Client Report :

Eco-Region North West England - integrated life cycle of material flows and mass balance of construction resources – final report

Client report number 15908

Prepared for :

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Executive Summary

BRE Scotland has collaborated with the University of Manchester on a project entitled 'Eco-Region North West England – integrated life cycle of material flows and mass balance of construction resources'. The project has been supported financially by the Biffa Environment Fund. There are a number of project partners and sponsors.

North West England is composed of Cumbria, Lancashire, Merseyside, Greater Manchester and Cheshire. This is being considered as an Eco-Region, allowing a mass balance of the whole life cycle of the construction resources within the region to be developed. All the stages of the whole life cycle of construction have been considered, as follows:

1) Raw materials;
2) Construction products;
3) Current building stock;
4) Construction waste;
5) Demolition and secondary waste materials;
6) Future construction.

Issues relevant to each stage have been considered. Also the most current and reliable data available has been collected and tabulated. If data was unavailable for North West England, corresponding data was gathered for Northern England, England, England & Wales or UK.

The most important issues for future construction in North West England are as follows:

1) Modern methods of construction;
2) The European Energy Performance of Buildings Directive;
3) The effects of climate change on construction and buildings;
4) The use of recycled and recovered materials in construction.

Contents

1. Introduction

BRE Scotland has collaborated with the University of Manchester on a project entitled 'Eco-Region North West England – integrated life cycle of material flows and mass balance of construction resources'. The project has been supported financially by the Biffa Environment Fund. There are a number of project partners and sponsors.

The idea of an Eco-Region allows the analysis of all the resource flows i.e. the development of a mass balance within a certain region. The region of North West England is considered to be composed of Cumbria, Lancashire, Merseyside, Greater Manchester and Cheshire. A mass balance of the whole life cycle of construction resources is being developed for this region. This includes the following parameters:

1) Raw materials
2) Construction products
3) Current building stock
4) Waste from construction
5) Demolition and other secondary waste materials
6) Future construction.

2. Methodology

The work was undertaken mainly as a desk based review of the available information to answer the questions in the following table:

ITEMS & QUESTIONS	NOTES	Sources of information
Data on existing housing stock, types, ages, annual provision numbers still needed	AM has annual provision numbers, while JRavetz flagged ODPM's housing condition survey as good source for this	See sections 5 and 8 and tables 7 and 8.
Need for a description of the typical UK house, as well as a list of main dwelling types, and C&I building types. Component analysis will help to 'deconstruct' bldgs, first by main component (e.g. walls, floors, roofs, etc), then by the main materials that make up each component.	Want to be able to evaluate diff bldg types using REAP, therefore, need to represent bldg types in terms of main bldg elements, which in turn can be defined in terms of REAP sectors. Ideally, BRE would provide a list of bldg elements, broken down into their material components. Further, the SIC code for each material would be listed.	See sections 5 and 8 and tables 9, 17 and 18. See Tanikawa & Lawson's report, - pages 16 to 18.
Does a 'recipe' of raw materials (minerals & aggregates) needed to build UK dwellings and C&I bldgs?		See section 5 & 8, & tables 17 & 18. See Tanikawa & Lawson's report - pages 16 to 18.
ENVEST has potential to score bldgs (C&I and residential) according to their 'ecopoints' and lifecycle cost	Need for 'typical' dwelling and specific dwelling types, as well as C&I bldgs, to be defined according to the ENVEST parameters (floor space area, amt of glazing, etc)	AM ? See appendix 2.
Want to be able to evaluate the in-use energy performance of bldgs.	Data on energy performance (GJ/m2) of UK dwelling types	See section 5.1.

ENVEST can contribute to this but this tool aggregates measurements into ‘eco-points’ and lifecycle costs.	likely to reside at BRE.	1.0 GJ/m^2 for typical semi–detached house.
Want to be able to compare energy performance of diff types of bldgs (eco-homes, Bedzed, those meeting blgd regs.) and link to footprint	Need to look at JR’s 2020 technical report for references to older analyses by BRECSU (energy conservation support unit) for energy performance data	See section 5.1, table 11 & appendix 1.
BREEAM / Eco-homes measure variety of bldg attributes related to overall performance, and although energy efficiency is key to BREEAM, material consumption and CO2 emissions is not well emphasized	We’re interested in how material flow analysis (MFA), ecological footprints (EF) and CO2 can be used to augment these rating schemes. Or, whether or not we can estimate the impact that ratings of ‘eco-homes excellent’, or ‘BREEAM very good/excellent’ will have on regional material consumption, footprint or CO2. Need a breakdown of the BREEAM assessment scheme and identification of how or where MFA and EF could be inserted or augment existing metrics	See section 5.3, table 12 and appendix 1.
For scenario work there is need for idea as to how demographic and technological changes, building regs, EU energy performance of bldgs directive EPBD, or climate change will impact on the way we shelter ourselves in the NW. Will houses be smaller? Will the number of HHs increase on a per capita basis? How will bldgs perform under climate change conditions? What innovations in bldg technology are under examination and what is the prognosis for market uptake?	Need to examine and discuss the following: EU EPBD will come into effect Jan 06 and will have large impact on new and existing UK bldgs. How will UK construction industry respond? What are the energy and MFA implications of the EU EPBD directive? What does the future hold for Prescott’s ‘pre-fab’ houses? What is the future for ex-situ manufacturing of buildings?	See section 5.1 and 8.3. See sections 5.1 and 8.3 See section 8.2. See section 8.2.

