tools determine particular aspects of sustainability, but are not holistic in their approach. The design tools are generally specific to energy issues and this is the case for other tools of this type that were not fully evaluated.

- All the tools contained environmental dimension and themes, most of the tools also contained either social and/or economic dimensions.
- The input data and associated databases are essential issues with regard to obtaining relevant and defensible results. The tools should however be flexible enough to take into account technical or legislative issues that affect the outcome.
- None of the tools evaluated was truly holistic with regard to the coverage of the three dimensions and the set out themes. However, the amount of coverage varied considerably between the tools.
- The stakeholders varied between the different categories. In each categories there was definable users, end-users and those affected by the sustainability assessment made.

The recommendations for further work are based upon the future issues identified in the discussion of section 3.7. The following points summarise the research needs and gaps to be filled:

- Definition and Scope – in order to define what is a sustainability tool, and how different types can be differentiated.
- Standards and Frameworks - The development of a standard would also allow stakeholders to determine when they had a sustainability tool and when a tool was intended for a more limited use. A standard would set the framework for sustainability tools. The standard itself would not be a 'sustainability tool', but would dictate what is required for such a tool.
- Input and Output Data - Further research will be required in order to determine how best to use and manage databases of information with sustainability tools.
- Communication to Stakeholders - Issues of communication and consistency of reporting are essential and there is a need for a minimum standard in communication.
- Policy, Legislation and Regulation - At present regulation has been unable to meet the whole issue of sustainability. The use of sustainability tools is a possible route towards meeting government policy on sustainable development.

1 Introduction

1.1 SUE MoT

The SUE MoT project is part of the EPSRC's Sustainable Urban Environment research programme. At present the project is at the scoping stage and background reviews are on-going with regard to sustainability tools and their development.

SUE MoT is seeking to develop the concept of sustainability tools and to research their use in order to provide a more sustainable framework for urban development.

1.2 Background

A consortium of Dundee, Glasgow Caledonian and Loughborough Universities is undertaking a scoping study into Metrics, Models and Toolkits for Whole Life Sustainable Urban Development. The study is being funded by EPSRC under the Sustainable Urban Environment (SUE) programme.

BRE has supported the proposal since its inception at a EPSRC workshop in Solihull in November 2001. BRE has assisted in the development of the proposal and added value with our industrial experience and research interests. BRE is nominated as a subcontracting to the project and will seek to further the study relevant to metrics, models and toolkits used in construction and urban development.

At the project Management Executive Meeting of 26 September 2003 BRE was invited to submit a proposal for a work package to assist the project consortium achieve the scoping studies objectives. The award of a subcontract to BRE was to add value to the work of the consortium and assist in the development of the full implementation stage of the research.

1.3 Aims and Objectives

The aim of the subcontract was to identify existing toolkits, metrics and models and catalogue their characteristics in a database. The tools will concentrate mainly on the environmental issues, but will where relevant take account of the economic and social aspects. The specific objectives were as follows:

- To determine suitable criteria against which to validate the available sustainability tools for the built environment.
- To evaluate a number of the sustainability tools (i.e. metrics, models and toolkits) for the urban environment.

2 Methodology

The methodology employed to undertake the evaluation of tools involved the following:

- Development of a framework from which to evaluate the tools, this included pre-evaluation criteria and full evaluation criteria.
- Identification of suitable tools for pre and full evaluation.

The identification of tools and development of the framework was carried out between BRE and Glasgow Caledonian University. Appendix 1 contains a copy of the evaluation spreadsheet that was developed for the project.

GCU and colleagues from Dundee and Loughborough Universities had undertaken as part of the research an extensive literature review of sustainability tools. This review identified in excess of 600 tools that measured or evaluated in some way the environmental, economic or social dimensions of sustainability. Some of the tools identified contained all three dimensions whilst others had one or two. The tools were relevant to a number of aspects of sustainability such as urban planning, design or building performance. The tools were relevant to one or more phases of the life cycle of a building or urban development. The type of tools varied and were represented in different categories. Project level tools were included that looked at specific building performance issues such as energy performance, whilst others considered the life cycle of a building or development. Whilst these tools are not mutually exclusive in their coverage of environmental or other issues, there can be differences in the use and users of such tools.

BRE had been subcontracted to assess the predominantly environmental tools. A total of 147 tools were identified for pre-evaluation. These were identified from the available literature as being potentially environmental based and relevant to one or more aspect of urban sustainability.

The pre-evaluation resulted in 41 tools being proposed for full evaluation, see Appendix 2. From these 41 tools sufficient information could be sourced to carry out a full evaluation, using the spreadsheet in Appendix 1, of 25 tools.

Table 1 shows the tools that were subject to full evaluation. These tools fitted into the categories of urban planning tools, design tools, building environmental frameworks and rating systems, LCA based and infrastructure. The full evaluation required full working models to be made available to BRE. This was a resource intensive exercise to source the relevant information. In some cases information was available by downloading the tool from the internet, however, in other cases it was necessary to obtain information from the tool owner. In some cases this was a lengthy process of negotiation.

The tools that were available for full evaluation differed in the depth of information that was available and the degree of complexity involved in the tools. In some cases the task of evaluating the tools was time consuming often involving days to complete.

The full evaluation process involved the following tasks:

- To review the available information on the tool.
- To complete the spreadsheet with respect to the tool background.
- To complete the evaluation of the tool characteristics.
- To complete the evaluation of the tool's environmental coverage.
- To complete the evaluation of the tool's economic coverage.
- To complete the evaluation of the tool's social coverage.

The evaluations were all carried out using the spreadsheets of Appendix 1. A database of the completed evaluations on spreadsheets is given in Part 2 of this report (a summary spreadsheet is also included).

The themes covered and the sub-themes in the full evaluation include the following:

- Tool background – name, source, date of availability, description, type, role, objectives, spatial dimension, geographic specificity, time scale, sustainability dimension, life cycle phase covered, component methodologies, data requirements (qualitative and/or quantitative), stakeholders considered by tool, stakeholders involved in the tool use, user, usability, costs, output, benchmarks and targets, post decision assessment, legislation.
- Tool characteristics – flexibility, upgrading, compatibility, aggregation/disaggregation, holistic, multidimensional, inclusive, scaleable.
- Environmental themes – support, energy, transport, water, materials, land use, ecology, pollution, environmental quality, sustainability criteria.
- Economic themes – viability, competition, employment and skills, transport, social benefits and costs, design.
- Social themes – social inclusion and equality, safety and security, health and comfort, liveability, employee satisfaction, corporate social responsibility, quality of life.

For each sub-theme there is a range of sub themes that are completed based on the available information and the available copies of each tool.

