



Forum for the Future

Mainstreaming Mass Balance

on farms and in
universities

The mass balance approach
for organisations

Biffaward
Programme on
Sustainable
Resource
Use

Mainstreaming Mass Balance on farms and in universities

Can the success of the mass balance tool in measuring and reporting complex resource use be replicated for organisations? This report shows how organisations – using the examples of universities and farms – can use the mass balance approach to streamline their resources and save money.

Forum for the Future is recognised as the leading sustainable development charity in the UK and has worked with Biffaward since 2002 to develop the mass balance methodology for more sustainable resource use.

Forum is an educational charity that aims to share positive lessons and solutions for sustainability with our many partners, and beyond. We would like to thank Biffaward for their support of the project.

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Biffaward Programme on Sustainable Resource Use

Objectives

This project report forms part of the Biffaward Programme on Sustainable Resource Use. The aim of this programme is to provide accessible, well-researched information about the flows of different resources through the UK economy based either singly, or on a combination of regions, material streams or industry sectors.

Background

Information about material resource flows through the UK economy is of fundamental importance to the cost-effective management of resource flows, especially at the stage when the resources become 'waste'.

In order to maximise the Programme's full potential, data will be generated and classified in ways that are both consistent with each other, and with the methodologies of the other generators of resource flow/waste management data.

In addition to the projects having their own means of dissemination to their own constituencies, their data and information will be gathered together in a common format to facilitate policy making at corporate, regional and national levels.

Biffaward has funded more than 30 different mass balance projects.

For more information on the Mass Balance UK programme please visit www.massbalance.org



Mainstreaming Mass Balance on farms and in universities

Executive summary

With the environmental performance of organisations under scrutiny, organisations are looking at ways to capture, manage and measure all of the resources that flow in, through and out of an organisation – so they can make improvements fast.

Mass balance has already proved its value as a resource flow management tool for industries – providing a framework for systematically accounting for all the resources that go in, through and out of an enterprise. *Mainstreaming Mass Balance on farms and in universities* reports on a study that tested the potential for applying the framework to individual organisations.

The study has cleared up many of the uncertainties around applying the framework at the organisational scale: would it provide useable management data? Would data be useful for benchmarking against peers? How easily could the results be communicated? Testing the framework with two very different types of organisation has given a depth and breadth to the following conclusions about the framework's applicability to organisations:

- An organisational mass balance provides a strong visual representation of resource use within a whole organisation, showing how resources flow between operations or departments and helping managers to rethink inputs and waste in a joined up way.
- An organisational mass balance can also show which individual departments use the most resources and why – allowing managers to focus on problem areas in the context of the whole organisation.
- An organisational mass balance uses standard shared figures making benchmarking between organisations – and even individual functions – simple. Similarly, using standard figures from an organisational mass balance can be related to other information at the regional or national level – useful for informing policy making.
- An organisational mass balance also has the capacity to act as a policy implementation tool. Its value lies in its ability to bring together the measurements demanded by new policy in one place. Furthermore, the resource data is firmly linked back to financial data – putting organisations using the framework at the forefront of developing a financial system that properly accounts for the real costs of social and environmental impacts.

So for example, in the farming sector waste management and energy efficiency issues have been pushed high up the agenda by new regulations. This combined with rising fuel prices means farmers are keen to track their resource use and see where savings can be made. As primary producers of crops and livestock with established data collection systems, farms fitted the model of measuring the 'solid' resources flowing in and out of the organisation very well. Demands for dramatic reductions in resource use are on the horizon for all farms – the mass balance approach could prove a valuable way of matching the resource management to financial planning.

Universities, on the other hand, are dependent on very different inputs and outputs that do not readily match the model. It has proved capable of giving an insight into the flow of resources through the organisation. Those with quality procurement data will also be able to lead the way in matching their budgets to resource use and emissions. With the pressure growing to demonstrate responsible resource use and financial efficiency to funders, the most successful universities and colleges will be those exploring tools like mass balance that are able to tie expenditure to resource use of all kinds.

Introduction

The mass balance approach aims to enhance sustainability by better accounting for resource flows. This is a report of a study that explored how the mass balance approach can be used as a resource management tool within organisations.

The approach has been developed by working with farms and universities. Substantial differences exist between the organisations, which have enabled the application of the mass balance tool to be tested in situations with very different needs and information sources, demonstrating a range of applications of mass based resource flow data.

Section 1 of this study explains the mass balance approach in more detail, and explains some conclusions about using the approach with two very different organisations. The major differences between the organisations are that a resource-dependent farm system already has a great deal of mass-related information and accounts available, whereas a university – whose aim is to produce learning and knowledge – may not have information available making the mass balance approach much more difficult to apply. The report explores these differences and suggests some next steps – both for the mass balance approach at organisation level, and for how this level of information can help inform the other Biffaward Mass Balance studies.

Section 2 examines the mass balance framework as it applies to the farming sector, using information from farms in the Forum Farm Network. One of the main drivers for this work has been changes to farm waste regulations and a detailed discussion of waste management at the farm level is presented, as the tool has been used to provide accurate measures of waste produced by each farm. The mass balance approach for farms can yield useful information about resource efficiency, energy use and waste production.

Section 3 describes the mass balance approach with universities, and how the process was applied with a number of Forum's higher education partners. It quickly became apparent that the type of information needed to complete a full, detailed mass balance in this sector was not available for entire universities. Nor could the usefulness of the information available from the mass balance justify a great deal of investment by universities in establishing this information for the purposes of this study. Instead, the applicability of the mass balance approach was tested with

selected departments and units within universities to build up a picture of resource use within a 'model' university.

The final outputs from this work with farms and universities, has been the development of two spreadsheet-based tools – one to apply the mass balance approach with farms, and one to apply the mass balance approach within any organisation, such as a university. These tools are described at the end of each section.

Section 1 Measuring resource flows – the mass balance approach

In this section the importance of a deeper understanding of resource flows to progressing sustainable development is explored, and the mass balance framework is introduced. How this approach could lead to more sustainable resource management within organisations is discussed, and this is illustrated with some findings from this study, focusing on farms and universities.

1.1 Introduction

1.1.1 Resource use

Evidence from the recent Millennium Ecosystem Assessment shows that resource consumption is proceeding at a pace that exceeds the earth's capacity to provide a life-sustaining environment for future generations.¹

At the heart of this assessment is a stark warning. Human activity is putting such strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted.

As human demands increase in coming decades, these systems will face even greater pressures – and the risk of further weakening the natural infrastructure on which all societies depend.

