Creating markets for recycled resources

Research Report: Aggregates

The promotion of the benefits of recycled and secondary aggregates (RSA) use in the reduction of CO_2 emissions

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Summary

This report describes the review of 26 sustainability and environmental assessment tools and approaches, and the subsequent development of a bespoke tool to promote the benefits of recycled and secondary aggregates (RSA) use in the reduction of CO_2 emissions. Two case studies were produced demonstrating CO_2 reductions deriving from the use of RSA compared to primary aggregates.

The project was commissioned by WRAP to a partnership between the Centre for Sustainability (C4S) at TRL Limited, Taylor Woodrow Technology (TWT) and Costain Limited.

Data availability and relevance were the key challenges to developing a bespoke CO_2 estimation tool. Where possible UK specific data was used, however this was not available for all processes. In these cases other European data has been used. However, the tool allows the user to add specific data to increase the data set relevance to specific projects.

The use of some non UK specific data and its impact on the calculations performed by the tool result in the greatest value being gained from comparing construction options rather than the estimates for individual options.

Choosing less energy intensive techniques, selecting sources of aggregates closer to the site and opting for green transport methods are ways of reducing energy use and associated CO_2 emissions.

A comprehensive user guide has been written to accompany the CO_2 estimator tool. This has been supplied separately to WRAP and it is envisioned that this will be made available on WRAP's AggRegain website.

As with the tool itself, the principles behind the guide were simplicity of use and transparency. The user guide has been written in a style that is clear and easy to understand, with step by step instructions leading the user through the inputs required to complete a CO_2 estimation. The guide also highlights helpful tips and warnings to further assist the user in the easy use of the tool.

1 Introduction

This is the final report for the project AGG079-007 "The promotion of the benefits of recycled and secondary aggregates (RSA) use in the reduction of CO_2 emissions", commissioned by WRAP to a partnership between the Centre for Sustainability (C4S) at TRL Limited, Taylor Woodrow Technology (TWT) and Costain Limited. The report contains information on the aims of the project and details of the project development and final outputs.

This report summarises the key issues raised in the three previous project reports submitted to WRAP by the project team:

- First Project Report – September 2005
- Second Project Report – October 2005
- Third Project Report – January 2006

2 Aim of the project

The objective of the project was to promote the use of RSA through raising awareness of the reductions in CO_2 emissions that can be achieved through their use. This objective was to be achieved through identifying effective environmental sustainability tools for measuring CO_2 emissions in typical construction scenarios. Furthermore, the study was to produce case studies demonstrating CO_2 reductions deriving from the use of RSA compared to primary aggregates. As the review of the available tools demonstrated that a suitable tool did not exist, WRAP and the project team agreed a change in the scope of the project. The project subsequently focused on developing a tool, with associated user guide, for calculating CO_2 emissions savings for a range of construction applications and innovative techniques involving RSA.

3 Project Development

This section details the work undertaken during the review of existing environmental and sustainability tools that could be applied to aggregate use, and the subsequent development of a bespoke tool, accompanying user guide and case studies.

3.1 Environmental and Sustainability Tool Review

The project team was aware of two existing databases collating some information on toolkits and approaches assessing the sustainability or simply the environmental impacts of aggregates use and construction activities respectively. Those databases constituted the main source of information for the first selection of applicable tools.

The Sustainability Matrix, the searchable database published on AggRegain within the Sustainability module, collates information on over 30 sustainability assessment toolkits and approaches.

The Balanced Value Toolbox is a searchable directory of existing tools and methodologies that contain information about, and help make decisions regarding, societal, environmental, economic or performance issues.

More specific information on Life Cycle Analysis type tools was also provided by the team's internal expertise and knowledge. Contacts with industry also allowed for the identification of further potentially applicable tools.

An initial list of 26 tools and approaches was complied from these sources and were evaluated against the following critical selection criteria:

- Does it calculate/rank CO_2 emissions for use of different materials?
- Are the owners willing to release the tool for trial?
- Are the assumptions/calculation mechanisms/supporting database used by the tool accessible?
- If accessible, are the data/assumptions etc robust?
- Is it relevant for applications required?