Tool Type	Sustainability Dimensions	User Country
Urban Planning Tools		
1. BRE Sustainability Checklist	3	U.K.
2. Community Sustainability Assessment	3	International
3. SPARTACUS	3	European
4. SEEDA Sustainability checklist	3	U.K.
5. SCALDS	2	U.S.A.
6. CITY Green	2	U.S.A.
7. PLACE3S	2	U.K.
Design Tools		
8. ECOTECT	1	Australia
9. DOE 2.2	1	U.S.
10. Building Design Advisor	1	U.S.A.
Building Environmental Frameworks and Rating Systems (Building)		
11. GBTool	3	International
12. LEED	3	U.S.A.
13. SPeAR	3	U.K.
14. Minnesota Sustainable Design Guide	3	U.S.A.
15. EcoCal	1	U.K.
16. BREEAM	1	U.K.
17. HK-BEAM	1	Hong-Kong
Assessment Tools: LCA Approach (Building)		
18. ENVEST	2	U.K.
19. BRE Environmental Profiles	2	U.K.
20. ATHENA	1	Canada

21. Boustead	1	U.K.
22. GaBi 4	1	Germany
23. TEAM	1	International
24. EcoPro	1	Germany
Infrastructure Tools		
25. CEEQUAL	2	U.K.

Table 1: List of tools for full evaluation by BRE

3 Findings and Discussion

3.1 The Tool Landscape

The evaluated tools are detailed in Appendix 2 of this report. This section contains a snapshot of the tools. The tools are summarised under the headings urban planning tools, design tools, building environmental frameworks and rating systems, LCA based and infrastructure. Appendix 3 provides a series of tables that summarise the results of the assessments and the results given in this section.

3.1.1 Urban Planning Tools

BRE sustainability checklist

This guide enables developers, planning authorities and their advisors to specify and assess the sustainability attributes of their developments. Described as a series of straightforward steps that can be followed to incorporate sustainability into developments, it reflects the latest guidance on sustainability. Wherever possible, the checklist uses existing systems and standards to define performance, such as 'BREEAM' (BRE's environmental assessment method), EcoHomes (the homes version) and 'Secured by Design'. It considers the environmental, social and economic aspects of sustainability under the following eight broad headings:

- Land use, urban form and design
- Transport
- Energy
- Impact of individual buildings
- Natural resources
- Ecology
- Community issues
- Business issues.

The guide was developed in partnership with local authorities (including Leicester City Council, Newcastle City Council, Watford Council and Hertfordshire County Council), English Partnerships, Nightingale Associates, West of Stevenage Development Consortium, Surrey University, Living Villages Trust and Llewellyn Davies, and was sponsored by DTI/DETR.

Community sustainability assessment

The Community Sustainability Assessment is a comprehensive checklist that anyone can complete to get a basic idea of how sustainable their community is. This assessment tool is applicable to any community. While it requires good knowledge of the life-styles, practices and features of the community, it does not require research, calculation and detailed quantification.

SPARTACUS

SPARTACUS is a method for assessing sustainability implications of urban land use and transport policies. The core of the systems is a computerised land use transport interaction model, MEPLAN. MEPLAN can be used to analyse the impacts of e.g. transport investment, regulatory, pricing or planning policies on e.g. overall mobility, modal split, journey times, movements of households and jobs and production costs of firms. The SPARTACUS method builds on the results of the model to calculate values for sustainability indicators. Sustainability is understood as consisting of environmental and social sustainability and economic efficiency. The environmental and social indicators are aggregated into indices using user-given indicator-specific weights and value functions. The social indicators include a set of justice indicators which assess the justice of the distributions of certain impacts among socio-economic groups. The methodology is being further developed in the PROPOLIS project.

SEEDA sustainability checklist

The Checklist is a tool which allows the sustainability aspects of a development to be addressed, and for reviewing organisations such as local authorities, SEEDA and Government Office of the South East (GO-SE) to understand the level of performance that might be achieved. It may also be used by developers to demonstrate the sustainability credentials of their development. The Checklist aims to form a common framework for the South East.

SCALDS

The SCALDS tool is a series of interconnected spreadsheets that estimate total costs for three accounting paths. The first cost estimation path focuses on physical employment, including local consumption, existing and projected housing mix, regional employment and local infrastructure capital and operating costs. The second accounting path estimates the annual peak and non-peak cost of travel on a passenger mile travelled (PMT) basis. The third path estimates non-dollar denominated costs such as the air pollution and energy consumption.

CITY Green

CITY green is a Windows™ based Geographical Information System (GIS). It was the first comprehensive, user-friendly attempt to make a financial case for urban forests. Based on the most up-to-date, peer-reviewed science, CITY green allows cities and conservation groups to calculate the economic and environmental benefits provided by

trees and other vegetation, and models the economic impact of various development and planning scenarios.

PLACE3S

PLACE^{3}S is an urban planning method designed to help communities establish an effective path towards sustainability. It is unique because it employs energy as a yardstick to measure the sustainability of urban design and growth management plans. Using a Btu-based accounting system, PLACE^{3}S can evaluate how efficiently we use land, provide housing and jobs, move people and materials, operate buildings and public infrastructure, site energy facilities and use other resources. PLACE^{3}S integrates public participation, planning, design and quantitative measurement into a five step process appropriate for regional and neighbourhood-scale assessments.

3.1.2 Design Tools

ECOTECT

ECOTECT is an environmental design tool which couples a 3D modelling interface with solar, thermal, lighting, acoustic and cost analysis functions. The tool is driven by the concept that environmental design principals are most effectively addressed during the conceptual stages of design. The software provides visual and analytical feedback from sketch models, progressively guiding the design process as more detailed information becomes available. The model is scaleable and can handle simple shading models to full-scale cityscapes.

DOE 2.2

DOE-2.2 is a widely used and accepted building energy analysis program that can predict the energy use and cost all types of buildings. DOE-2.2 uses a description of the building layout, constructions, usage, conditioning systems (lighting, HVAC, etc) and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills.

Building Design Advisor

The BDA approach is based on a comprehensive design theory that was developed in collaboration with the Department of Architecture at UC Berkeley. The BDA uses a single, expandable representation of the building and its context in terms of objects such as floors, walls, windows and roofs. This representation is internally mapped onto the specialised representations required by simulation tools. In this way, BDA shields building designers from the modelling complexities of the individual tools, allowing them to concentrate design decisions.

3.1.3 Building Environmental Frameworks and Rating Systems

GB tool

GBC is a hierarchical system of environmental assessment criteria for buildings developed for international comparative purposes in order to select and analyse the environmental performance and impact of buildings, initially for Green Building Challenge '98 and subsequently for the Sustainable Building 2000 conference. Three versions exist: multiunit residential buildings, office buildings and schools. In each version a comprehensive list of environmental criteria in 19 categories is addressed and scored using a weighting system.

LEED

The LEED Green Building Rating System™ is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. LEED is a self assessing system designed for rating new and existing commercial, institutional and high-rise residential buildings. It evaluates environmental performance from a "whole building" perspective over a building's life cycle, providing a definitive standard for what constitutes a "green building."

SPeAR

The Sustainable Project Appraisal Routine (SPeAR®) is based on a four-quadrant model that structures the issues of sustainability into a robust framework, from which an appraisal of performance can be undertaken. SPeAR® brings sustainability into the decision-making process with its focus on the key elements of environmental protection, social equity, economic viability and efficient use of natural resources. As such the information generated by the appraisal prompts innovative thinking and informs decision-making at all stages of design and development. This allows continual improvement in sustainability performance and assists in delivering sustainable objectives.