	How will existing bldgs perform under UKCIP climate change scenarios? What is the forecast dwelling size and type profile in 10, 20, 30 yrs.	See section 5.4. Getting smaller.
BRE case studies	Need to investigate specifics of case studies included in interim report on waste arisings from 3 diff types of development (i.e. how many square metres of construction involved in each? Units of measure for waste materials?) Investigate utility of SMARTstart tool. Need for better understanding about materials that go into diff bldg types (by SIC code), average distances travelled by materials, environmental profiles of bldg materials (see BRE tool on same), total m2 constructed, etc. Look at NW examples of 'eco-bldgs' achieving BREEAM or Eco-Homes designations and assess for MFA, environmental profile of materials, lifecycle costs, in-use performance, etc. If necessary, can look to take ENVEST parameters from selected case studies and run them in the model to at least come up with 'eco-points' and lifecycle costs.	See section 6 and tables 13 and 14. Also Tanikawa & Lawson's study is a case study. Also pfa, Fiddlers Ferry – section 7. See appendix 2. No BREEAM data specific to NWE available. But see section 5.3 for N England data. AM ?
C&D waste remains unclarified over and above Viridis report and NW Regional Technical Advisory Body	EA expected to release C&D waste arising data in coming months. Will move forward with	No new data.

(RTAB) report.	what data we have and hope that this data comes quickly. Need to validate Viridis findings and NW RTAB data with BRE expertise and experience Can we forecast waste arisings using data on waste arisings from selected construction projects and estimated new build numbers (note: will have to allow for waste from infrastructure construction)	Not possible Limited data on construction waste in tables 13 and 14. See Tanikawa & Lawson report page 28.
Drivers for recycling waste material markets.	Need a review of material recycling trends and targets in NW. A review of construction material recycling trends and opportunities (given prefab technology and landfill constraints) by BRE needed.	AM and JRidal See sections 8.2 and 8.5.

The main sources of information were as follows:

1) Publications, reports and other information from BRE, University of Manchester, other project partners and other contacts.
2) Internet World Wide Web (www) sites and search engines such as Google and Lycos.

The most current and reliable data available for the whole life cycle of construction resources in NW England was collected and tabulated for the following stages:

1) Raw materials
2) Construction products
3) Current building stock
4) Construction waste
5) Demolition and secondary waste materials
6) Future construction

If data was not available for NW England, corresponding data was gathered for Northern England, England and Wales or UK.

3. Raw materials

3.1 Production of raw materials

The most common type of raw material is aggregate. Data has been collected for aggregates production, imports, exports and consumed in North West England, as shown in Table 1.

The aggregates produced and consumed in North West England as a percentage of that that for England and Wales is shown in Table 2.

It can be seen that less than half the amount of crushed rock consumed in North West England is produced there. Slightly more land won sand and gravel is consumed in North West England than is produced there whereas slightly less marine sand and gravel is consumed in North West England than is produced there.

The imbalance in North West England between consumption and production of crushed rock aggregates is clearly reflected in the inter-regional imports and exports.

Some limestone and sandstone are imported into North West England, as outlined:

Main sources of imports

Limestone: East Midlands (4,700 tonnes), Yorkshire and Humberside (1,149 tonnes) and North Wales (2,298 tonnes)

Sandstone: East Midlands (114 tonnes), West Midlands (219 tonnes), Yorkshire and Humberside (298 tonnes)

Some land won sand and gravel and sandstone are exported from North West England.

Main destinations of exports

Land won sand and gravel: West Midlands, Yorkshire and Humberside, North East England and North Wales

Sandstone: Yorkshire and Humberside

Under planning permission, the permitted reserves of crushed rock (limestone, sandstone and igneous rock) and sand and gravel in NW England have been estimated, known as the landbank, as shown in Table 3.

In comparison, the landbank for England and Wales has been estimated to be 28.9 years for crushed rock and 11.3 years for sand and gravel.

Costings for aggregate production and transport in North West England have been estimated. The ex-quarry cost of limestone is approximately £4.60 per tonne (including £1.60 per tonne quarry tax) whereas sand and gravel is approximately £ 6.50 per tonne including quarry tax. Transport costs are estimated to be £3.00 per tonne for 10 miles, £4.40 per tonne for 25 to 30 miles and £7.00 per tonne for 50 miles. Aggregates tend not to transported more than 50 miles by road. If the distance is greater than 50 miles, aggregates are transported by rail, boat or barge and this is normally outside NW England. For aggregates delivered to a construction site in North West England, limestone and cheap fill tends to cost £7.50 per tonne whereas sand and gravel costs £10.00 to £11.00 per tonne, depending on location and market (Dennan 2004).

Data was unavailable for timber production in North West England.

3.2 Use of raw materials

The main uses of primary aggregates in England have been collated, as shown in Table 4.

In England, nearly one quarter of the primary aggregates is used in the construction of roads and one fifth is used in the construction of housing, these two being the major uses of primary aggregates.

The sales of primary aggregate production in North West England in 2001 by the main end uses have been collated, as given in Table 5.

In North West England in 2001, one quarter of primary aggregates was sold for use in concrete whereas another quarter was sold for use as fill material in construction, the two uses making up half of the total sales for that year.

Common clay and shale

The production of common clay and shale in North West England in 2001 was 512,000 tonnes. The end use for bricks, pipes and tiles was 410,000 tonnes, for construction use was 13,000 tonnes and the other uses amounted to 89,000 tonnes (BGS 2003).