Protecting and improving our future well-being requires wiser and less destructive use of natural assets. This in turn involves major changes in the way we make and implement decisions.

*Statement of the Millennium Assessment Board, 2005*²

There are also issues of equity of resource use on a global basis. In the UK, ecological footprinting suggests that we use almost three times the amount of resources that are available according to an average 'earthshare' whilst less wealthy countries use far less.³

Factor four or factor ten improvements are often cited as being necessary to ensure sustainability. Factor four refers to the need to increase resource productivity fourfold, by

¹ Millennium Ecosystem Assessment (2005) Ecosystems and human well being www.millenniumassessment.org

² Living Beyond Our Means: Natural Assets and Human Well-Being – Statement of the MA Board (2005) www.millenniumassessment.org/proxy/document.429.aspx

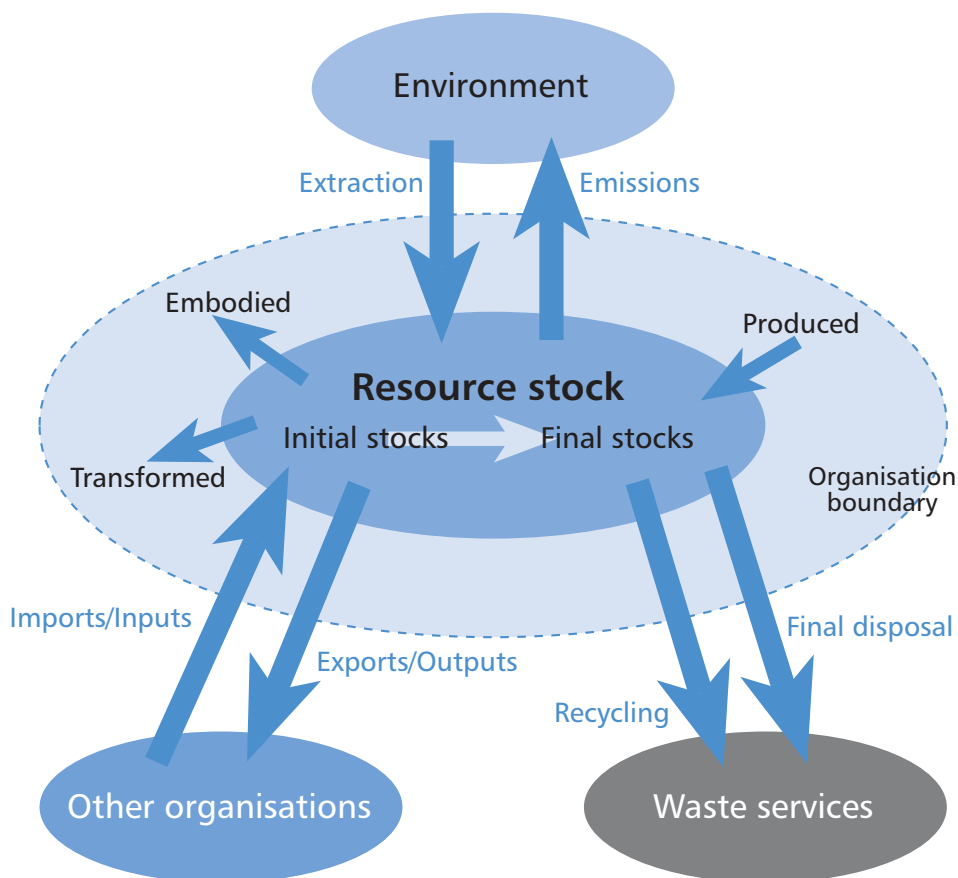
³ Barrett & Simmons (2003) An Ecological Footprint of the UK: Providing a tool to measure the sustainability of local authorities. John Barrett (Stockholm Environment Institute) & Craig Simmons (Best Foot Forward) www.york.ac.uk/inst/sei/odpm/ODPM%20Main%20Report.pdf

simultaneously doubling wealth and halving resource consumption. Factor ten improvements suggest that in the long-term, resource use in developed countries needs to be reduced tenfold if we are to approach sustainability.⁴ Either way, in the quest for sustainability, maximising resource and energy use efficiency, whilst minimising the wider impacts of resource and energy use and driving waste out of the system are paramount. To manage resources effectively, certain information must be established: how much resources are used, how much waste is produced, and the wider impacts of these activities. Robust data, tied in with national, regional and sub-regional accounting and reporting systems is key to managing and achieving this.

1.1.2 The mass balance approach

The mass balance approach provides a framework to account for resource use in a systematic way, based on the fundamental principle that the amount of mass in a system remains constant. It measures the flow of resources into and out of any system and assesses stocks of resources. Figure 1 shows how matter flows from the system or organisation to the environment and to other organisations, for each resource or material taken into account. The stock of each resource or material changes from ‘initial’ to ‘final’ over the accounting period. Table 1 shows the ten categories of resources used for mass balance accounting.

Figure 1 Conceptual model for organisation level mass balance



⁴ Factor Four targets were outlined by Weizsäcker, Lovins and Lovins in their 1997 book 'Factor Four. Doubling Wealth, Halving Resource Use'. The Factor Ten target was proposed by Schmidt-Bleek, of the Wuppertal Institute in 1994.

Table 1 Ten mass balance categories

1 Initial stock	Resource within the unit at the beginning of the period
2 Inputs/imports	Resource entering the unit over the accounting period
3 Produced/extracted	Resource created or produced within the unit during the accounting period
4 Outputs/exports	Resource moving out of the unit over the accounting period
5 Embodied	Resource that has been combined with other resources to make a new product (the resource retains its identity, i.e. it can still be separated out)
6 Transformed	Resource transformed into another resource, i.e. it cannot be separated out, chemically transformed
7 Recycled/recovered	Resource leaving the system and going to recycling or recovery (includes energy recovery)
8 Final disposal	Resource going to final disposal, e.g. landfill or incineration, non-recoverable
9 Emissions	Resource emitted to the environment, e.g. gases emitted or liquids leaving the system, non-recoverable
10 Final stock	Resource remaining in the system at the end of the accounting period.