Minnesota Sustainable Design Guide

The Minnesota sustainable design guide is a design tool that can be used to overlay environmental issues on the design, construction, and operation of both new and renovated facilities. It can be used to set sustainable design priorities and goals; develop appropriate sustainable design strategies for a particular project; and to determine performance measures to guide the design and decision-making process. It can also be used as a management tool to organize and structure environmental concerns during design, construction, and operations phases. The design guide builds on other design guides and rating systems, including LEED, Green Building Challenge '98, and BREEAM.

EcoCal

EcoCal® is used to find the environmental impact of your household. The result is measured in eco-calories. Dials are used to compare households with similar households. On the dials Green is good, Amber is average and Red means that there is a lot more environmental action that the householder can take. The EcoCal questions

are divided into seven activity areas. 1. Transport, 2. Water, 3. House and Garden, 4. Community Action, 5. Energy, 6. Shopping and 7. Waste.

BREEAM

BREEAM provides a broad ranging assessment of the environmental impact of a building. Issues covered include those relating to the global, local and internal environments. BREEAM relates to design stage assessments (i.e. new build and refurbishment) and relates to the ongoing operation and management of the building. Assessors operating under license from BRE carry out the assessments.

HK-BEAM

The HK-BEAM scheme was established in 1996 with the issue of two assessment methods, one for 'new' and one for 'existing' office buildings. Environmental issues were categorised under 'global', 'local' and 'indoor' impacts, respectively. In 1999 the 'office' versions were re-issued with minor revisions and updated references, together with an entirely new assessment method for new high-rise residential buildings. Both Version 4/03 covering 'new building developments' and Version 5/03 for 'existing building developments' represent significant upgrades to the previous HK-BEAM documents. Besides broadening the types of building developments that can be assessed these versions of HK-BEAM take into account recent developments, both locally and internationally, in respect of so-called 'green buildings' techniques and practises. In HK-BEAM 4/03 environmental aspects are grouped within a general framework similar to other schemes in use worldwide.

3.1.4 Assessment Tools: LCA Approach

ENVEST

A lifecycle assessment approach for the construction of new buildings.

BRE environmental Profiles

Environmental Profiles are a method of gathering and presenting environmental data to compare the environmental performance of building materials. They enable architects, specifiers and clients to make informed decisions about construction materials and components, by providing a method for independent, 'level playing field' information about the relative environmental impacts of different design options.

ATHENA

Athena is an easy to use, computer modelled LCA decision tool which was developed in Canada. The tool can stand alone or can fit within an assessment framework such as Green Building Challenge (GBC). It is essentially a tool that can be used by designers to gain an environmental profile of a building allowing side-by-side comparisons of alternative building designs or efficient material use, without going through the rigorous LCA process. This essentially is used to reduce the buildings life-cycle environment impact.

Bousted

The Boustead Model is a self-contained database and software application, which enables the user to construct full life-cycle inventories for virtually any process situated anywhere in the world. The database that accompanies the application is the largest, open, fully-editable inventory database that is commercially available

GaBi 4

Software System for Life Cycle Engineering developed by the Institute for Polymer Testing and Science at the University of Stuttgart in cooperation with PE Europe GmbH. The GaBi 4 software is one of the leading experts systems for balancing complex and data-intensive process networks. Parallel analysis of environmental problems in product life cycles according to DIN ISO 14040 ff. and the optimization of production sequences from an economic point of view is ensured thanks to the thoroughly developed functionality of the GaBi 4 software package. GaBi 4 includes approximately 650 sets of data (cradle to gate), generated by IKP/PE. This data is based on information from patent/specialist literature and industry. These data sets include the decisive areas of the pre-chains to metals (steel, aluminium and non-ferrous metals), organic and non-organic pre-products, synthetics, mineral materials, provision of energy (steam, thermal energy, electricity mixes and power stations), end of life and disposal and processing.

TEAM

TEAM for building enables the user to perform the environmental evaluation of a building, based on the Life Cycle Assessment methodology. It is a flexible tool which allows the user to select the level of details for the building description, the life cycle stages under study as well as the environmental impact indicators kept for the environmental impact indicators kept for the environmental evaluation.

EcoPro

Ecopro is a calculation tool to optimise the material mass, energy-flows and the costs during an early planning process. Basics are the element method and the life cycle analysis. It serves actors with information on the environmental impacts of buildings during the whole life cycle. It is possible to compare four buildings at the same time with different criteria.

3.1.5 Infrastructure Tools

CEEQUAL

The Civil Engineering Environmental Quality Award Scheme is an assessment and awards scheme for publicly rewarding high environmental quality of civil engineering projects. It builds on current guidance and environmental good practice in construction and supports UK Government strategy by providing the civil engineering industry with an incentive and protocol for assessing, benchmarking and labelling the environmental quality of its projects as part of their contribution to sustainable construction. Four types of award are available; · Whole project award - for a joint application by the client,

designer and principal contractor, · Design and build award - for partnership contract teams, · Design award - for principal designers only, · Construction process award - for principal contractors only.

The assessed tools fall into the five broad categories set out previously. Three of the categories, urban planning, rating systems and LCA approach contained seven tools each. There were three design tools and one infrastructure tool. The tools range in their type and nature requiring in some cases qualitative and in other cases quantitative measures of sustainability.

It is noticeable that some tools have been in existence for a number of years such as BREEAM and HK-BEAM and there has been a growing acceptance and use of these tools. Other tools have been developed as checklists of sustainability, a checklist approach is simplistic and can assist the user to cover a whole range of sustainability issues.

Each tool has been developed for specific purposes, some considering specific issues such as energy use and others the whole range of sustainability themes. It is noticeable that the recent tools, e.g. the sustainability checklist and SEEDA checklist, have been driven by non governmental organisations for specific purposes, whereas the earlier tools were developed within research projects and rolled out as outputs from the research.

The development of tools is recognised as an important issue. The assessed tools have generally allowed for development as a result of changes in legislation or technological advances.

3.2 Stakeholders

3.2.1 Urban Planning Tools

The range of stakeholders involved in the use of these tools includes government (central and local), developers and the local community. The evaluations consider both those considered and those using the tools.

The issue of those considered by the tools is perhaps more complex than those using the tools. In the case of government they are likely to be both a user and a considered party, i.e. how does a planning issue meet local or central government policy. Those tools that are used by planners in government will consider the needs of end users (the public mainly) and developers. However, they will be driven by the need to meet local and national policy objectives.

Only one tool (Community Sustainability Assessment) has been developed for local communities themselves, it is a self assessment tool. It has been developed to be simplistic in its approach to data gathering and entry.

Those tools targeted at developers are primarily to allow them to make an assessment of the impact of their development, this may help them to meet the needs of government and understand planning restrictions.

3.2.2 Design Tools

The three design tools evaluated are primarily for the use of building professionals in order to achieve more sustainable buildings through design. The emphasis is on the ability to design a building for better energy efficiency or other environmental theme.