Since 2001 industry has contracted in a much smaller number of large quarry operators whose strategies are thus greater than North West England region (national and even international) so regional strategies are compromised by the companies strategy. The British Geological Survey Aggregate Mineral Survey is considered to be 90% accurate. Four annual surveys are planned, the next will be for 2005 and is due for publication in 2006. New and reduced estimates of requirements outlined in Table 8.3 of March 2004 submitted draft of Partial Review of Regional Planning Guidance for the North West (RPB13) imply less reliance on imports and greater compliance with the directive towards regional supply meeting regional demand. However, regional 'sustainability' for the supply of aggregates is overstated as it is cheaper and nearer to import aggregates in to Cheshire from North Wales and in to Greater Manchester from Derbyshire than from the north of the North West England region and market forces will dictate the origin of supply. The comment by NWRAWP on the "4sight" report was that clarification was sought by industry on the information sources in the report. Industry felt it was performing better than the report illustrates. Readers of the report should beware of over-interpreting the facts and figures due to lack of reliable data.

4. Construction products

Construction products for which production data was available were bricks and pre-cast aggregate concrete blocks. Data was unavailable for glass and glazing.

4.1 Bricks

For the year November 2001 to October 2002, there were 293,396,000 bricks estimated to be produced in North West England. For the year August 2003 to July 2004, the total deliveries of bricks into and within North West England were estimated to be 295, 978,000 bricks, i.e. the sum of the number of bricks produced in North West England and the number of bricks imported into the region from other regions of the UK. The number of bricks imported into the UK from abroad is estimated at 200 million per annum.

A reasonable estimate of the number of bricks used in the North West England is 320 million per annum at an average weight of 2.75kg per brick. Thus Brick usage in the NW England for the year August 2003 to July 2004 is estimated at 880 Mt p.a. (J Hattersley 2004).

4.2 Pre-cast aggregate concrete blocks

Annual data for the production, stock and delivery of pre-cast aggregate concrete in North West England is given in Table 6. The quantity of dense aggregate blocks produced and delivered in North West England was more than twice that of lightweight aggregate and aerated blocks in 2001.

5. Current building stock

The current building stock in North West England includes the following:

- Dwellings (homes);
- Commercial buildings;
- Industrial buildings;
- Public buildings.

There are approximately 2.9 million dwellings in North West England including approximately 1 million in Greater Manchester as compared with 24.4 million dwellings in Great Britain (Shorrock and Utley 2003, Ravetz 1996). Table 7 contains a frequency analysis of dwelling type and age in North West England whereas table 8 gives a cross-tabulation of dwelling type by age. In North West England the most popular type of dwelling is the semi-detached house, making up nearly one third of the housing stock, with medium and large terraced houses being the next most popular (table 7). The most active period of building dwellings was the twenty year period immediately after the Second World War (1945 to 1964) when much reconstruction of infrastructure was necessary (table 7). The next most active period was after the First World War and during the Second World War (1919 to 1944) (table 7). Semi-detached houses have increased in popularity since the First World War but at the expense of terraced houses (table 8).

Recently built dwellings are on average smaller, and on smaller plots than older housing. The average size for a post 1980 home is 83m^2 compared to 88m^2 for those built before 1980. Where they can afford it, households in the private sector opt for more living space (EHCS 2001).

The distribution of compositions of roofs in dwellings in North West England is summarised in table 9. Pitched roofs are the most popular type of roofing in dwellings in North West England, making up 95% of roof structures. The concrete tile is the most popular type of roof covering material (49.4%) with the slate being the second most popular material (29.9%) and clay being third (14.6%). BRE Approved Environmental Profiles for similar roof constructions are given in appendix 1.

The distribution of compositions of walls in dwellings in North West England is also given in table 9. Cavity walling is the most used type of wall structure (75.8%) with nine inch solid masonry being the second most popular wall construction (only 14.9%) and thicker than nine inch solid masonry being third (only 6.2%). The mostly frequently used wall finish type is masonry pointing (77.1%) with the second most popular being a rendered finish (20.3%). BRE Approved Environmental Profiles for similar wall constructions are contained in appendix 1. Timber frame with blockwork walls and concrete floors is also used in dwellings.

The distribution of external elements in dwellings in North West England is given in table 10. The mean number of bay windows (both single-storey and multi-storey) exceed the mean number of either dormer windows, porches, conservatories or balconies. PVC-u framed double-glazed windows are the most used type of windows with wood framed single-glazed casement windows being the second most used. PVC-u single-glazed windows are the least popular. Externally, the mean number of timber doors and frames used exceed the mean number of PVC-u doors and frames used, with even less metal doors and frames used.

In Greater Manchester, there are approximately 73,000 commercial and industrial premises and about 15,000 public buildings of varying types, sizes and ages (Ravetz 1996). These can be composed of cavity walls or solid masonry walls (brick, concrete block or stone) or be timber framed or steel framed with blockwork walls. Floor construction is timber or concrete. Roofs are pitched or flat, pitched roof of slate, concrete or clay tiles on timber and flat roofs of organically coated metal or felt on timber.

5.1 Energy use

The relationship between the energy consumption of a dwelling and the external temperature also depends on the heat loss from the dwelling and the energy used for space heating.

The heat loss from dwellings depends on the surface area to volume ratio and so will depend on the dwelling type. Typical average heat losses of existing dwellings would be as follows:

- Detached house = 365W/^{o}C;
- Semi-detached house = 276W/^{o}C;
- Terraced house = 243W/^{o}C;
- Bungalow = 229W/^{o}C;
- Flat = 182W/^{o}C.