The mass balance model has a number of advantages as a resource flow analysis tool:

- It can highlight material flow pathways, allowing identification and visual representation of the size of the flows
- It is transparent and is robust enough to be subject to more in-depth analysis, or to be systematically repeated to monitor changes over time
- It presents a balanced account allowing the inputs to be reconciled with the outputs (wastes, emissions, products) so that the fate of each of the resource inputs is determined
- Accounts of resources are based around a standardised classification of materials, so that micro-level accounting can be accumulated to contribute to the macro-level evidence base of resource use
- It is consistent with the Five Capitals model of sustainable development, using the principles of stocks and flows to measure progress in sustainable development. The Five Capitals model is more expansive, including human, social and financial flows as well as natural and manufactured flows. Connecting mass balance to this fuller model means that a more complete picture of the relative health of an organisation can be built up.

1.1.3 The mass balance approach and organisations

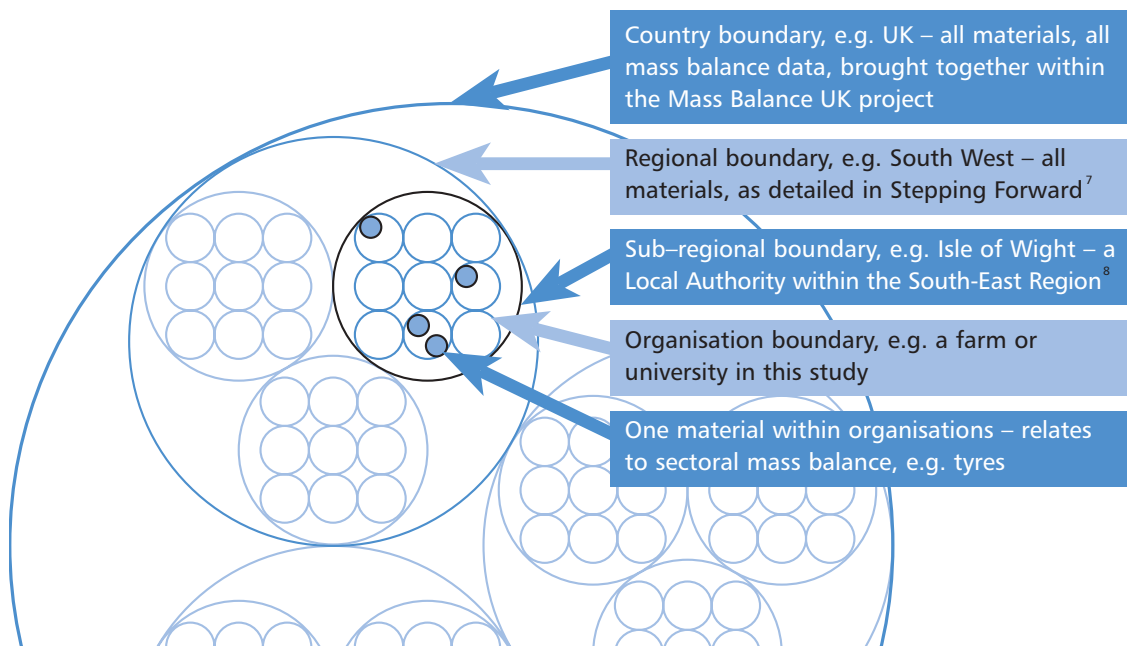
The Biffaward Mass Balance UK projects⁵ aimed to quantify resource use across industrial activities and regions, building up data across the UK. Approximately 40 research projects have examined and quantified the movement of resources through different economic sectors or geographical areas.⁶ The Mass Balance UK report made recommendations that suggested the future development of the framework for individual organisations.

Applying the mass balance framework to organisations opens up new challenges; it must be able to offer real management information to managers within the organisation to help them deliver efficient resource use and move towards sustainability.

At an organisational level, significant efficiency gains can be made through changing the ways resources are managed. As well as making financial savings and avoiding the costs of negative externalities, organisations are increasingly reporting to shareholders and stakeholders on their environmental performance and can benefit from communicating improved resource use.

In principle, a mass balance for organisations should relate to sub-regional, regional and national mass balance figures. This would enable tracking of resources through the economy to and from the organisation level. Specific materials used within each organisation relate also to a material-specific mass balance for the whole country. The relation between the organisation mass balance and other mass balance studies is shown in figure 2.

Figure 2 The mass balance approach at different scales



⁵ *Mass Balance – an essential tool for understanding resource flows*, co-authored at Forum for the Future's Sustainable Economy Programme (SEP) by Conor Linstead, Caroline Gervais and Paul Ekins
www.forumforthefuture.org.uk/uploadstore/MassBalanceFull.pdf

⁶ A list of all Biffaward Mass Balance projects is included on page 64 of this report.

⁷ *Best Foot Forward (2005) Stepping Forward – A resource flow and ecological footprint analysis of the South West of England* www.steppingforward.org.uk

⁸ *Best Foot Forward (2003) Island State – An Ecological Footprint of the Isle of Wight*
www.massbalance.org/projects/summaries/Reports/Island%20State.pdf

By focusing on the relationship between the organisational mass balance and larger-scale studies, results from this project can be used to inform ongoing databases and mass balance projects such as Ecological Budget UK,⁹ REMAT¹⁰ and Waste Flow.¹¹

The aim of this study has been to develop the mass balance framework for application at the organisational level, developing tools that can be used by managers within organisations with responsibility for resource use decisions.

1.2 How useful is the mass balance approach for organisations?

The major factor determining the benefits of applying a mass balance framework to an organisation is the purpose or aim of the organisation. This factor in turn determines:

- Availability of resource flow information within the organisation
- Structure of the organisation and how the constituent parts of the organisation are arranged
- Existing tools or approaches for managing resources within this type of organisation, e.g. if it useful to measure and account for resource use, there may already be systems for doing this, both within the organisation and available from other sources.

To develop this approach, Forum worked with farms and universities to adapt the mass balance approach and investigate whether this is a useful approach for organisations to take to measure resource flows.

Farms and universities have different resource flows, inputs and outputs. They are centred on very different production systems, farms producing primary crops and livestock outputs, and universities focusing on building up intellectual or human capital, in the form of knowledge, skills and research outputs. For universities, most discussion about resource use relates to environmental performance, rather than affecting the key business output, as is the case for farms. See Table 2 opposite.