All three tools consider solely environmental issues, mainly energy related. The tools are not directly related to compliance with standards or building regulations. However, in at least one case government is a stakeholder and may seek compliance with local energy regulations through the use of the tool.

3.2.3 Rating Systems

The majority of the rating system tools are used by consultants and building professionals in order to determine the 'green' credentials of a building. The users tend to be the developer or building owner, who is looking to have a building that has low impact on the environment. Only one tool (EcoCal) has been designed for non-expert use such as by and for end users and local communities.

End users are taken into account in the other tools that are used by professionals, especially where social impacts are concerned. However, tools such as BREEAM have been developed for developers to demonstrate the environment credentials of their building.

This set of tools has not been developed as design guidance, however, there is increasing interest in using these rating tools to guide design. Their accredited use is in rating the sustainability performance of new or existing buildings.

3.2.4 LCA Tools

The LCA tools have a common theme in the users and those considered by the tools. Most tools are used by professional advisors, developers and architects in order to determine the preferred environmental choices of materials, designs or building systems (e.g. services).

Materials, component and system producers are important stakeholders in LCA tools. The outcome of tools will directly affect specification options and may disadvantage some types of materials or systems. It is important that these tools are flexible enough or updateable to reflect manufacturing advances and changes in production of components.

The local community and end users are also stakeholders in LCA tools. However, there are no tools that are directly related to these groups.

3.2.5 Infrastructure

The one tool in this category has been developed in order to provide the basis of judging the sustainability of civil engineering projects. It has a range of stakeholders, but those using the outcome of the tool are designers, contractors and developers (private and public). The scheme allows projects to be rated for public scrutiny and awards. This tool is rather unique amongst the tools evaluated.

3.3 Characteristics of Available Tools

The characteristics of the sustainability tools have been reviewed. This section provides the characteristics of the tools in a summarised form, the detail being provided in the Appendices.

The characteristics and their definitions are as follows:

- Flexibility – this refers to the adaptability of the tools to be used or changed at different times in the life cycle of an urban development. Flexibility also covers some measure of user control in the process of the assessment.
- Upgrading – the ability to upgrade the tool over time to take account of changes to legislation, regulation, technology or scientific understanding.
- Compatibility – the use that the tool makes of output from other tools as input data, or indeed the potential to make use of data from the tool to input into others.
- Aggregation / Disaggregation – does the tool allow scores for individual issues to be aggregated into an overall score or rating. Can the overall rating be broken down.
- Holistic – does the tool cover the whole range or just some of the sustainability phases; ten phases are described (feasibility, conception, scheme, detailed, manufacturing, construction, operation, maintenance, decommissioning demolition and decommissioning disposal).
- Multidimensional – does the tool cover the three dimensions or less of sustainability, environmental, economic and social..
- Inclusive – the range of stakeholders covered by the tool, including input and output.
- Scaleable – is the tool applicable over a number of spatial scales; can it be applied to a building and an urban region, is it applicable over a number of timescales.

3.3.1 Urban Planning Tools

The tool characteristics considered are as follows:

- Flexibility – the majority of tools are not flexible. The main reason for the lack of flexibility is in the context within which the tool is used. The tools are generally fixed to for example planning issues. As the process moves forward the issues covered by the tool cease to be as relevant. It is difficult to determine how such tools could be made more flexible. Those that are based on checklists perhaps have the greatest potential for increasing the flexibility of their approach.

- Upgrading – the majority of these tools have the potential to be upgraded as a result of technical or legislative changes.

- Compatibility – the checklists have the most compatibility with other tools. Indeed, a checklist may direct the user to a calculation or rating based tool at some point. Other tools seem to be less compatible as they are used to rate particular planning issues.

- Aggregation / Disaggregation – Only one tool that is based on a GIS model had no information on these characteristics. The others all had elements of both aggregation and disaggregation. However, the tools vary in their relevance to aggregation. The checklists lend themselves to a certain amount of aggregation, however, they also do not necessarily add up 'scores'.

- Holistic – In general the number of identified phases covered is in the region of 3 or 4, one tool covered 7 phases.

- Multidimensional – The tools vary in their coverage of the sustainability dimensions. The results for each is given earlier in table 1.

- Inclusive – None of the tools consider all identified stakeholders in the evaluation. This is not surprising as tools are developed generally for specific groups of stakeholders, especially planners and developers in this category. Typically three to seven stakeholders are covered by these planning tools.

- Scaleable – This refers to spatial, time and building or urban environment. None of the tools cover all scaleable dimensions. However, there is significant difference in the range of scaleable issues covered, perhaps reflecting the development of the tool and the use to which it is put.

3.3.2 Design Tools

- Flexibility – the majority of tools are flexible. Although they are used in the design stage there is no reason why they cannot be used to assess later design changes or aspects of a completed building.

- Upgrading – there was no information found for any of the tools on upgrading, however, different versions are available indicating the relevant upgrading has taken place.

- Compatibility – the output from the tools can be used with other sustainability tools.
- Aggregation / Disaggregation – None of the tools had any information on this aspect.
- Holistic – The tools covered only two to four aspects of the life cycle of the building, most relevantly the operational phase.
- Multidimensional – The results for each is given earlier in table 1, all three tools covered the environmental dimension only.
- Inclusive – None of the tools consider all identified stakeholders in the evaluation. The design tools stakeholders are consultants, designers and developers/owners. The end users and government may also be involved.
- Scaleable – Each tool is restricted in the scales that it covers, generally concerning only with building performance.

3.3.3 Rating Systems

- Flexibility – the majority of tools are flexible and can be used at various times in the lifetime of a building. Tools such as BREEAM and HK-BEAM that include assessment by third parties are intended to be assessed only at specific times. However, the framework offered by these systems can still be used by designers to guide their project development. In HK-BEAM there is room for the design team to change the design and achieve a higher rating. Other tools are more flexible and can be used throughout the design, construction or operation of a building.
- Upgrading – the majority of these tools have the potential to be upgraded as a result of technical or legislative changes.
- Compatibility – most of the tools had a degree of compatibility with other tools. Indeed, BREEAM, SPeAR, LEED and HK-BEAM can take output from other tools to enable an assessment to be made. There is therefore an interdependency between the tools.
- Aggregation / Disaggregation – A number of the tools such as BREEAm allow aggregation of scores to give an overall rating. However, others such as HK_BEAM and SPeAR do not count up the scores. The difficulty of finding the correct weightings or ranking makes this difficult. This is especially the case if more than one sustainability dimension is considered by the tool.
- Holistic – None of the tools cover all the phases of the life cycle. The maximum number considered is seven, with the minimum being four. Often issues of manufacture or demolition are not considered.
- Multidimensional – The tools vary in their coverage of the sustainability dimensions. The results for each is given earlier in table 1.

- Inclusive – None of the tools consider all identified stakeholders in the evaluation. This is not surprising as tools are developed generally for specific groups of stakeholders, especially building owners, developers, consultants and designers. Typically three to seven stakeholders are covered by these planning tools.