The overall average heat loss for all dwellings in the existing housing stock in 2001 were about 259W/^{o}C (Shorrock and Utley 2003).

The energy use in dwellings depends on the type of dwellings. Detached houses use the most, with semi-detached using less, terraced houses consuming even less and flats and maisonettes using the least. The average detached house is three times as energy intensive as the average flat (Ravetz 1996). The average energy consumption per dwelling in Great Britain was found to be 80.8GJ, with the majority being for space heating (50.0GJ) whereas the average external temperature was 6.6^{o}C in 2001 (Shorrock and Utley 2003). For an average semi-detached house of floor area 80m^2, the average energy consumption is 1.0GJ/m^2 (0.6GJ/m^2 for electric powered heating and 1.325GJ/m^2 for gas powered heating).

The Beddington Zero Energy Development (BedZED) is an environmentally-friendly energy-efficient mix of housing and work space in Beddington, Sutton, Surrey, rather than in North West England. During its first year of occupancy, its energy performance was significantly better than for the national mean and new homes built to 2000 Building Regulations (table 11). The heating requirements of BedZED homes are approximately 10% of that for a typical home. To gain credits under the EcoHomes scheme, the thermal performance of the building fabric of homes must be better than between 10% and 30% of the 2000 Building Regulations requirements (appendix 1).

For Greater Manchester, the types of commercial and public buildings that use the most energy are those in the health, education and distribution sectors, with more than 5000GJ/year being consumed (Ravetz 1996).

Buildings contribute almost half, about 46%, of the UK's carbon dioxide, a greenhouse gas, which contributes to climate change. The 24 million dwellings in the UK contribute about 27% of the carbon dioxide produced. In the Energy White Paper, the government aims to reduce carbon dioxide emissions by 60% by 2050, with real progress by 2020. Since approximately half of the carbon dioxide emissions arise from buildings, improvements in Building Regulations are considered a major contributor towards achieving this aim. Building Regulations Part L (Thermal) now gives greater consideration to existing buildings.

The European Energy Performance of Buildings Directive (EPBD) requires that minimum energy performance standards are set for large existing buildings being refurnished (floor area greater than 1000m^2). The EPBD also requires energy performance certificates to be provided whenever buildings change ownership or tenancy. There are also requirements for regular inspection of boilers and air conditioning plant.

When an existing home is being extended and the building works costs exceeds £8000, not only must the extension meet current standards, but cost effective improvements to the existing part of the building, such as increased insulation of loft spaces, filling cavity walls or replacing the central heating boiler, could also be required. Although some of these measures may be not welcomed by some on cost terms, they would be cost effective and provide pay-back in a short time.

5.2 Aerial thermal surveys

BRE has undertaken aerial thermal or infra-red imaging surveys in various regions of UK to determine heat loss from buildings. The information gathered could possibly be used to determine the number and types of existing building stock in the surveyed area. However, to date BRE has not undertaken any of these surveys in NW England.

5.3 BREEAM

For 15 years, BRE's Environmental Assessment Method (BREEAM) has been used to assess the environmental performance of both existing and new buildings. A number of types of buildings can be assessed, as follows:

- Homes - the version of BREEAM for homes is called EcoHomes (Rao et al 2000);
- Offices = BREEAM Offices (Baldwin et al 1998);
- Industrial buildings = BREEAM Industrial Buildings;
- Other types of buildings = BREEAM Bespoke Assessments.

BREEAM assesses the performance of a building in the following issues:

- Energy – carbon dioxide emissions, thermal performance of the building fabric, provision of drying space (EcoHomes), provision of eco-labelled white goods (EcoHomes), provision of low energy external lighting system;
- Transport – developing a site with good access to public transport, provision of cycle storage, proximity to local amenities, provision of a space and services for a home office (EcoHomes);
- Pollution – ensuring no ozone-depleting substances are used in the construction of the building, specification of boilers with low NO_x emitting burners;
- Materials – sustainably managed timber including for fittings, storage of recyclable waste including composting (EcoHomes);
- Water – reducing water consumption;
- Land use and ecology – ecological value of land, change of ecological value of the site, making effective use of the building foot-print;
- Health and well being – provision of adequate daylighting, designing for improving sound proofing, provision of private or semi-private external space (EcoHomes).

Marks are awarded for the performance in each area. The marks are then amalgamated to produce a single overall score rated on a scale of Fail, Pass, Good, Very Good or Excellent. A pre-assessment rating checklist allows a quick evaluation of the likely marking for a BREEAM assessment. The scores required for Pass, Good, Very Good and Excellent and a rating prediction checklist are given in appendix 1.

There are no BREEAM assessments available specific to North West England but data has been gathered for Northern England (North West and North East England, Yorkshire and Humberside), as summarised in Table 12. These results are a measure of the environmental performance of these assessed buildings in Northern England, including some in North West England.

The following issues are not as yet considered by BREEAM:

- Carbon storage and offset;
- Space devoted to cars;
- Local materials and labour;
- Light pollution;
- Proximity to employment (Ecohomes);
- Adaptability and flexibility (Ecohomes);
- Residents' stewardship (Ecohomes);
- Wildlife corridors;
- Easy to use controls (Ecohomes);
- Social mix/mixed tenure (Ecohomes);
- Permeable landscape.