At this stage of the review, the following eight tools were selected as having potential to estimate CO_2 emissions for different aggregate sources:

- Envest Tool – BRE
- Carbon Calc – Best Foot Forward
- ESRSA tool – WRAP (developed by Viridis (now C4S))
- Sima Pro 6 – Pré
- BEES 3.0 – NIST
- CO_2 calculator for road maintenance – WS Atkins
- Roadstone Recycling Ltd tool for cold recycled bitumen bound material
- Life Cycle Inventory Model for Asphalt Pavements – European Asphalt Pavement Association (EAPA) / EuroBitume

The tools listed above were assessed in more detail according to the following three criteria areas:

Inputs, outputs and mechanism

- Does it break CO_2 down into the different components of the process?
- Which specific applications the tool does and does not apply to and at what level of details?
- What are the boundaries of the processes included in the calculations, both in the assumptions and in the tool?
- How does the tool handle RSA in products such as concrete blocks made with varying percentage of RSA?

Availability and usability

- Costs to the user
- Single/multiple use
- Download/access on line
- Expertise required
- Project knowledge level
- Training required?
- Likely time needed to obtain results
- Decision tool/ assessment tool or both?
- Flexibility: default data only, user input only, both?

Other

- Are the data relevant for UK?
- Are the data reasonably recent?
- Other indicators/measures provided
- Accreditation/endorsement
- Is the tool well established? Is there any available case study demonstrating its use?

This assessment resulted in discounting a further four of the eight tools:

- BEES 3.0: The tool does not cover aggregates and it is based on US data
- CO_2 calculator for road maintenance: this Whole Life Value tool by WS Atkins was still under development
- Envest2: The tool does not have a recycled aggregates option and is not available for analysis of its assumptions
- SimaPro 6: This is a very complex tool which requires expertise in LCA and/or training

Appendix section 6.1 lists all the tools discounted from the trialling section of this review, each with a brief explanation of the tool capabilities and reasons for discounting.

The remaining tools listed below were subjected to further trialling using existing case study data:

- Roadstone Recycling Environmental Wizard
- WRAP's ESRSA
- EAPA/EuroBitume's LCI model for asphalt
- Corporate StepWise

Costain and TWT trialled these four tools to assess usability. Data readily available from previous projects, such as the A34 Chieveley road construction, were used to test the tools in terms of user-friendliness. All four tools had strengths and weaknesses which limited their useability and applicability, these are summarised below.

Tool	Strength	Weakness
Roadstone Recycling Environmental Wizard	✓ very simple front end and mechanism ✓ compares options and calculates savings	× limited scope within a single application × assigns planing impacts to RAP
ESRSA	✓ covers all applications ✓ provides comparison for different aggregates (data per tonne)	× CO_2 calculations are not the primary scope of this complex tool and are hidden × not job specific therefore further calculations are needed for calculating the overall impact × assigns planing impacts to RAP
EAPA/EuroBitume's LCI model for asphalt	✓ relatively simple front end and transparent calculation mechanism ✓ provides default data but allows informed user to input own information for energy parameters	× applies only to asphalt × uses Scandinavian data
Corporate StepWise	✓ covers all applications ✓ assume recycled aggregates have same impacts as primary	× results vary considerably depending on parameters chosen × not enough engineering details

A comparison of the results obtained for a road building scenario – the only one which could be estimated with all four tools – show how the results vary considerably, see Table 1. This variation depends on a number of factors, as the tools have different underlying assumptions. However, the most relevant reason for this difference seems to be the lack of reliable data for RSA as well as the difficulty of finding aggregates processing data relevant to the UK.