- Scaleable – This refers to spatial, time and building or urban environment. None of the tools cover all scaleable dimensions. However, there is significant difference in the range of scaleable issues covered, perhaps reflecting the development of the tool and the use to which it is put.

3.3.4 LCA Tools

- Flexibility – the majority of tools are flexible and they can be used throughout the lifetime of a building or its component parts. However, most LCA tools are used to assist design decisions and will therefore be used at that time. At the same time decisions on how to refurbish buildings can use these LCA tools.

- Upgrading – the majority of these tools have the potential to be upgraded as a result of technical or legislative changes.

- Compatibility – The majority of the tools take data output from other tools and means of assessment.

- Aggregation / Disaggregation – This is not obvious in the majority of the tools. The BRE tools (ENVEST and Environmental Profiles) do have means of adding up different assessments, or aggregating for example greenhouse gas emissions. The other tools gave no real information relating to aggregation.

- Holistic – In general the number of identified phases covered is in the region of 3 or 4, one tool covered 7 phases. This is perhaps surprising for LCA tools, but issues such as demolition as opposed to disposal or recycling of demolished materials might be too subtle for the current tools.

- Multidimensional – The tools vary in their coverage of the sustainability dimensions. The results for each is given earlier in table 1; four tools cover all three dimensions and the other three only one dimension.

- Inclusive – None of the tools consider all identified stakeholders in the evaluation.

- Scaleable – This refers to spatial, time and building or urban environment. None of the tools cover all scaleable dimensions. Four tools covered timescales of more than 20 years. Although twenty years would be considered well within the lifetime of most urban developments, a minimum of 20 years would seem reasonable as a means of assessing the impact of materials specification in buildings for example. The other scaleable items are variable in their coverage, however, none of the tools covers all areas being specific to perhaps materials or a whole building.

3.3.5 Infrastructure

- Flexibility – The CEEQUAL tool evaluated is flexible.
- Upgrading – The tool can be updated.
- Compatibility – The tool is compatible with the UK government's policy on sustainability. It is also compatible with the client panels sustainability plans and tools.
- Aggregation / Disaggregation – There is no information available on this aspect.
- Holistic – The tool only covers two phases of the life cycle.
- Multidimensional – The tool covers environmental and social dimensions.
- Inclusive – Not all identified stakeholders in the evaluation are considered.
- Scaleable – The tool does not cover all spatial, product or time scales.

3.4 Data Issues

3.4.1 Urban Planning Tools

The tools require different requirements for data input. In some cases they are entirely based on qualitative information requirements, whilst in others there is a mix of quantitative and qualitative information required.

The Community Sustainability Assessment is intended for use by a whole range of stakeholders. It is an empirical method that might take two to three hours to complete. It is therefore not possible to input detailed quantitative data in this time.

The other models use varying amounts of quantitative data. The quantitative data can be described in three ways, as follows:

- Data that needs to be calculated using another computer model or calculation procedure, e.g. carbon dioxide emissions of a new urban development.
- Data that is already available such as geographic location or embodied energy of building materials.
- Data input that can be estimated from the design or a building or other form of urban development, e.g. density of housing or number of increasing car journeys.

3.4.2 Design Tools

The three design tools all requirement quantitative data input. This is generally straightforward information on design issues including building location, orientation and dimensions. It can be specific to window dimensions or service performance. However,

all tools require good data input, otherwise the results of the design modelling is not relevant to how it will work in reality.

3.4.3 Rating Systems

These tools mainly contain requirements for both quantitative and qualitative data input. The quantitative input includes issues such as energy use or water use predictions. Whilst qualitative input includes issues such as presence of certain features, e.g. recycling schemes.

One tool has (Eco-Cal) has only qualitative requirements as it is intended to be used for householders and therefore a simplistic approach is taken.

3.4.4 LCA Tools

The LCA tools all require quantitative data as input. In some cases the tools have their own in built database from which life cycle impacts can be calculated within the model. The user will pick out the necessary data themselves. In other cases data can be sourced external or from an internal database.

The output from the tools often refers a development or the use of a certain building material to its life cycle impact, e.g. tonnes of carbon dioxide over a 60 year period.

3.4.5 Infrastructure

The CEEQUAL tool has elements of both quantitative and qualitative data input. There is no hard and fast requirements on how or where the information is sourced from, however, it will be checked by an independent assessor.

3.5 Identifiable Gaps

The gaps in the tools have been identified during the assessments. The gaps vary widely depending on the type of tool and its use. The following section describe the gaps in general within each type of tool. In addition, Appendix 4 summarises the gaps by tool, plus an assessment of the development potential of each tool.

3.5.1 Urban Planning Tools

The range of tools in this category contain a range of issues that cover environmental, social and economic dimensions of sustainability. There was no one tool that covered all the issues identified in the evaluation themes and sub-themes. This is not surprising as it is evident that each tool has been developed for different purposes. CITY-Green for example covers issues of urban greening, but the range of themes covered is therefore limited.

Other tools that are based on checklists encompass a much wider range of sustainability themes and sub-themes. The identified gaps are perhaps in issues such as materials issues that are more difficult to complete when considering large scale development.

Appendix 2 contains the database of urban planning tools and the completion of the evaluations has demonstrated the breadth of coverage in the tools.

3.5.2 Design Tools

These tools are predominantly intended to address the energy use and energy use (e.g. embodied) within a building. Issues that are relevant to energy are covered, but issues such as waste and water are not covered.

The tools as far as they are designed do not have significant gaps, however, they cover only a limited range of stakeholder interests in building design.

3.5.3 Rating Systems

The rating systems are generally quite comprehensive in their coverage of environmental issues. The main issues that are not addressed are ecological impacts, some of the transport and some of the pollution issues. Most of the rating tools are intended for environmental impact, but the tool SPeAR has social and economic impacts covered to a reasonable degree.

Appendix 2 gives the database of evaluations on the ratings tools.

3.5.4 LCA Tools

The LCA tools tend to cover few of the environmental themes and sub-themes. The issues covered are related to materials use, land and pollution created. Embodied energy is also significant and is considered necessary for some of the tools.

The LCA tools are limited in their coverage across the sustainability spectrum in terms of the input data required.

3.5.5 Infrastructure

The CEEQUAL tool has a limited range of sustainability themes and few sub-themes covered. For its purposes it is sufficient as it currently stands, however, it cannot be considered a tool that could be adapted for design of auditing purposes. The tool is intended to be used with the minimum of resources and as such the use to which this tool can be put is limited.

3.6 Discussion on Database of Tools

The evaluation of the sustainability tools has been comprehensive covering the three sustainability dimensions. The tools fall into five defined categories and the proceeding findings sections describe some of the issues included with the tools.

The sustainability tools that underwent the full evaluation were not chosen at random, but there was a pre-evaluation process that took place. The tools that were ultimately evaluated give a good overview of the available tools. Ultimately, the SUE MOT

consortium is looking towards the development of tools that cover the full range of sustainability issues and the review undertaken will contribute to that aim.