The above issues are not considered for a number of reasons as follows:

- No clear improvement on current regulations or normal practice can be defined to help designers or developers reduce their impacts on the environment;
- There is no satisfactory way to assess a particular issue at the design stage;
- Understanding of the issue is not advanced sufficiently to devise robust assessment criteria;
- The issue is not applicable universally to different developments.

5.4 Effects of climate change

Although difficult to predict, climate change is likely to cause the following effects in North West England up to 2080 (UKCIP 2002):

- Increased sea level;
- Increased mean annual temperature;
- Reduced summer rainfall
- Increased winter rainfall;
- Decreased ultra-violet radiation;
- Increase in wind speed in autumn;
- Increase in gales in summer but slight decrease in winter.

Climate change could cause a number of impacts on the existing building stock in North West England. Increases in rainfall and wind speed would affect the weather-tightness of buildings. If no preventative action is taken, there would be increased rain penetration of properties. Possible preventive actions would include recessed windows and doors, greater eaves overhang, better detailing around openings and wider cavities in masonry.

Increases in temperature and rainfall would affect the durability of construction materials. If no preventative action is taken, plastics and timber are likely to have poorer durability, there would be increased potential for cracking of masonry and concrete and corrosion of metals is more likely. Possible preventative actions would include using higher quality materials, improving workmanship and detailing movement joints.

Increased mean annual temperatures would be likely to dry out soils in summer, causing movement of foundations. If no preventative action was taken, there is likely to be increased damage to properties due to foundation movement. Possible preventative actions include increasing the depth of foundations in susceptible locations.

Increased winter rainfall events in addition to construction on flood plains would increase the risk of flooding to properties. If no preventative action was implemented, there would increased damage to properties. Possible preventative actions include designing buildings to accommodate the ingress of water in vulnerable locations and to help buildings dry out quickly and the use of resistant materials.

For existing buildings, increased wind speeds will mean roofs are more likely to get damaged and so roof tiles will need to be replaced more frequently. If masonry suffers from rain penetration, it may need to be rendered. Windows would need to be maintained; good quality insulating glass units should be used if possible. Foundations may be damaged by subsidence and should be underpinned or repaired. To protect against flooding, flood defences need to be maintained and the resilience of the building should be improved, such as water resistant plasterwork. Rainwater can be collected from roofs to water gardens. For ventilation in buildings, the temperature should be raised to dispel damp in winter. Summer overheating in buildings could become more common, encouraging the use of more air conditioning, which would increase energy use and produce more carbon dioxide. Better natural ventilation and passive shading would be a more satisfactory remedial measure.

6. Construction waste

BRE has developed the SMARTWaste™ system (www.smartwaste.co.uk), which is a set of tools to help construction companies implement sustainable waste management practices. The individual tools are as follows:

- SMARTStart™ is a simple tool for auditing waste that enables the quantities across all of a company's construction sites to be evaluated. It is the first stage towards to developing a sustainable waste management plan. As waste containers leave a site, the percentage volume of waste in 14 common waste groups is visually assessed and recorded.
- SMARTAudit™ is an accurate tool for benchmarking and categorising waste by source, type, quantity, cause, cost, quality, condition and potential. This data is a springboard to identifying and prioritising actions to reduce waste arisings (producer responsibility), reuse at source (proximity principle) and maximise recovery to extend life cycles of materials.
- SMARTStartLG was developed in partnership with the Movement for Innovation (M4I). It is a tool for auditing and benchmarking waste to help inform and influence decisions on process re-engineering and to maximise opportunities for waste minimisation, reuse and recycling. It allows monitoring of segregation targets throughout the lifetime of a project and encourages continual improvement. The tool can be used to help:
    - Contractors set challenging waste segregation and recycling targets to improve efficiency, add value to clients and increase profit margins;
    - Local government officers in assessing contracts on the basis of best value at the tender stage and monitoring performance of the portfolio of projects in their area;
    - Managers to monitor that best value is being achieved.
- BREMAP™ is a web-based Geographical Information System (GIS) developed by BRE and funded by Biffaward through landfill tax credits and a grant from the Institution of Civil Engineers (ICE) Research and Development Enabling Fund. By imputing the postcode of a construction site into BREMAP, waste management facilities and materials or products available within a specified distance of the site can be identified.

BRE's SMARTStart™ waste auditing tool was used to determine the types and quantities of waste generated during various construction projects in the UK but not specific to North West England (Tables 13 and 14).

It can be seen that the type of waste generated depends on the type of construction project being undertaken. The largest quantities of waste for both office and construction were for insulation, metals, miscellaneous, packaging, plaster and cement, plastics and timber although the quantities varied for the different types of projects (table 13). The largest quantities of waste for road construction projects were for concrete and inert material. The floor area for office construction projects considered was twice that for residential construction projects whereas the area for road construction projects was relatively small (table 14).

7.Demolition and other secondary waste materials

Estimates of the arisings and uses in construction of recycled and secondary materials in England and Wales have been gathered and are summarised in Table 15. Some of these materials are wastes generated from construction activities but others are by-products of other industrial processes.

A significant proportion of total arisings of secondary and recycled materials are not reused in construction in the UK. However some are outlined, as follows:

Construction and Demolition (C&D) waste is increasingly used as aggregate in construction. This is likely to be encouraged by increases in the rate of the Landfill Tax and the introduction of the Aggregates Levy. The estimated composition of construction and demolition waste is given in Table 16.