Table 1 Comparison of calculated CO_2 emissions from A34 Chieveley data

Assessment Tool	Calculated CO_2
Roadstone Recycling Ltd. "Environmental Wizard"	3,310t
EAPA/EuroBitume "LCI model for asphalt"	5,510t
ESRSA tool	9,254t
Corporate StepWise tool	6,600t to 45,850t

The A34 Chieveley case study has also been used to demonstrate the bespoke tool, see section 3.4.

None of the tools appeared to meet the specific requirements of the project objective i.e. a tool, and related guidance, which enables the construction industry to calculate the savings in CO_2 from using RSA in a variety of applications. Therefore a bespoke tool was developed as described in section 3.2.

3.2 CO_2 Estimator Tool Development

This section describes the development of a bespoke tool that meets WRAP's specific requirements. It is envisioned that the bespoke tool developed for this project will be made available on WRAP's AggRegain website.

Tool specification

The first step to developing the bespoke tool was to agree a specification for the tool. It was agreed with WRAP that simplicity of use and transparency were the guiding principles of the tool. The agreed specification is shown in Appendix section 6.2 with the ideal tool having the following characteristics:

- be easy to use – for anyone in the supply chain;
- be independent, i.e. not a marketing tool for specific materials;
- include the assumption that processing (crushing and screening) of recycled aggregates is the same as for primary aggregates;
- account for impacts from recycled aggregates in a consistent manner – i.e. RAP embodied energy should not include impacts of generating the waste (planing processes), in line with other recycled/secondary materials
- enable the user to input distances from point of delivery to point of use;
- cover the following applications:
    - bituminous bound, hot and cold processes
    - unbound
    - hydraulically bound
    - concrete
- be job specific, i.e. calculate the total amount of CO_2; generated by using the materials in a range of applications on a project;
- allow for different options (aggregates and/or techniques) to be compared in one single run;
- calculate estimates of CO_2 generated by adopting each option and calculate savings.

Tool format

The format of the EAPA/EuroBitume LCI model was used as the basis for the bespoke tool development. Permission was granted by EAPA/EuroBitume and a Letter Of Transmission was provided allowing the use of the EAPA/EuroBitume LCI model.

Tool data set

The EAPA/EuroBitume tool was based on default data collected mainly in Scandinavia and it does not model unbound or hydraulically bound materials. Therefore for the bespoke tool's database was extended through research conducted by all parties, C4S mainly from literature search; TWT and Costain from their operations, contractors and suppliers.

Tool trialling

The tool was trialled by WRAP, Costain and TWT throughout its development using existing case study information such as the A34 Chieveley case study for road examples. This trialling was to ensure the user-friendliness of the tool and the clarity of the associated guidance document.

The tool was also trialled by the Quarry Products Association (QPA). The comments and suggestions mainly focused on the clarification of assumptions and data sets, and were addressed appropriately within the timescale of this project. The QPA also commented that the figures obtained from their use of the tool were the same order of magnitude to some of their own data and assumptions.

Tool sensitivity

The purpose of this sensitivity analysis was to determine which elements of an application are the 'hot spots', i.e. the most energy intensive, and therefore those which produce the most CO_2.

To conduct the sensitivity analysis, three examples of construction works were chosen.

1. Pavement maintenance on the A34 at Chieveley: works included use of aggregate in unbound, bitumen-bound and hydraulically bound applications.
2. Ashford Airport surface enlargement: this example allows cement bound applications to be investigated.
3. Pavement maintenance on the A38, which allows for a direct comparison between hot and cold bituminous mixing.

Details of these case studies are available from WRAP's AggRegain web site.

The results on the analysis showed that the production of binder material has a significant impact on CO_2 emissions e.g. cement or bitumen for bound layers. This is due to the relatively high embodied energy of these products. Cement has an embodied energy of approximately 4770 MJ per tonne, and bitumen has an embodied energy of approximately 173 MJ per tonne. In addition the energy required for the standard hot mixing of asphalt is approximately 340 MJ per tonne. The estimated CO_2 emissions for these products are 3821 kg per tonne of cement, and 45.4 kg per tonne of mixed bitumen.