⁹ *Ecological Budget UK* (2005) WWF & Stockholm Environment Institute (Biffaward Mass Balance Study) sites.wwflearning.co.uk/ecobudget/

¹⁰ The REMAT (REsource MAnagement Tool) information system is designed to help organisations manage the challenges of asset compliance from waste regulations contained in Producer Responsibility Obligations such as Waste Electrical and Electronic Equipment (WEEE) www.surrey.ac.uk/PRC/library/docs/PRO/exec_sum.htm#RD

¹¹ Waste Flow is the CIWM developed software for Local Authority reporting of municipal waste flows www.wasteflow.co.uk

Table 2 Inputs and outputs related to the aim of an organisation

	Farms	Universities
Main aim or function of the organisation	<ul style="list-style-type: none"> • Primary production of crops and livestock. • Secondary importance of conservation or agri-environment goals. • Main output/aim of the organisation is manufactured capital. 	<ul style="list-style-type: none"> • Education, skills raising and building intellectual capital through teaching and research. • Management of resources, e.g. food, heat, light, is a necessary activity in order to enable education. • Main output/aim of the organisation is human capital.
Production system	A production system: materials enter the system, products leave the system.	Not a production system: products enter the system and are used up.
Are outputs dependent on mass of inputs?	Desired outputs are mass dependent, i.e. decreasing inputs will directly decrease outputs.	Desired outputs are not directly mass dependent, i.e. intellectual capital or educational targets are not dependent on physical inputs (although they can benefit from them).

1.2.1 Availability of resource flow information

Organisations in different sectors may have very different requirements in terms of keeping information relating to resource flows, particularly in a format that directly relates to mass.

Farms

- Detailed resource-based records are available for farms. As well as purchases and sales, separate records are kept relating to inputs applied, e.g. sprays applied on a per hectare basis, and losses from the system, e.g. livestock culled.
- Production efficiency is closely related to financial sustainability of the business, so it is in a manager's interests to maintain up-to-date and accurate records.
- Many records are directly related to mass, as a necessary measure of resource efficiency for the farmer, e.g. the amount of fertiliser applied per hectare relates directly to the gross margin for the crop.
- The farm organisation usually involves one manager or a few enterprise managers, so that it is straightforward to maintain accurate and accountable records, with few areas of discrepancy.

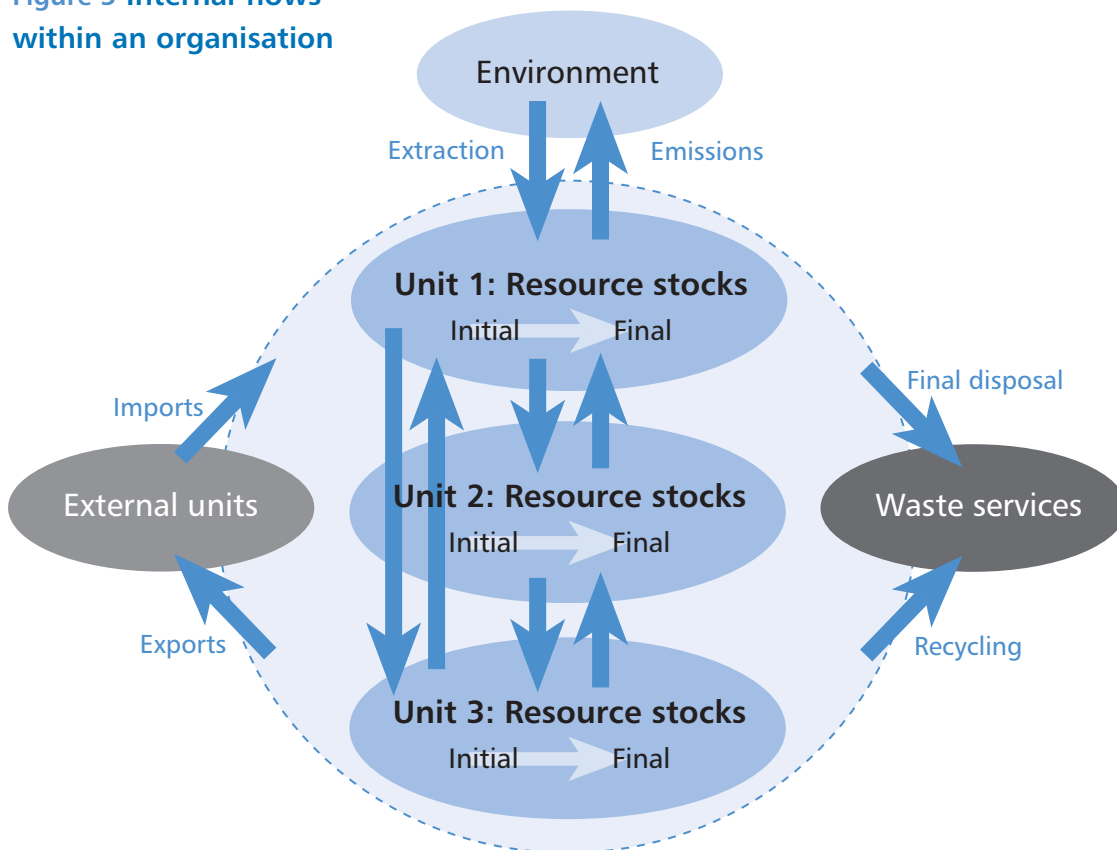
Universities

- Purchase information for inputs to the university departments is available, although this may not be in a format which is directly related to mass, as cost is the main factor affecting purchase decisions, e.g. catering department records showing expenditure on bread, without detailing the mass of the bread purchased.
- There is little recording of outputs from departments in terms of wastes, and few instances where a mass of product would leave the organisation.
- With a large number of people entering and leaving a university on a daily basis, there is a lot of resource movement which it is very difficult to account for, e.g. course materials being given to students and leaving the site, or packaging waste being brought onto the site and disposed of.

1.2.2 Structure of the organisation

Most organisations are organised into sub-units or operational units. The organisational mass balance can be constructed by taking information from each of these operational units and accumulating resource flows for the whole organisation. This then enables resource flows to be looked at for each unit, and flows from outside the organisation to be differentiated from those circulating within the organisation. This is shown in figure 3.

Figure 3 Internal flows within an organisation



Farms

- Farms fall into one of several main types of farm, depending on the mix of enterprises that are present. Farm enterprise relate directly to the idea of operational units.
- There may be resource efficiency issues centred on resource flows between the different farm enterprises, so that there is value in differentiating between resource flows from outside the farm and resource flows within the farm. For example, flows of feed crops from the arable unit to livestock units, or use of livestock manures by the arable unit.

Universities

- Several types of operational units are identified within universities, relating directly to departments, or estate management units.
- There are few resource flows or transfers between university departments, which affect the resource efficiency of the organisation. There is perhaps less to be gained from differentiating between flows from outside and from within the organisation than for a production-based system.