The tools evaluated have been developed generally within the last ten years in response to an increasing demand from stakeholders to improve the environmental performance of buildings and urban developments. The tools have been developed in a variety of ways and for different stakeholders. This variety has shaped the particular tools, their contents and how they are run.

The majority of the evaluated sustainability tools have been developed from research projects and then either made available for general use or through a licensing arrangement. The most advanced form of commercialisation is through the BREEAM tool. This tool is now made available and maintained from BRE and is used for at least 25% of new offices developments since it was launched. BRE trains consultants to carry out the assessments and then these consultants can undertake the assessment for their clients. No other tools have this degree of voluntary use in the UK, although HK-BEAM that is similar to BREEAM is widely used in the Hong Kong property sector.

The types of tools available vary as a result of the purpose to which they are put. A number of tools are based on checklist type approaches, these are related primarily to urban planning. For such a wide ranging topic as urban planning a checklist type approach is an acceptable means of assessing potential impacts of new developments at planning stages. Other tools such as the design tools and the life cycle assessment tools provide a quantitative output based on the modelling of energy use or impact on the environment. There are a number of simplistic tools, such as Eco-Cal or CSA that allow non-expert users to assess their impact or the impact of a new development on the environment.

The type of tools available also vary in what point should they be used, for example the urban planning tools are clearly intended to assist planning, the design tools at the design stage and the rating tools before or after construction. None of the design tools is holistic in its approach concentrating instead on the particular issues of energy. The ratings tools are much more holistic in their coverage, but are not particularly intended to direct the design of a new building.

The input data is highly variable as a result of the discrete nature of the development of most of the tools and the different types of tools involved. The majority of tools have quantitative data input, but this itself differs from one tool to another. Three types of input data has been identified for the urban planning tools and they are all valid form of data to use. The sourcing of the data is important and in some cases the data originates from internal databases to the tools. Most models require input data that is sourced or calculated from the assessors own source, or is factual data such as the geographic location of a building. The quality of the input data is of particular importance to the quality of the output from the model. The models themselves must use data that is up to date reflecting changes, for example, in the manufacturing process of a building material. In the future materials such as concrete are likely to contain a higher percentage of recycled material, this should reduce its environmental impact. The sustainability tool has to be able to deal with such a change.

The output of some tools can be aggregated either into a numeric or ranking type assessment. Some of the tools acknowledge the difficulty of aggregating data as individual themes and the three dimensions of sustainable have different basis. The summation of different issues can therefore be impossible to achieve in a meaningful way.

The flexibility of the tools is acknowledged and there is a recognition that they can adapt to changes in technical and non-technical aspects. However, updating the appropriate version of the tool to reflect these changes may require a change to the training requirements for users and may have implications for the design of a building or new planning applications.

A larger number of tools were pre-evaluated and it is acknowledged that other tools have been picked up in literature reviews by the SUE MOT researchers. One of the questions posed from this study was would these other sustainability tools fill the gaps not covered by others. It is difficult to perceive that any of the tools not fully evaluated would fill the needs of a holistic sustainability tool. The tools fully evaluated can be considered state of the art for what they are individually intended to achieve.

It is clear from the evaluation exercise undertaken that there is no definition of a sustainability tool, what it should cover or when it should be undertaken, or indeed even for its purpose the stakeholders involved.

The evaluation exercise has shown that there is no set framework for the development or management of a sustainability tool. The available tools cover such a variety of issues that have been determined by the objectives of developing any particular tool. There are no standards available in the UK or other countries that dictate what should be involved in a sustainability tool.

3.7 State of the Art

The current state of the art in sustainability tools is a wide spectrum of tools intended for different purposes by different users. The first widely accepted sustainability tool is the BREEAM assessment developed by BRE in the early 1990s. This has been developed and the support network enabled over the years, training is provided and licensing of assessors is closely controlled. A number of tools have been introduced that have been based on BREEAM but extend into social and economic issues as well.

There are a whole range of tools that have limited application, most especially in the area of building design. These relate to issues such as energy use in buildings and do not cover a wide range of issues.

If the question is posed, what is a sustainability tools then there is no clear answer. It is perhaps misleading in some cases to use the term to describe a particular tool. There is a need for research and a consensus to be reached on what a sustainability tool should or could be. In the absence of a set framework or standard then there will be difficulties in comparing the output from more than one tool. This issue more than anything should

guide the development of sustainability tools and surrounding frameworks for their development.

3.8 Future Issues for Tools and Plugging the Gaps

The evaluation exercise on the sustainability tools has demonstrated a number of issues that have been discussed in the previous section. Sustainability tools are available in a range of types and for a range of purposes. It appears that there will continue to be uses for sustainability tools and that this use will in fact grow. In common with any developing field there is a need to develop both the tools and the framework within which they develop. This section discusses some of those issues and the way in which the identified gaps can be filled.

The idea of a sustainability tool has been developed for the purposes of this SUE MOT research project. It is intended to determine all aspects of the tools and to look at their future development. As has been identified the variety of tools available do a number of different things. It is not the case the all the tools evaluated address all sustainability dimensions or themes and it needs to be remembered that this is neither necessary nor desirable.

To be able to compare the output from different tools must be a positive step forward, however, this can only be achieved by putting into place appropriate items, these are discussed in this section.

3.8.1 Definition and Scope

Sustainability has been defined in various ways in the context of urban development in recent years. Definitions inevitably encompass the three dimensions of environment, society and economics. However, there is no definition of what a sustainability tool is or what its scope should contain.

By definition, a sustainability tool would be expected to include not only all three sustainability dimensions, but also all themes. However, no tool currently covers this full spectrum of sustainability. A more practical move would be to define the essential requirements for a sustainability tool and set out the scope that should be covered. Tools that did not cover the full range of identified issues should explain why they do not cover certain issues and how these should be dealt with differently.

3.8.2 Standards and Frameworks

There are no current British or International standards that cover the development of sustainability tools. This is not surprising as tools for sustainability have only recently evolved. However, the development of a standard would set the definition and scope of sustainability tools.

The development of a standard would also allow stakeholders to determine when they had a sustainability tool and when a tool was intended for a more limited use.

A standard would therefore set the framework for sustainability tools. The standard itself would not be a 'sustainability tool', but would dictate what is required for such a tool. It would also set in context the following issues:

- the data input requirements
- the use of databases of input data, their acceptability criteria and their updating
- the use of supporting tools
- the way in which a tool could be used, e.g. in planning, design, operation or as a post project evaluation. All these scenarios could be covered.
- the output data and the presentation of this data to a range of stakeholders.

Other issues would undoubtedly also develop.

The development of a standard and framework would improve consistency between the different models that is not currently obvious. The differing nature of the tools makes comparison between them difficult and could in fact be dangerous. Communication to stakeholders could also be covered by the standard.

3.8.3 Input and Output Data

The input and output data is important to the proper interrogation of the tool. Input data should as far as possible be quantitative, although there should also be room for qualitative data.

Further research will be required in order to determine how best to use and manage databases of information with sustainability tools. The range of data required for a sustainability tool is so wide ranging that there is no point in developing a database simply for the its own purposes. However, there needs to be a standard for the database and input data into the tools.