On site crushing of C&D waste, including stacking for storage typically costs £2.00 per ton. The value of C&D Waste is usually £1.00 per ton below cost of primary aggregate and subject to market conditions, for example, much increased demand in winter for use for constructing farm tracks. Much C&D Waste is taken to exempt sites and transfer stations. C&D Waste also often left on site for fill for future development (Dennan 2004).

Bituminous road planings are primarily reused in road repair schemes and as capping layers, preferably on site as arising.

Blast furnace slag and steel slag from the iron and steel making industry are reused in asphalting and road stone in areas in which they arise.

China Clay waste stockpiles are all in SW England and some now lie under areas of nature conservation interest. China clay waste has an established sand and aggregate use. The feasibility of moving substantial quantities of material by rail and sea to bulk fill projects in the NW England is currently being investigated.

Colliery spoil stockpiles are at working mines and most are used as bulk fill in site restoration. However, the aggregates levy has improved the commercial feasibility of using minestone as aggregate.

Pulverised Fuel Ash (PFA) from power stations is most commonly used as a cement substitute in concrete and as a fill material. Some PFA may be recoverable from some old landfills.

Furnace Bottom Ash (FBA) from power stations is used as an aggregate in the manufacture of lightweight pre-cast aggregate concrete blocks and in blended cements.

Spent Railway Track Ballast is used as a graded aggregate after crushing

Slate waste exists in long-term stockpiles in North Wales (approximately 453 million tonnes), Cornwall (approximately 12 million tonnes) and Cumbria (approximately 5 million tonnes). The introduction of the Aggregate Levy makes transporting and reuse as aggregate more commercially feasible.

Waste glass is mainly to reuse container glass in manufacturing new containers. Waste glass can also be used as a substitute for aggregate in asphalt for road construction, in concrete, in loose fill and in back fill.

Municipal Solid Waste (MSW) Incinerator Bottom Ash (IBA) is generated from combusting waste in municipal incinerators. The main uses of IBA as an aggregate in asphalt in road construction and in pre-cast aggregate concrete blocks. Other applications include bulk fill, road base material and daily cover at landfill sites. Factors such as increased cost of disposal, exemption from aggregates levy and increased arisings should increase the use of MSW incinerator bottom ash as an aggregate, so long as regulatory constraints driven by negative publicity over dioxins do not become over-onerous.

Scrap tyre rubber, in the form of crumb, is used as a substitute for aggregate in surfacing sport and play areas and in road surfacing. Road surfacing is still in the trial stage in the UK but is now well established in France. The resultant surface is quieter and less reflective than asphalt but is 10% more expensive. Principal non-aggregate use is as fuel for cement kilns.

Fired ceramic waste is used as bulk fill for roads and paths.

Spent foundry sand many smaller geographically scattered stockpiles exist at casting works but high transport costs restrict use. Anecdotal evidence suggests that there are some substantial dedicated landfills of spent foundry sand at major casting works, possibly amounting to several million tonnes. The main use of spent foundry sand is in the manufacture of pre-cast aggregate concrete blocks and in ready-mix concrete. A comparatively smaller quantity is used in asphalt manufacture.

Case study: PFA generated at Fiddlers Ferry Power Station, Cheshire

Arisings of PFA in 2003 were 300,000 tons p.a. Sales at Fiddlers Ferry average 200,000 tonnes per annum, 50% being used for cement production at Clitheroe, Lancashire and the rest as fill and for concrete block making. The stockpile is 12 million tonnes. There is sufficient storage to outlast the life-time of the power station which is estimated at another 12 years.

A potential use of up to 1 million tonnes of PFA would be to fill subsidence causing voids in Northwich salt caverns. In 2001, Fiddlers Ferry lost the sale of 200,000 tons PFA for fill at new Junction 8 on adjacent M62 to the Highways Agency who accepted a cheaper quote from the developer of a sand quarry at Croft (Warrington). Because of the value of the subsequent hole, the sand quarry developers were able to undercut the Fiddlers Ferry quotation (Jones 2004).

8. Future construction

Each year 6500 hectares of rural land in the UK is developed. 130,000 new homes are being built in England per year. The UK government aims include building 3.8 million new homes in the UK by 2016 and building 60% of new development on brownfield land. These would probably be mainly flats, possibly due to high land values and high property prices. It is estimated that new construction in North West England will be 1.0% to 1.5% per year.

English Partnerships on behalf of the Office of the Deputy Prime Minister is running a competition with the aim to demonstrate that high quality, cost effective housing can be built with a target construction cost of £60,000. 33 organisations have been invited to participate in the next stage of the Design for Manufacture Competition (June 2005).

8.1 Materials use

Almost 150 tonnes of materials are used to construct a typical house (Anderson and Howard 2000). The quantities of construction materials used in each building element for typical housing and offices have been estimated and are given in tables 17 and 18. Data was unavailable for individual types of housing or offices.

8.2 Modern methods of construction

Modern methods of construction (MMC) are increasingly used along side traditional methods of construction. MMC techniques includes the follows:

- Prefabrication and modular construction;
- Off-site and ex-situ manufacture and construction;
- Pre-cast concrete piling;
- Timber-framed construction;
- Steel-framed construction.

Building elements are usually manufactured in a factory before transportation to site, making construction on site generally simpler and safer. These techniques will be used increasingly to construct a range of buildings, including the following:

- Houses;
- Schools;

- Hospitals.

MMC will likely compliment traditional methods of construction but not replace them. Prefabricated building elements have the potential to be reused.