1.2.3 Existing resource management tools

Management tools are available to help organisations examine and manage resource use such as Life Cycle Assessment, Environmental Impact Assessment, Environmental Management Systems (EMS), and Strategic Environmental Assessment. All of these tools deal with particular sets of circumstances and are appropriate for organisations to achieve specific outcomes. For example, an EMS such as ISO 14001 will enable an organisation to identify its significant environmental impacts and aspects and put protocols in place to manage them.

Within different sectors there may already be different tools that an organisation can use or access to determine better resource management and ensure compliance with regulations.

Farms

Sources of information and existing resource management tools that are used by farmers include:

- Nutrient budgeting tools, for example to calculate necessary storage requirements for animal wastes
- Field application software to keep track of application of fertilisers and sprays on a per hectare basis, for example total nutrients applied
- Business management information to record accurately livestock inputs and outputs, for example dairy records to show concentrates fed and milk output.

Universities

Resource management tools available focus mainly on environmental reporting, e.g.

- ISO 14001, used by a small number of universities and colleges
- Estates Management Statistics (EMS) whose aim is to give UK Higher Education institutions access to relevant information to enable better strategy and decision-making.

In summary, managers within organisations may only invest time in using the mass balance approach, if they can directly apply the information it delivers, for example to bring about increased resource efficiency and potential cost savings.

1.2.4 The future for the mass balance tool for organisations

Different sectors have specific drivers for improving resource flow efficiencies and external pressures to closely examine mass-based flows. For some, the mass input efficiency is driven by waste costs and for others mass flows are intrinsically linked with their core business as a production system. Other organisations will have little need to examine mass flows. For those sectors which are not production-driven, e.g. education, greater pressure for environmental reporting and resource use efficiency will increase the need for consistent reporting on mass flows, particularly waste production and energy use. The mass balance approach would provide information in an accurate and consistent form, and would also be consistent with regional or national accounting frameworks.

Theoretically, the mass balance concept is useful for organisations as it clearly links resource efficiency with cost efficiency and resource use savings. Sections 2 and 3 of this report outline how it can deliver useful information for farms and universities. With wider use of the tool, a knock-on effect in encouraging sector-wide adoption is likely to be seen. As a step towards this, the mass balance tool for organisations could be trialled across a wide range of organisations, examining how it links with regional and sectoral data that is available from the wider suite of mass balance projects.

Section 2 Farm Mass Balance

This section of the report outlines how Forum has worked with farms to apply the mass balance approach. This has enabled the development of a mass balance tool for farms to look at resource flows. The report describes some of the findings from using the tool, and their relation to sustainable agriculture. A particular focus in this section is the extension of waste controls to farm wastes, and the role of the mass balance approach in farm waste, resource and energy management.

2.1 Introduction

2.1.1 Sustainable farming and resource use

Farm sustainability is about much more than providing food and fibre; land and all of its functions, underpins resource production at many levels with a whole range of private and public goods provided through farming. This was recognised in the Defra's Strategy for Sustainable Farming and Food in 2002.¹² Farming also builds social capital in many areas, in the form of business relationships, informal networks and providing public goods such as education and access to the countryside.¹³



Efficient production forms the basis of sustainable farming systems for all farm businesses, from both financial perspective and environmental perspectives. Depending on the production system used, 'closing the loop' makes sense financially, and environmentally, for many farmers.

¹² Defra (2002) Strategy for Sustainable Farming and Food: Facing the Future

¹³ Defra (2002) Farming and Food's Contribution to Sustainable Development - Economic and Statistical Analysis

The mass balance approach, with a focus on physical resource flows through a system, has direct application for farms for sustainable resource management. For example, the approach can help to focus on:

- Direct use of resources such as water, fertilisers and sprays
- Energy use
- Production and management of natural wastes (e.g. animal manures) and non-natural wastes (e.g. packaging waste).

Forum’s Farms for the Future report¹⁴ highlighted several examples of how farms can maximise and maintain sustainability in these areas, for example:

Direct resource use	<ul style="list-style-type: none"> ● reusing and recycling water on farm (Sheepdrove Organic Farm, Berkshire) ● Integrated pest management techniques (Loddington, Leicestershire)
Energy use	<ul style="list-style-type: none"> ● producing renewable energy on farm and using sources of renewable energy such as biomass (Loddington, Leicestershire) or biofuel (Bank Farm, Kent) ● adopting techniques which cut down on machinery and energy use (Shackerdale Farm, Nottinghamshire)
Waste production	<ul style="list-style-type: none"> ● using organic manures and compost within the system (Bank Farm, Kent) ● providing a waste disposal service to the local area for biodegradable and green wastes (Sheepdrove Organic Farm)

By applying the mass balance with individual farms, indicators will be highlighted that can be used to show progress towards sustainability in these areas, and outline some practical examples of what can be achieved. One of the main drivers behind this study has been the extension of waste controls to farm wastes. This is discussed in more detail in section 2.2.

A key phrase at the moment is catchment sensitive farming and area-based catchment level information is the key to this. A consistent mass balance approach can enable information about resource use within a group of farms, a catchment, or a region to be built up, as well as at an individual farm level, by accumulating information.

2.1.2 Previous agricultural mass balance studies

Previous Biffaward mass balance studies have been carried out in the farming sector, but not at an individual farm level and have focused on non-natural waste flows. The Environment Agency report, Towards Sustainable Agricultural Waste Management¹⁵ arrived at figures for waste quantities through a combination of a mass balance and a bottom-up approach based on farm practice. Waste estimates were based on the mass

¹⁴ Forum for the Future (2005) Farms for the Future: How farming is meeting the challenge of sustainability. www.forumforthefuture.org.uk/farming

¹⁵ Environment Agency (2001) Towards sustainable waste management

balance assumption that waste outputs were equal in mass to those purchased inputs which ended up as waste, e.g. silage wrap.

Estimates of UK waste arisings (1998) derived from the 'Agricultural Waste Estimate Model' ¹⁶	UK total estimate (tonnes/year) for 1998
Packaging plastic (e.g. agrochemical packaging, seed bags, oil containers etc.)	32,219
Packaging paper & card (e.g. agrochemical packaging, feed bags, silage wrap boxes etc.)	9,985
Packaging metal, wood, glass and rubber (e.g. oil drums, sheep dip containers, etc.)	1,951
Non-packaging plastics (silage plastic, horticultural films) (without contamination) Cores for films, net wrap and bale twine, tree guards)	60,506
Non-packaging cardboard	929
Animal health products (including sheep dip and used syringes)	116,500
Oils	27,095
Batteries, Tyres, Redundant vehicles and machinery	52,098
Asbestos cement roof sheeting	33,602
Total	334,883

These figures were calculated at a national and UK level. Farm practices for waste disposal were shown as the percentage of farms undertaking different waste disposal activities for each waste stream, rather than the mass of waste being disposed of by different methods. Another project¹⁷ explored the agricultural waste balance more closely, at a sectoral level, concluding that there is huge potential for commercial on-farm operations to utilise waste for energy and useful by-products. The work was also able to produce estimates of waste production and energy use within different agricultural systems.