The output data and in particular the issues or aggregation and dis-aggregation requires further research. Finding a common means of summing the individual components of the sustainability tools is important. The use of the standard as described above is important in this respect.

3.8.4 Communication to Stakeholders

The evaluation of the sustainability tools has demonstrated the importance of different stakeholders. There are managers, users, end-users and others affected by the results of the sustainability tool.

Issues of communication and consistency of reporting are essential and there is a need for a minimum standard in communication. There is also the need for better understanding of the results of sustainability modelling using any particular tool.

3.8.5 Policy, Legislation and Regulation

At present sustainability is part of government and European policy related to development and the construction of buildings. The legislation is also moving in this direction. An example of this is the Building Scotland Act 2003. This Act includes reference to sustainability and that requirements could or should be set to improve the sustainability of buildings.

At present regulation has been unable to meet the whole issue of sustainability. The use of sustainability tools is a possible route towards meeting government policy on sustainable development. Providing the necessary tools allows the stakeholders to understand and act on government policy. In the absence of appropriate tools that support regulation then the whole sustainability agenda will not move forward.

4 Conclusions and Recommendations

4.1 Conclusions

BRE has carried out an evaluation of available sustainability tools for the SUE MOT Project. The sustainability tools have concentrated on the environmental dimension, however, many of those evaluated also contain social and economic dimensions.

The evaluation criteria included was developed in collaboration with GCU and involved some pre-evaluation and then the selection of a number of tools for full evaluation. A total of 25 tools went through the full evaluation, these have been described in this report. Appendix 2 contains a database of the evaluations undertaken, giving information on each of the sustainability tools.

The following points are concluded from the work undertaken:

- The tools fell into the categories of urban planning, design, rating systems (for buildings), LCA tools and infrastructure. Of these the most developed as sustainability tools are urban planning and rating systems. The LCA tools determine particular aspects of sustainability, but are not holistic in their approach. The design tools are generally specific to energy issues and this is the case for other tools of this type that were not fully evaluated.
- All the tools contained environmental dimension and themes, most of the tools also contained either social and/or economic dimensions.
- The input data and associated databases are essential issues with regard to obtaining relevant and defensible results. The tools should however be flexible enough to take into account technical or legislative issues that affect the outcome.
- None of the tools evaluated was truly holistic with regard to the coverage of the three dimensions and the set out themes. However, the amount of coverage varied considerably between the tools.
- The stakeholders varied between the different categories. In each categories there was definable users, end-users and those affected by the sustainability assessment made.

4.2 Recommendations

The recommendations for further work are based upon the future issues identified in the discussion of section 3.7. The following points summarise the research needs and gaps to be filled:

- Definition and Scope – in order to define what is a sustainability tool, and how different types can be differentiated.
- Standards and Frameworks - The development of a standard would also allow stakeholders to determine when they had a sustainability tool and when a tool was intended for a more limited use. A standard would set the framework for sustainability tools. The standard itself would not be a 'sustainability tool', but would dictate what is required for such a tool.
- Input and Output Data - Further research will be required in order to determine how best to use and manage databases of information with sustainability tools.
- Communication to Stakeholders - Issues of communication and consistency of reporting are essential and there is a need for a minimum standard in communication.
- Policy, Legislation and Regulation - At present regulation has been unable to meet the whole issue of sustainability. The use of sustainability tools is a possible route towards meeting government policy on sustainable development.

Appendix 1: The Evaluation Spreadsheet

Appendix 2: The Evaluation Results for Tools

Appendix 3: Summary of assessments of tools

Tool	Inputs and Outputs	Scale of operation	Phase of operation	Main issues	User addressed	Quality of tool
Urban Planning Tools						
1. BRE SC	Existing data	Checklist, toolkit	Planning	S, Ec, En 8 broad categories	Developers Planning Consultants	High Widely accepted
2. CSA	Existing data	Checklist, toolkit	Scheme Construction Operation	S, Ec, En	End users Community People	High Widely accepted
3. SPARTACUS	Existing data	Experimental, model	Feasibility Scheme Dimension	S, Ec, En	Government	Medium Under development
4. SEEDA SC	Existing data	Checklist, toolkit	Conception, scheme, detailed, construction	S, Ec, En	Developers Architects End users Government Community	High
5. SCALDS	Existing data, all quantitative, spreadsheet input	Spreadsheet based, model	Feasibility Conception	S, Ec, En	End users Government Community	High Transport emphasis
6. CITY Green	Existing data	GIS system Windows based, toolkit	Conception Scheme Detailed	En	Lenders End users Community People	High Greening specific
7. PLACE^{3}S	Existing data, quantitative only	Yardstick approach, toolkit	Feasibility Conception Scheme Detailed	S, Ec, En	Developer Architect End user Government Community People	High

S – social, Ec - economic, En – environmental

Tool	Inputs and Outputs	Scale of operation	Phase of operation	Main issues	User addressed	Quality of tool
Design Tools						
8. ECOTECT	Existing data, quantitative, build plans, materials and components	3D environmental modelling Data output, toolkit	Conception Detailed	En	Architect Contractor End users	High
9. DOE 2.2	Existing data, quantitative, build plans	Energy modelling, model, toolkit	Conception Scheme Detailed	En	Developer Architect Contractor People	High
10. BDA	Existing data, quantitative, build plans	Energy modelling, model, toolkit	Conception Scheme Detailed	En	Architect Contractor End users People	High

Tool	Inputs and Outputs	Scale of operation	Phase of operation	Main issues	User addressed	Quality of tool
Building Environmental Frameworks and Rating Systems (Building)						
11. GBTool	Existing data	Rating system, toolkit	Scheme Detailed Manufacturing Construction	En	End users Community People	High
12. LEED	Existing data	Rating system, self assessment, toolkit	Scheme Detailed Manufacturing Construction Operation Maintenance	En	Raw materials End users Community	High
13. SPeAR	Existing data	Rating system, decision making, toolkit	Feasibility Conception Scheme Detailed Manufacturing Construction	S, Ec, En	Developer End users Community People	High
14. MSDG	Existing data	Design guide, toolkit	Detailed Construction Operation Maintenance Demolition Disposal	En	Developer End user Community People	High
15. EcoCal	Existing data	Household based rating scheme, toolkit	Operation Maintenance	En	End users People	High, self assessment
16. BREEAM	Existing data	Rating system, licensed and trained assessors, voluntary, toolkit	Conception Scheme Detailed Construction Operation Maintenance	En	Developer Architect End users FMs Community	High, widely applied
17. HK-BEAM	Existing data	Rating system, voluntary, toolkit	Conception Scheme Detailed Construction Operation Maintenance Disposal	En	Develop Architect End users FMs Community	High