Tool assumptions and limitations

The following assumptions are used in the tool, further information is available in the user guide.

- The tool does not differentiate between different compactors and excavators but uses only one type of machinery for all applications.
- A few activities such as loading/unloading of materials from/to plant and equipment have been considered to be included in the energy use of the plant or equipment.
- The tool assumes that the hot mix plants for bituminous mixtures are fuelled by diesel, as it was not possible to find information on gas use during the course of the tool development.
- The emissions associated with PFA are derived from BRE's Environmental profiles, in which the emissions are based on the burning of the coal generating the PFA. The burning of 100 tonnes of coal produces 9 tonnes of PFA. No information was available on the CO_2 associated with the treatment of the PFA prior to incorporation in construction. In the tool we have taken the assumption that this is equivalent to 9/100 of that energy is attributable to PFA in the BRE environmental profiles.
- The emissions for road transport are calculated assuming the return trip is empty. This mirrors the assumption taken in the EAPA/EuroBitume's LCI for asphalt.
- It was not possible to find data for mixer trucks and therefore transport of ready-mix is modelled with normal trucks. This does not influence the results of the comparisons, as the transport of the ready-mix should account for the same amount for all options.

The results of the tool, in particular the total emissions generated by each option, provide an estimate of the quantity of CO_2 generated but should not be taken as definitive values. The main focus of the tool was to provide an estimate of the savings in CO_2 emissions realised through using more sustainable practices and materials. Therefore more confidence is placed on the CO_2 savings measured when comparing construction options rather than the individual option estimates. This is because some of the inaccuracies in the data sets used to estimate the individual options should cancel each other out when calculating the differences between the options.

The data set could be improved with more UK specific data; the tool allows for users to input their own data if known. When this is done the users must identify which data has been changed.

3.3 CO_2 Estimator Tool User Guide

A comprehensive user guide has been written to accompany the CO_2 estimator tool. This has been supplied separately to WRAP and it is envisioned that this will be made available on WRAP's AggRegain website.

As with the tool itself, the principles behind the guide were simplicity of use and transparency. The user guide has been written in a style that is clear and easy to understand, with step by step instructions leading the user through the inputs required to complete a CO_2 estimation. The guide also highlights helpful tips and warnings to further assist the user in the easy use of the tool.

Case study examples are shown in the guide to demonstrate what CO_2 savings can be achieved by the use of RSA. See section 3.4 for case study development.

The guide was trialled along side the tool by WRAP, Costain, TWT, and QPA with changes being made as appropriate.

3.4 Case Studies

The original scope of the project allowed for approximately eight new case studies to be developed. However, when the project scope was changed to allow for the bespoke tool development the resources available to develop new case studies was reduced. The reduced resources allowed for two new case studies to be developed as part of this project, which have been supplied separately to WRAP:

- A2/A282 Dartford Improvement
- Victoria Wharf Housing Development in Cardiff

So that there was an adequate number of case studies to illustrate CO_2 savings in the user guide existing AggRegain case studies where used:

- Small NHS Building (Selly Oak)
- A34 Chieveley M4 Junction 13 Improvement
- Head Office Building (Bracknell)
- A38: Ex-situ recycling of a trunk road in South Devon

The case studies where identified through the knowledge and contacts held by the project team. Prior to the change in project scope, potential case studies where reviewed against the four assessment tools that performed the best in the review. Table 2 shows which tools could be applied to the proposed case studies.

Table 2 Matching case studies to tools

Case Study	**Assessment Tool**			
	Roadstone	ESRSA	LCI Model	Corporate StepWise
Telford Millennium Community Project	✗	✓	✓	✓
Housing Developments and Mixed Housing Developments (Houses and Apartments)	✗	✓	Partly	✓
Commercial (Supermarket Construction, Extensions and Associated Works)	✗	✓	✓	✓
Porth Relief Road South Wales	✗	✓	✗	✓
A2/A282 and M25 Junction Improvement	✓	✓	✓	✓
Robin Hood Airport, Doncaster	✗	✓	✗	✓
Rockingham Road Renewal Works	✓	✓	✓	✓
A38 Peartree	✓	✓	✓	✓

Draft versions of the case studies where reviewed by WRAP and subsequent changes made to meet WRAP's requirements. The final versions of the new case studies were produced in a format agreed with WRAP and should be published on the case study section of the AggRegain website.