2.1.3 Focus on farm waste

From early 2006, farm-produced wastes such as plastic and card packaging wastes, demolition waste and redundant machinery, will be reclassified as controlled wastes. Farms will have to dispose of these non-natural wastes through licensed operators, rather than disposing of them on-farm through burning and burial, as has been done in the past. In the UK it is estimated that the amount of farm waste that will fall under new regulations is about 337,000 tonnes, and this does not include the amount of waste currently stockpiled on farms which should be disposed of.

Farmers face many practical issues in disposing of farm wastes. There are various types of plastic involved in farm materials, all of which are recyclable, however in many cases the volumes are small and they may be difficult to separate and store. There are also few collection schemes for farm plastics in operation across the country.

¹⁶ Environment Agency (2003) Agricultural Waste Survey – a study of the management of non-natural agricultural waste on farms www.environment-agency.gov.uk

¹⁷ C-Tech Innovation Ltd. (2002) Agricultural waste Mass Balance: opportunities for recycling and producing energy from waste technologies

Particular farm wastes may be hazardous, for example, sheep dip chemicals and pesticides, low in value and therefore uneconomic to dispose of, or bulky and difficult to handle, for example plastic farm films and containers, so that special vehicles and equipment are needed for recycling. Contamination is another problem, for example silage wraps contaminated with soil, with added costs for cleaning prior to recycling. The different wastes may also be dispersed across the farm.

In relation to these particular non-natural farm wastes, the mass balance approach at the farm level can result in a number of useful outcomes:

- Accurately quantifying wastes produced throughout the year, on an enterprise basis
- Providing a cumulative account of waste management practices at the farm level, for example showing the total amount of waste collected for recycling and the costs of different waste management practices, at a local or regional level
- Showing the cost implications of changing waste management practices both for the farmer, and for example for the waste disposal authority in the local area.

2.2 Aims of this study

Farming is an industry undergoing immense changes, including price pressures, increased regulations, shifting consumer behaviour, and the physical effects of a changing climate. In this challenging situation for farm businesses, what can be gained through a mass balance tool? What information can it provide and how can that information be used?

This section of the report aims to:

- Discuss how the mass balance approach has been adapted for application at farm level
- Demonstrate what the mass balance approach can offer at farm level by applying it to a number of farms
- Use the results from applying the tool to examine resource use and waste management on farms in more detail
- Relate these findings to national pictures of farm resource use and overall farm sustainability
- Introduce the Farm Mass Balance Tool that can be used across a wider range of farms to apply the mass balance approach.

Farms involved in the study

Farms involved in the study are part of the Forum Farm Network, a diverse group of farms, established in 2001. A number of different farming types covering a range of enterprises are represented within the network, and farm managers are highly motivated to look at sustainability issues within their farm businesses. Waste audits were carried out with all the farms in the network and detailed information has been gathered from the

following five farms, to build up the mass balance methodology and discuss the applicability of the tool to farms in general.

- Royal Agricultural College Farms, Gloucestershire
- The Allerton Research and Education Trust, Loddington, Leicestershire
- Clinton Devon Estates Farms, Devon
- Hillfairs Farming Ltd, Suffolk
- Sheepdrove Organic Farm, Berkshire

Section 2.3 discusses how the mass balance approach has been adapted for application at the farm level, using examples from the farms involved in the study.

2.3 Methodology: applying the mass balance with farms

There were four main stages to applying the mass balance approach with farms, as outlined below:

Stage 1 Examining farm resource flows

What products and materials are included in the mass balance?

What farm level information is available to indicate the masses involved?

Stage 2 Defining boundaries

How can farm enterprises be represented as operational units?

What are the implications of farm harvest years and accounting years for the mass balance timescales?

Stage 3 Stocks and flows

How do farm resource flows fit into the ten mass balance categories?

How can the approach differentiate resource flows between farm units and flows to and from the farm?

Stage 4 Standard figures

What standard figures are available from other sources to provide information for the mass balance?

The mass balance framework has been adapted to accommodate a wide range of farm enterprise types and management practices. The result of this process has been to develop a user-friendly tool that can be used to apply the mass balance framework with farms. This tool is introduced in section 2.4.

2.3.1 Examining farm resource flows

Stage 1 Examining farm resource flows

Stage 2 Defining boundaries

Stage 3 Stocks and flows

Stage 4 Standard figures

In its strictest sense, a farm mass balance should include everything that is physically part of the farm such as fields, buildings, crops, livestock and the resource flows between them in the production system. All resources on the farm should be quantified and included.

The first stage in the mass balance was to list all possible resources involved in farm stocks and flows. This involved working with the farms involved in the study, examining farm input and output records and building a picture of resource flows on which to base the mass balance figures. Key questions that were asked included, for example:

- **Areas of cropping, forage production and pasture**
 - *timing of cultivations and rotations*
 - *primary and secondary crops produced and their destinations*
- **Livestock units**
 - *number of days outside/housed*
 - *manure and slurry management*

A farm waste audit was also carried out with farms in the Forum Farm Network, to examine overall waste produced on the farm, discuss their management, and look at the potential for waste minimisation and waste recovery with each farm. This gave a partial mass balance for those farms where the complete study was not carried out, and also gave figures for whole-farm waste arisings such as vehicle and construction waste, where a full mass balance was carried out.

Significant natural resource flows

The farming systems under study obviously rely heavily on interaction with the natural environment and are sustained by natural processes and cycles, including soil nutrients and water, gas exchange, and rainfall.