Tool	Inputs and Outputs	Scale of operation	Phase of operation	Main issues	User addressed	Quality of tool
Assessment Tools: LCA Approach (Building)						
18. ENVEST	Existing data	Software tool, toolkit	Detailed Construction Operation Disposal	En	Raw materials Decommisioners Community People	High, widely applied
19. BRE EPs	Existing data in databases	Profiles, comparing specifications, toolkit	Scheme Detailed Operation Maintenance	En	Developers Manufacturers Raw mats Decommissioners Community People	High, widely applied
20. ATHENA	Existing data	Decision tool, stand alone or within other tool, toolkit	Conception Scheme Detailed	En	Developer End users People	High
21. Boustead	Existing data, in database	Software application, model	Scheme Detailed Manufacturing	En	Manufacturers Raw mats Decommissioners Community People	High
22. GaBi 4	Existing data, in database	Software system, product based, toolkit	Detailed Disposal	En	Manufacturers Raw mats Community People	High
23. TEAM	Existing data	Evaluation, toolkit,	Scheme Detailed Manufacturing Construction Operation Maintenance Disposal	En	Developers Raw mats Community People	High
24. EcoPro	Existing data	Calculation tool, toolkit	Construction Operation Maintenance Demolition Disposal	S, En	Developers End users People	High

Tool	Inputs and Outputs	Scale of operation	Phase of operation	Main issues	User addressed	Quality of tool
Infrastructure Tools						
25. CEEQUAL	Existing data	Rating, toolkit	Detailed Construction	S, Ec, En	Contractors Raw mats Decommissioners Government Community	High

Appendix 4: Summary of identified gaps in tools

	Major gaps in sustainability Issues			
Tool	**Social**	**Economic**	**Environmental**	**Amendment or development potential**
1. BRE SC	Health and comfort (HC) Employee satisfaction (ES)		Pollution	Some development potential possible, however, primarily a planning tool, so ES difficult to address
2. CSA	Corporate social responsibility (CSR)	Viability Competition Social benefits Costs	Flooding Land use* Pollution	Yes, tool covers most issues, input is simplistic
3. SPARTACUS	ES CSR	Competition Employment* Social benefits Design	Energy Transport Water Land use* Ecology Pollution* Environmental quality (EQ)	Yes, tool is intended to cover wide range of sustainability issues
4. SEEDA SC	Employee satisfaction		Pollution*	Wide coverage already with few gaps, as a planning tool employee issues are difficult to assess
5. SCALDS	Safety/Security HC ES CSR Quality of Life (QL)	Competition Employment* Design	Energy* Transport* Water Materials Land use Ecology Pollution* EQ	Predominantly based on transport issues, some development possible, but unlikely to be a holistic tool
6. CITY Green	*No issues covered*	*No issues covered*	Transport Water* Materials Land use Ecology* Pollution EQ	Limited to urban greening issues, development possible, but unlikely to be a holistic tool.
7. PLACE^{3}S	Social inclusion Safety/Security* HC* Liveability* ES QL	Viability Competition* Social benefits Design	Materials* Ecology Pollution*	Potential exists for development, many main issues covered, but no apparent depth at present.

- * - one or two items may be covered in the issue, but no significant coverage.

	Major gaps in sustainability issues			
Tool	**Social**	**Economic**	**Environmental**	**Amendment or development potential**
8. ECOTECT	*No issues covered*	*No issues covered*	Transport Water Materials* Land use Ecology Pollution*	Mainly an energy tool, unlikely to develop into a holistic tool. Can feed in as data to holistic planning or rating tools.
9. DOE 2.2	*No issues covered*	*No issues covered*	Transport Water Materials Land use* Ecology Pollution	Mainly an energy tool, unlikely to develop into a holistic tool. Can feed in as data to holistic planning or rating tools.
10. BDA	*No issues covered*	*No issues covered*	Transport Water Ecology Pollution	Mainly an energy tool, unlikely to develop into a holistic tool. Can feed in as data to holistic planning or rating tools.

- * - one or two items may be covered in the issue, but no significant coverage.

	Major gaps in sustainability issues			
Tool	**Social**	**Economic**	**Environmental**	**Amendment or development potential**
11. GBTool	No issues covered	No issues covered	Transport Land use* Ecology*	Building environmental rating scheme, could add other issues and sustainability dimensions. The latter would require significant effort in development.
12. LEED	No issues covered	No issues covered	Pollution*	Building environmental rating scheme, most environmental issues are covered. Could add other sustainability dimensions. The latter would require significant effort in development.
13. SPeAR		Design	Pollution*	This tool covers a wide range of issues across the dimensions. Some further development would be possible. For example, most energy issues are considered, but not efficiency.
14. MSDG	No issues covered	No issues covered	Pollution*	Building environmental rating scheme, most environmental issues are covered. Could add other sustainability dimensions. The latter would require significant effort in development.
15. EcoCal	No issues covered	No issues covered	Pollution* EQ	Intended as a household tool, further development is possible but not as a holistic tool.
16. BREEAM	No issues covered	No issues covered	Pollution*	Extensive coverage of environmental issues. Further environmental issues could be added. Intention to develop S and Ec issues as well, but difficult. Retraining of assessors would be an issue.
17. HK-BEAM	No issues covered	No issues covered	Transport* Ecology	Extensive coverage of environmental issues, gaps could be addressed. Other dimensions would be difficult to add, but possible.

- * - one or two items may be covered in the issue, but no significant coverage.

	Major gaps in sustainability issues			
Tool	**Social**	**Economic**	**Environmental**	**Amendment or development potential**
18. ENVEST	No issues covered	No issues covered	Energy Transport Water Land use Ecology	LCA tool for materials, some development potential but not a holistic tool. Data can feed into sustainability assessments.
19. BRE EPs	No issues covered	No issues covered	Land use Ecology EQ	LCA method for building materials. Some development potential, but not a holistic sustainability tool.
20. ATHENA	No issues covered	No issues covered	Transport Water Land use Ecology Pollution* EQ	LCA method for building materials. Some development potential, but not a holistic sustainability tool.
21. Boustead	No issues covered	No issues covered	Transport Ecology Pollution* EQ	LCA method for building materials. Some development potential, but not a holistic sustainability tool.
22. GaBi 4	No issues covered	No issues covered	Energy Transport Water Ecology	LCA method for limited building products. Some development potential, but not a holistic sustainability tool.
23. TEAM	No issues covered	No issues covered	Energy Transport Water Land use Ecology	LCA method for buildings. Some development potential, but not a holistic sustainability tool.
24. EcoPro		No issues covered	Transport Water Land use Ecology	LCA method for buildings in planning. Some development potential, but not a holistic sustainability tool.

- * - one or two items may be covered in the issue, but no significant coverage.

	Major gaps in sustainability issues			
Tool	**Social**	**Economic**	**Environmental**	**Amendment or development potential**
25. CEEQUAL	Social inclusion Safety/Security HC Liveability ES CSR* QL	Viability Competition ES Transport* Social benefit Design	Energy* Transport Water* Materials* Land use* Ecology* Pollution EQ	This tool covers a number of issues across the range of sustainability tools. However, it is relatively shallow in coverage and there is much scope for development into a holistic rating system. As it is self use, development may make it more difficult to use due to increasing complexity.

- * - one or two items may be covered in the issue, but no significant coverage.