4 Conclusions

The project team found that a large number of environmental and sustainability assessment tools and approaches are available on the market to estimate the sustainability of aggregates use and general construction practices. Some of those tools are free to use and some have an associated cost. However, the review of 26 of these tools and approaches demonstrated that a suitable tool did not exist to meet WRAP's requirements.

The development of a bespoke tool to meet WRAP's requirements focused on estimating the savings in CO_2 emissions realised through using more sustainable practices and materials. The tool was produced as an Microsoft Excel spreadsheet with accompanying User Guide. Two new case studies were developed to illustrate the application of the tool.

Data availability and relevance were the key challenges to developing a bespoke tool. Where possible UK specific data were used, however this was not available for all processes. In these cases, data from a European study, the EAPA/EuroBitume Life Cycle Inventory, have been used. The data from the EAPA/EuroBitume LCI were collected mainly in Scandinavia and so may not be as relevant as UK data. However, the tool allows for specific data to be entered by the user to increase the data set relevance.

A sensitivity analysis of the bespoke tool highlighted that the production of binder material has a significant impact on CO_2 emissions e.g. cement or bitumen for bound layers. This is due to the relatively high embodied energy of these products.

Choosing less energy intensive techniques, selecting sources of aggregates closer to the site and opting for green transport methods are ways of reducing energy use and associated CO_2 emissions.

The use of some non UK specific data and its impact on the calculations performed by the tool result in the greatest value being gained from comparing construction options rather than the estimates for individual options.

5 Recommendations

Recommendations for further work are split into two areas as follows.

Tool Updating and Development:
- Cross reference links between the case studies and the user guide should be updated once the web location of each is known.
- A UK data gathering project to improve the tool's data relevance and accuracy, which could improve the CO_2 estimations made by the tool.

Tool Promotion and Dissemination:
- Promotion of the tool at future WRAP events similar to the Recycled Roads and Material Resource Efficiency workshops. Training could be provided on how to use the tool and delegates could use the tool in the practical workshops.
- Encourage the use of the tool in prestigious UK construction projects such as the Olympics.

6 Appendix

6.1 Tools discounted in the review

The table below reports the discounted tools, each with a brief explanation of the tool capabilities and reasons for discounting.

Analytical Hierarchy process (AHP) - not branded
This broadly applicable tool provides a methodology for assessing, prioritising and selecting amongst a broad number of options. This was discounted because although it is a decision-making tool it does not provide data by itself.
Athena Environmental Impact Estimator 3.0 – Athena Sustainable materials Institute
The Athena Version 3 Environmental Impact Estimator was a lifecycle assessment tool produced by the Sustainable Materials Institute based in Canada. Much of the information required to enable an assessment of the tool under the project criteria, were not provided on the website or apparent while using the demo. Several key limitations were apparent and are listed below. It has been assumed that you can only use the default data provided in the tool It appears unlikely that the tool can calculate or rank lifecycle CO_2 emissions for different materials The assumptions made and calculations used were not accessible on the website or through the demo version. The data was North American, and the US LCI Database was referred to. The demo and website did not provide any information on assumptions made, and it was not possible to gauge if the data was robust The tool was unlikely to cover the range of products being assessed, and to the level of detail required for the project Aggregate energy figures provided were likely to be relevant to North American extraction processes rather than European or UK equivalents. The key advantages include: A purchase price for educational institutions was offered and it was possible that may be extended to publicly funded research A number of North American companies active in cement manufacture were members of the Sustainable Materials Institute It was possible to undertake assessments of lifecycle impacts for different stages of a process/parts of a product, separately, and to subsequently build elements together to represent a whole process or product
ATROiD 3.0 (or ProdTect) – Kerp Engineering
The tool provides the means to make plans for a product's End of Life (EOL) phase. It can be used to keep recycling cost as low as necessary, and to ensure the maximum number of components were amenable to recovery. It allows designers to plan ahead when designing products, to directly influence and control its EOL. This tool was therefore designed to look very specifically at design parameters associated with manufactured products. This allows products to be designed for dismantling, and to select the most favourable recycling process. From a financial point of view this allows identification, planning, and control of the EOL and recycling product costs. Therefore this tool was an assessment and decision tool for design choices from the supply side rather than the demand side. It was therefore unlikely to be unsuitable to this project.
BR392 - Quality Control for the production of recycled aggregates – BRE Digest
Superseded by WRAP' Quality protocol.
BRE Digest 433: Recycled Aggregates - BRE
This document was used to set a specification for recycled aggregates and did not provide information on CO_2 emissions.
Construction Industry Key Performance Indicators – Constructing Excellence
The KPIs enable organisations to measure and monitor their performance along the three areas of customer satisfaction, people and environment. Constructing Excellence has also developed further Environmental Performance Indicators
Deconstruction and reuse of construction materials – BRE
The package includes a reference book and a checklist. The book describes a methodology and auditing