Table 3 Additions and losses from natural environment mass flows

	Materials	Source
Losses	Nitrates in ground water Potassium in ground water Phosphates in ground water	Fertilisers – organic and inorganic
	Pesticides in ground water	Pesticide runoff from plant and soil surface
	Organic matter	Crop residues wind and water borne, pest destruction
	Soil	Wind and water borne soil particles
	Ammonia (NH ₃) Nitrous oxide (N ₂ O) Methane (CH ₄)	from livestock housing, manure and slurry storage land spreading of fertilisers and manures CH ₄ from livestock digestion
	Carbon dioxide (CO ₂)	from respiration of livestock and crops and use of fossil fuels
	Additions	Nitrogen Phosphorous Potassium
Nitrogen fixation		Fixing in soil by nitrogen-fixing bacteria in root nodules of leguminous plants

Direct measurement of these flows could be carried out to establish an accurate and complete mass balance, or there are standard figures available for some of these flows, for example gaseous losses of methane and nitrous oxide.¹⁸ Including estimates for natural capital flows such as nutrients, involves a large number of parameters such as previous cropping, soil factors and weather conditions. The complexity of these factors has meant it has not been practical to include these estimates in the farm mass balances carried out in this study, however it may be possible to refine this model in line with the recently completed nitrogen mass balance project.¹⁹

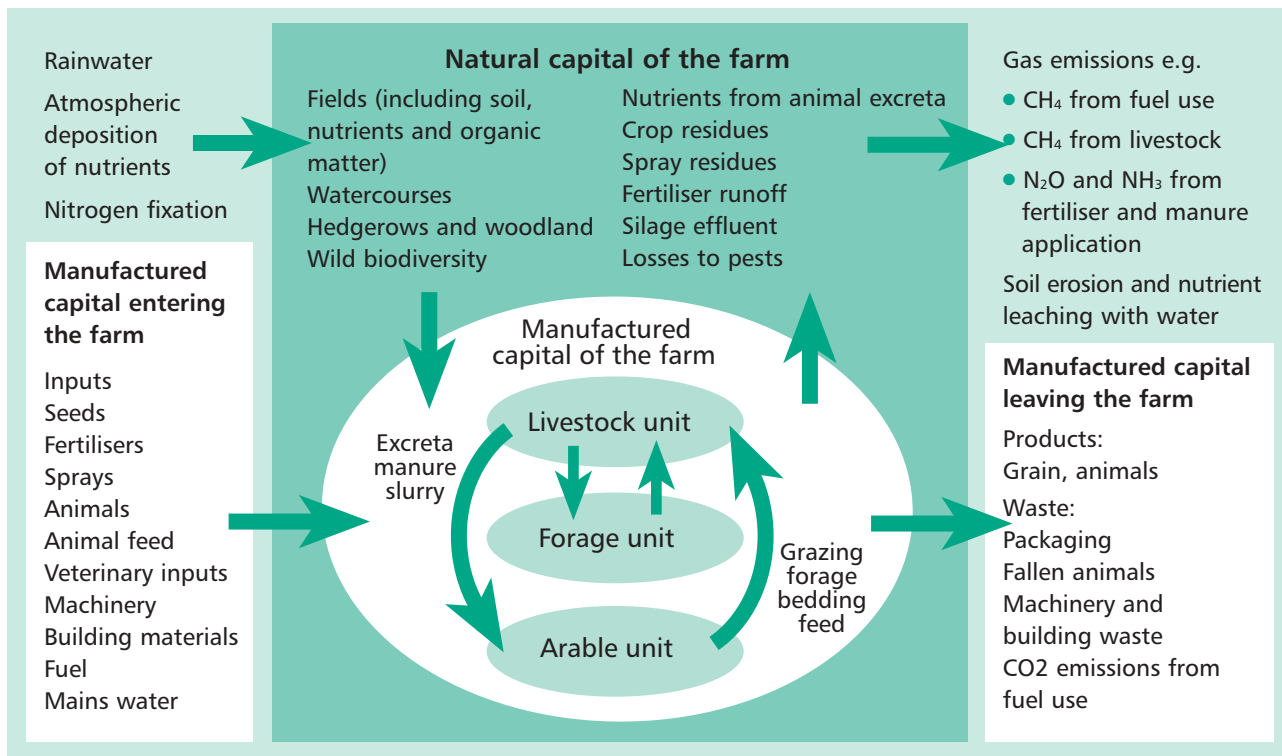
The resources and materials that have been included in the mass balance for this study are shown in the diagram below, highlighted in white, using the example of a mixed beef farm. These flows relate to manufactured capital. Carbon dioxide emissions from the direct use of fossil fuels on the farm can be calculated easily and have been included. An additional flow, which does not have a mass, but which has been included in this study, is electricity, as an important indicator of farm energy consumption.

Figure 4 overleaf highlights the complexity of the flows that are associated with the natural environment, as well as the dependency of the farm system on these flows.

¹⁸ National Atmospheric Emission Inventory – emission factors database www.naei.org.uk

¹⁹ Nitrogen UK (2005) Biffaward Mass Balance project
www2.warwick.ac.uk/fac/sci/hri2/research/nitrogenandenvironment/nmassbal/

Figure 4 Farm mass balance flows



Assumptions made in constructing the farm mass balance

As illustrated in the above diagram, a number of assumptions have been necessary to adapt mass balance principles to the farm situation:

- Soil and groundwater are outside the boundaries of the system. Organic matter, nutrient or water stocks in the soil are not included as part of the mass balance stocks
- The mass of crop, forage or grazing that is 'produced' is the increase in plant matter through growth, using water and nutrient uptake (from the soil), as well as through the process of photosynthesis. This is calculated as the mass of crop that leaves the farm, is consumed by animals or is added to stores. Crop residues are not accounted for as these are added to the soil 'stocks', which are not included.
- All sprays applied are used up (transformed) and none are shown as being emitted to the environment as runoff or waste – this is discussed further in section 2.7.
- All fuel has been used up (transformed) and none is lost, for example from drips or leaks. Waste oil is accounted for separately in the waste account.
- All mains water is used up (transformed). In practice, water used for arable inputs some will be taken up by crops, some will evaporate and some will enter the groundwater. Of water used for livestock, some will be taken up by the animal, most will be excreted or respired.
- Rainwater has not been included as an input.

The implications of excluding soil based nutrient flows from the farm mass balance is illustrated when an organic system is considered. The organic rotation is dependent on the build up of fertility in the soil over many previous years. In order to include these accurately in the model, the cropping pattern over several preceding years would have to be included, to discount the loss of nutrients from the system every year. In its current form, the mass balance includes only application of animal manures, compost and inorganic manures on a mass basis, so the model is limited in application to nutrient cycles without further development.

Classification of materials and resources

The mass balance framework, as used in Mass Balance UK, uses a standard classification for products and materials based on the combined nomenclature (CN). In order for farm-level data to be used within this framework, for example at the regional or national level, the mass balance classification can be applied to farm materials. This information is included within the tool that has been developed.