BRE has hosted two exhibitions at its Watford headquarters, showcasing MMC – OffSite 2003 and OffSite 2005.

8.3 Energy use

The European Energy Performance of Buildings Directive (EPBD 2004) must be implemented by January 2006. This requires that minimum energy performance standards are set for all new buildings. In the UK, the Standard Assessment Procedure (SAP) will be used for assessing dwellings and the National Calculation Tool (NCT) will be used for assessing other buildings.

It is estimated that the government’s new proposals will lead to a 25% improvement in the energy efficiency of new buildings and a reduction of 25% in the carbon dioxide they would otherwise have emitted. The type of domestic heating system which generate the least emissions of carbon dioxide is gas powered condensing boilers so this is the preferred heating system for the future. Thermal insulation in homes such as loft insulation, cavity wall insulation and double-glazed windows will be used to decrease energy use. Renewable energy sources such as photovoltaic cells and other low carbon technologies such as Combined Heat and Power (CHP) will be incorporated into non-domestic buildings.

8.4 Effects of climate change

The predicted climatic effects of climate changes were outlined in section 5. During the construction of new buildings, work is likely to be disrupted by the effects of climate change (UKCIP 2002). Increased rainfall and increased wind speeds will affect the health and safety of site operatives. Construction materials such as double-glazing units and timber will need to be stored well on site to prevent deterioration due to increased wind and rain. Modular and off site construction methods will be preferable to traditional construction methods in increased wind and rain conditions.

For new buildings, fixings for roofs would need to be chosen to withstand increases of 5% to 10% in wind loadings. For masonry, use good building practice to avoid cracking and design for greater exposure to driving rain. When specifying windows, good quality insulating glass units should be chosen which would be weather-tight and resistant to ultra-violet radiation. For foundations, the foundation depth for clay soil susceptible to shrinkage or subsidence should be increased by 0.5m. To prevent the effects of flooding, new buildings should not be built on flood plains, floor levels should be raised and underfloor wiring should be avoided. To avoid coastal erosion, new buildings should not be built in vulnerable areas. Water resources should be considered an integral part of new developments, so sustainable drainage schemes and grey water collection systems should be incorporated. New construction should incorporate good ventilation, increased insulation levels such as cavity fill, loft insulation and double-glazing and an efficient heating system.

8.5 Recycling and reuse of materials

The recycling and reuse of materials, including in construction, is being driven by a number of carrots and sticks, as follows:

- The sustainable construction and sustainable development agendas and support and encouragement for construction waste minimisation, recycling and reuse from government, local authorities and the Environment Agency;
- Guidance on recycling and reuse from BRE, CIRIA, Envirowise and WRAP;
- The European Landfill Directive which restricts the landfilling of certain materials such as rubber tyres;
- The UK Landfill Tax payable on all landfilled waste;
- The Aggregates Levy payable on all primary aggregates;
- The harmonisation of construction product standards should create a level playing field for the use of primary, secondary and recycled aggregates;
- In major government funded construction projects, 10% of the materials value has to be derived from recycled content.

There are opportunities for using recycled and recovered materials in construction. The main strategies, as follows:

- Product substitution – such as using precast concrete blocks with 50% instead of 0% recycled content);
- Changing to an alternative design or specification.

There are opportunities to reuse recycled and recovered materials in the full range of construction and civil engineering projects (WRAP 2004, 2005), as follows:

- House building;
- Public and industrial buildings;
- Commercial developments;
- Road construction;

- Infrastructure.

9. Discussion

All the stages of the whole life cycle of construction resources in the Eco-Region of North West England have been considered, as follows:

1) Raw materials
2) Construction products
3) Current building stock
4) Construction waste
5) Demolition and other secondary waste materials
6) Future construction

Issues relevant to each stage have been considered. Also for each stage, the available, current and reliable data available has been collected and tabulated. If data was unavailable for NW England, data was gathered for Northern England, England and Wales or the UK. Although some data was available for construction resources in North West England, much was not.

9.1 Raw materials

The main raw material considered was aggregate. Less than half of the crushed rock consumed in North West England is produced there whereas slightly less marine sand and gravel is consumed in North West England than is produced there. In North West England in 2001, one quarter of primary aggregate was sold for use in concrete whereas another quarter was sold for use as fill material in construction. No data was available for timber production in North West England.

9.2 Construction products

The major construction products considered were bricks and pre-cast aggregate concrete blocks. In North West England the number of bricks produced per year is estimated to be approximately 293 million whereas the number of bricks used in the same period is estimated to be approximately 320 million so bricks must be imported from other regions of the UK. The quantity of dense aggregate concrete blocks produced and delivered in North West England was more than twice that of lightweight aggregate and aerated blocks in 2001. Data was unavailable for glass and glazing.

9.3 Current building stock

Currently there are approximately 2.9 million dwellings (homes) in North West England including approximately 1 million in Greater Manchester as compared with 24.4 million in Great Britain. The most active period of building dwellings was the twenty year period immediately after the second World War (1945 to 1964) when much reconstruction of infrastructure was necessary. Semi-detached houses have increased in popularity since the First World War but at the expense of terraced houses. Recently built dwellings are on average smaller and on smaller plots of land than older housing. Pitched roofs of concrete, slate or clay tiles are the most common type of roof. Cavity walling with masonry pointing or a rendered finish are the most type of external walling. PVC-u framed double-glazed windows and timber doors are the most popular types of windows and external doors in North West England.