system for the refurbishment and demolition of four types of structure – steel concrete, masonry and timber. This tool has been discounted because it does not provide sufficient information to enable users to calculate their own CO_2 emissions.
Demonstration of re-use and recycling of materials – BRE
The book reports on the best practices applied for the construction of the BRE offices in Watford. It was therefore a good practice case study more than an assessment tool and has therefore been discounted.
EcoProfile – Norwegian Building Institute
The Ecoprofile was a voluntary Norwegian labelling system termed the 'Ecoprofile Method'. The system includes labels for external environment, resources (energy performance) and indoor climate This indicates that the method incorporates data for individual buildings, which was translated into these three labelling formats. This would suggest that the tool was flexible allowing for data to be applied. Ecoprofile was described as a method for simplistic environmental assessment of buildings, giving a picture of a building's resources and environmental profile. This would suggest that it was not designed for detailed and specific inputs and outputs of scientific data such as carbon dioxide emissions. There was no evidence to suggest that it considers the actual embodied energy of individual building products. It seems more likely that this was a tool aimed at assessing the energy performance of different building designs, and was therefore more likely to be considering insulation characteristics, design and heating and cooling systems. Outputs were presented as bar graphs or rose diagrams. The principal components contributing to energy performance can be combined indicating large, medium or small environmental impacts for the three labelling systems.
Environmental Performance Indicators - M4i
The Movement for Innovation (M4i) was formed following Sir John Egan's task force report, "Rethinking Construction" and aimed to pioneer radical changes of attitude throughout the design and construction industry. At the forefront of these changes was the establishment of a culture of measurement across all aspects of the industry, from safety and productivity to quality, so that performance can be monitored and improvement can be continuous. The EPIs were developed to set an appropriate number of targets across the most common building-types that could be used by planners, designers, contractors, suppliers and, of course, users - i.e.; from inception of the project to completion and beyond. Embodied Carbon Dioxide (kg CO_2/m^2), i.e. the carbon dioxide produced from the energy used in the extraction, fabrication and transportation of the materials used in the construction was one of the six EPIs. This tool has been discounted, as it was mainly dealing with benchmarking. The users would need to search by themselves for information to calculate the EPIs of their construction project. BRE' environmental profiles were mentioned as source of information for the users. Since 2001 BRE has developed various interactive tools using the same information. Furthermore, the M4i EPIs have evolved under Constructing Excellence.
Environmental profiles – BRE
The environmental profiles provide information about environmental impacts of building materials and components. They identify and assess the environmental effects of building materials over their entire life cycle, through their extraction, processing, construction, use and maintenance, and their eventual demolition and disposal. Environmental Profiles allow designers to demand reliable and comparable environmental information about competing building materials, and give suppliers the opportunity to present credible environmental information about their products. Cradle to grave Environmental Profiles were calculated for building elements (walls, floors, roofs, etc) with a 60 year lifetime. This anticipated lifetime was needed to allow maintenance, replacement and disposal factors to be taken into account. In addition, Profiles can be calculated for building elements as they were installed in to the building, these being limited to an assessment from cradle to installation. They were for use by designers who have specific life information about the elements - for example, an element may be in a building designed to have a life span of just 20 years or a particular maintenance plan may be envisaged. Profiles were also calculated for building materials (steel, aluminium, concrete, etc). A database of Environmental Profiles was accessible on line from the BRE website. This was a fundamental directory of information, which has been used by BRE during the years to build various decision making tools and guidance, from the Green Guide to ENVEST. The Environmental Profiles in database form were therefore discounted as the ENVEST tool provides a more interactive way to use them.
Green Guide to Specification (and for Housing) – BRE
The Green Guide (currently under review) was a guidance document for specifiers, designers and their clients on the relative environmental impacts of over 250 elemental specifications for roofs, walls, floors etc.