In Greater Manchester, there are approximately 73,000 commercial and industrial premises and about 15,000 public buildings of varying types, sizes and ages.

The heat loss from dwellings depends on the surface area to volume ratio and so depends on the type of dwelling. For typical existing dwellings, the average heat loss for a detached house is 365W/^{o}C whereas that for a flat is 182W/^{o}C. The energy use in dwellings also depends on the dwelling type; detached houses use the most whereas flats use the least.

In Greater Manchester, the types of commercial and public buildings that use the most energy are those in the health, education and distribution sectors. The European Energy Performance of Buildings Directive (EPBD) should help improve the thermal performance of buildings in North West England.

For 15 years, BRE's Environmental Assessment Method (BREEAM) has been used to assess the environmental performance of both existing and new buildings. There are no BREEAM assessments available specific to North West England but data has been gathered for Northern England (North West and North East England, Yorkshire and Humberside).

Climate change is likely to cause impacts to existing buildings in North West England. Increases in temperature and rainfall are likely to affect the durability of construction materials and remedial work may be necessary. Increased mean annual temperatures would be likely to dry out soils in summer, causing movement of foundations and so require remedial work. Increased winter rainfall events in addition to construction on flood plains would increase the risk of flooding to properties.

9.4 Construction waste

BRE had developed the SmartWaste system which is a set of tools to help construction companies implement sustainable waste management practices. One of the tools was used to determine the types and quantities of waste generated during various construction projects in the UK but not specific to North West England.

9.5 Demolition and other secondary waste materials

There are a range of demolition and other secondary materials available in North West England, some of which are reused in construction. For example, Construction and Demolition (C & D) Waste is used increasingly as aggregate. Bituminous road planings are reused in road repair work. Pulverised Fuel Ash (PFA) from coal fired power station is used as a cement substitute in concrete and as a fill material.

9.6 Future construction

In the future the government plans much development in North West England. Modern methods of construction (MMC) including prefabrication and off-site construction will be used increasingly alongside traditional methods of construction and will be important in constructing homes, schools and hospitals. The European Energy Performance of Buildings Directive (EPBD) will require that minimum energy performance standards are set for all new buildings.

During the construction of new buildings, work is likely to be affected by the effects of climate change. Increased wind speeds and increased rainfall will affect the health and safety of site operatives. Construction materials will need to be stored well on site. Modular and off site construction methods will be preferable to traditional construction methods in increased wind and rain conditions.

The recycling and reuse of materials in construction is being driven by a number of carrots and sticks. In major government funded construction projects, 10% of the materials value is to be derived from recycled content. There will be increasing opportunities for using recycled and recovered materials in the full range of construction and civil engineering projects in the North West of England.

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Table 1: Primary aggregate production, imports, exports and consumption in North West England during 2001 to 2002 (in thousands of tonnes) (BGS 2003, Dickinson 2003, Lawson et al 2003, NWRAWP 2004, Worsley 2003)

Aggregate type	**Aggre-gate production in NW England**	**Aggregate imports into NW England**	**Aggregate exports from NW England**	**Net imports into NW England**	**Total aggregate consumtion In NW England**	**Non aggre-gate production in NW England (Industrial use)**	**Multiplier for waste and overburden (to total material moved)**
Limestone	5,600	8,253	86	8,167	13,767	1,400	+ 15%
Sandstone and Igneous Rock	4,600	888	1,031	(143)	4,457	27	+ 15%
Land won Sand and Gravel	3,200	901	430	471	3,671	1,694	+ 25%
Marine Sand and Gravel	500		24	(24)	476	2	+ 7.5%
Harbour Authorities Sand and Gravel	50				50		+ 7.5%
Total (% total primary aggregate consumption**)**	13,950 (62%)	10,042	1,571	8,471 (38%)	22,421	3,123	
Slate	158 (135 crushed as aggregate plus 23 crude blocks)						Blocks x 15
Gypsum	175						nil

Table 2: Aggregate produced and consumed in NW England as a percentage of that for England and Wales/%

Aggregate type	**Production/%**	**Consumption/%**
Limestone, Sandstone and Igneous rock (crushed rock)	7.5	15.5
Land won sand & gravel	5.1	5.7
Marine sand & gravel	3.2	3.1

Table 3: Landbank for NW England on 31/12/2002 (NWRAWP 2004)

	Permitted Reserves (Thousand Tonnes)	**Annual Average Apportionment (Thousand Tonnes)**	**Landbank (Years)**
Crushed Rock	327,900	12,550	26.1
Sand and Gravel	47,300	4,650	10.2

Table 4: Main uses of primary aggregates in construction in England (MPG 6)

Use	**Percentage of aggregate used/%**
Housing construction	20
Housing repair & maintenance	8
Road construction	24
Road repair & maintenance	8
Private industry	11
Private commercial	12
Public works	13
Other	4

Table 5: Sales of primary aggregate production in NW England in 2001 by main end use (BGS 2001).

Use	Percentage of aggregate sold/%
Course and fine aggregate for concrete	25
Sand for building and asphalt	8
Coated gravel roadstone	11
Uncoated roadstone	12
Other screened and graded aggregate	17
Construction fill	25
Undifferentiated	2

Table 6: Quantity of production, deliveries and stocks of pre-cast aggregate concrete blocks in NW England in 2001 (in thousands of square metres) (ONS 2002).

Block type	Production	Deliveries	Stock
Dense aggregate	4519	4517	590
Lightweight aggregate & aerated blocks	2056	2100	178
Total	6575	6617	768