Environmental ratings of these specifications were based on Life Cycle Assessment using the Environmental Profiles. This document has been discounted as it provides advice on specific products and their impacts but does not offer a way to calculate overall CO_2 emissions for a range of alternatives. Furthermore, it was understood that other interactive tools by BRE make use of the information collected in the Environmental profiles.
Key Performance Indicators – The Construction Best Practice programme
Superseded by the above Construction Industry Key Performance Indicators.
Methodology for Environmental Profiles of materials, components and Buildings - BRE
This document provides an insight into the method used to calculate the Environmental profiles which constitute the basis for a number of interactive tools produced by BRE, and has therefore being discounted, as it was not a tool in itself.
Reclamation and recycling of building materials: industry position report - BRE
This short document published in 2000 was based on a survey and gives a snapshot of the present position in the reclamation and recycling industries with regards to its commitment to lessening its impact on the environment; reducing waste and making better use of unavoidable waste. This document has been discounted as it provides only "static" information
Towards a Framework for Environmental Assessment of Building materials and components
This report published in 1998 aims to develop a framework, acceptable across Europe, for assessment of the major environmental impacts of building materials. This book was discounted as it provides a methodology rather than a tool for the user – furthermore, BRE' Life Cycle Analysis studies and results have been used in other interactive tools taken forward for further assessment.
The use of recycled aggregates in concrete - BRE
Information paper published in 1994 now obsolete.
BEES 3.0 – NIST
A closer analysis of the toolkit revealed that the tool does not cover any construction products containing aggregate. Furthermore, the tool was based on US' construction practices and data. The tool was discounted from further investigation.
CO_2 calculator for road maintenance – developed by WS Atkins
C4S contacted WS Atkins to gather additional information on the tool. Atkins was developing a Whole Life Value tool for the Highways Agency which includes calculations and costing of CO_2 emissions from road surfacing techniques (including thin surfacing). The tool was due to be finalised by March 2005 and it was not therefore available for assessment.
Envest2 – BRE
Liaison with BRE allowed the team to further the understanding of the capabilities of the Envest2 tool and its potential applicability to the project. The tool does not have recycled aggregates option and it was not available for analysis of its assumptions.
SimaPro 6 – Pré
Having obtained a full version of the tool for investigation, it was clear that the tool was very complex. Users' assessment highlighted how training or the involvement of an expert environmental consultant would be necessary to understand it and use it. The tool was therefore discounted.

6.2 Bespoke tool specification

Discussions with WRAP on the tool to be developed during the project highlighted the following ideal characteristics. Simplicity of use and transparency were the guiding principles of the tool.

The ideal tool should:

- be easy to use – for anyone in the supply chain;
- be independent, i.e. not a marketing tool for specific materials;
- include the assumption that processing (crushing and screening) of recycled aggregates is the same as for primary aggregates;
- account for impacts from recycled aggregates in a consistent manner – i.e. RAP embodied energy should not include impacts of generating the waste (planing processes), in line with other recycled/secondary materials
- enable the user to input distances from point of delivery to point of use;
- cover the following applications:
    - bituminous bound, hot and cold processes
    - unbound
    - if possible, hydraulically bound
    - concrete
- be job specific, i.e. calculate the total amount of CO_2; generated by using the materials in a project;
- allow for different options (aggregates and/or techniques) to be compared in one single run;
- calculate estimates of CO_2 generated by adopting each option and calculate savings.

The LCI model was identified by the team as ideal for its relative simplicity and transparency. The challenge was however to enlarge the scope of the tool to cover other applications, providing that the owners of the tool agree to it being used.

There was not time within this project for developing a full LCI for other applications nor was this understood as within the scope of the project.

Tool mechanism

The tool will be developed in an Excel spreadsheet environment. Excel formulae were to be used for the calculations and all base data will be accessible to the user, to ensure maximum transparency.

The inputs of the tool will be divided into two categories:

- Job specific inputs: to include quantities and types of materials and aggregates used, distances from materials and aggregates sources. The users will be able to input data for up to three different options per application (e.g. different % of RSA or different techniques);
- Process specific inputs: to include energy used by pieces of equipment and transport modes and various conversion factors. These data will be provided as default.

Users will be required to fill in the job specific inputs, and will be given the choice to access the process specific inputs. Informed users might be able to modify the process specific inputs with data from their own equipment.

Outputs of the tool will be:

- Estimates of CO_2 emissions for each option
- A calculation of the estimated savings of each option with respect to the base scenario.

Applications and RSA

In general, the tool will assume that embodied energy of RSA is the same as embodied energy of virgin aggregates. "Embodied energy" of aggregates is assumed to be the energy needed for processing, i.e. crushing and screening and moving around the processing site.

On that basis, the tool should not differentiate between different applicable RSA. Users will have the opportunity to choose mixes containing up to three generic RSA, which will be differentiated only by quantities in the mix and distances travelled. The users will be referred to the Specifier within AggRegain for technical information.

Energy for mixing aggregates and binders and for placing the "mixture" does not depend on the components.

Transport will cover two elements:

- Transport of single components to mixing plant. For unbound applications, the distance covered under this element should be set to 0.
- Transport of material to site. For unbound applications, this should be the distance travelled from the origin of the aggregate to site.

For each transport element, users should be able to choose one or a combination of transport modes: water, rail, road.

To make the tool more flexible and job specific, we propose to include a number of scenarios for each application (e.g.: layers of bitumen bound mixtures, different concrete specifications, types of unbound applications, types of hydraulically bound applications). The users would be able to input up to three options (including base option) for each scenario. This should help the users in modelling most of the materials used in their project so as to obtain an overall estimate of CO_2 emitted and savings.

Coverage of the tool

Bitumen bound mixtures:

It will consider up to three different scenarios (three bitumen bound layers)

Techniques:

- Hot processes
- Cold processes (in situ/ex-situ will be captured by transport distances, to be set to 0 for on site working)

Materials:

- Crushed rock, sand and gravel
- Cement, bitumen
- RSA

Unbound applications

It could consider up to two different scenarios (to cover two amongst fill, sub-base, working platform, capping etc.)

Materials:

- Crushed rock, sand and gravel
- RSA

Hydraulically bound applications

It could consider up to two different scenarios (e.g. base and subbase)

Techniques:

- Imported materials

Materials:

- Crushed rock, sand and gravel
- Cement, lime
- RSA

Concrete

It could consider up to three different scenarios (e.g. different ready-mix specifications, or different pre-cast products or a mix).

Materials:

- Crushed rock, sand and gravel
- Cement
- RSA

Appearance

Unused facilities (e.g. applications and/or repetitions) will be “hidden” so to present the users with a simpler screen.