2.3.2 Defining boundaries

Stage 1
Examining farm
resource flows

Stage 2
Defining boundaries

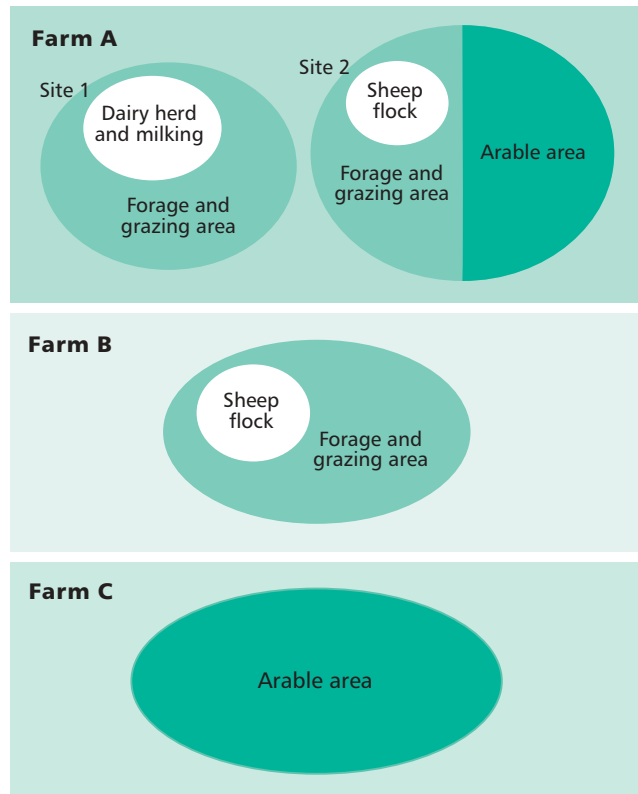
Stage 3
Stocks and flows

Stage 4
Standard figures

In order to build up a mass balance for a whole farm, the farm enterprises are looked at separately, as operational units, with resources flowing in and out of each operational unit accounted for separately. This enables the impact of each enterprise on the whole farm mass balance to be gauged, and possibly, parallels can be drawn between different farms with similar enterprises. Showing how resources flow between different enterprises on the farm can also indicate the degree of integration of the different units on a farm, for example for a mixed organic farm there may be a high degree of integration, with resources moving between the units on a regular basis.

Figure 5 overleaf illustrates some examples of farm enterprises and how these relate to operational units.

Illustration of farm operational units



- Different farms of different sizes may include the same operational units, e.g. Farm A and Farm B
- The same operational units may be represented on more than one site on a single farm, e.g. Site 1 and Site 2 on Farm A
- The geographical spread of the farm may affect the way in which farm records are organised. e.g. for Farm A, the two forage and grazing areas could be considered as one operational unit, producing forage and grazing for all livestock, but field application records or records of purchases of inputs may be kept separately for each site.
- The distance between operational units and sites may affect resource use of the farm, for example fuel use, and practicalities of purchases, with deliveries to multiple sites. Different waste management strategies may also be required for each site.

Contracted land

The amount of land being farmed may massively increase or decrease from year to year, depending on the amount contracted in and out of production. If this takes place in the middle of the mass balance accounting period it will affect the end measures of input or productivity per hectare. The area that is included in the mass balance needs to be defined by each farm to ensure that all contract areas are included at the start and end of the accounting period.

Machinery used

There may be certain machinery or vehicles that are only used for one enterprise. For ease of allocating machinery use, a single account for all machinery is used for the mass balance, with a percentage allocation of mass of machinery between units. This may be inaccurate and is an area for future development, so that machinery use can be more accurately defined for each enterprise.

The mass balance only indicates the mass of machinery in the unit, which is not as useful as looking at intensity of use. Useful measures of machine use intensity include fuel use and horsepower of self-propelled machines, which can be presented alongside mass information.

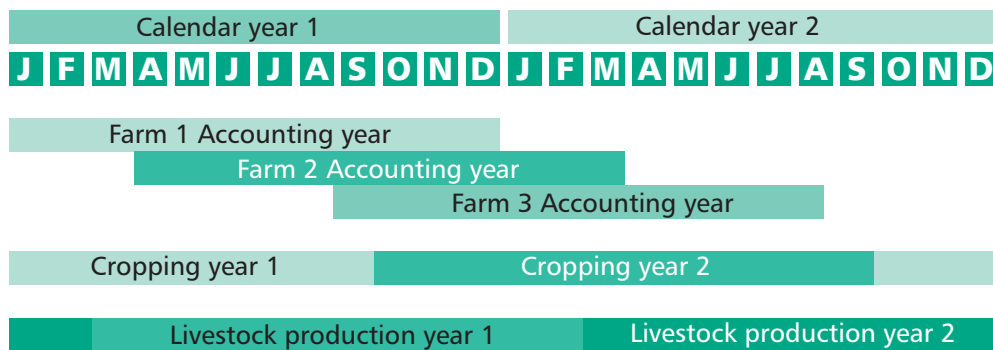
Timescales for the mass balance accounting period

For some organisations the resource use pattern may be consistent through the year so a mass balance over a short time period, will give an accurate picture. For farms, the seasonal variations and cyclical nature of agricultural production mean that a longer time

period is more appropriate. A year may be a short time period for a farming cycle, particularly for a farm with a long rotation of several years. By looking at one year in isolation the average overall resource use for the farm would not be captured. It is recommended that the farm mass balance is carried out for the whole farm over a period of one full year, and for the farms involved in the study this was the case. However there may be situations where this is not practical or where a farm mass balance over a shorter or longer time period will yield more useful results.

Different farms with different accounting years may correspond to the cropping year or livestock production cycle in different ways, as illustrated in Figure 6. Crops from one cropping cycle may also be sold in the timeframe of the next cropping cycle.

Figure 6 Differences in accounting and cropping cycles



By defining a timescale for the farm mass balance, there may be some situations where there is a need to clearly define which figures are included for a particular year. If management practices on the farm change significantly then the mass balance figures for one year to the next should reflect the changing practices. In addition, as financial years may be different between farms, one farm’s figures will be enable comparison from one year to the next, but will not allow benchmarking to be carried out between different farms.

2.3.3 Stocks and flows

- Stage 1**
Examining farm resource flows
- Stage 2**
Defining boundaries
- Stage 3**
Stocks and flows
- Stage 4**
Standard figures

There are ten standard mass balance resource categories, as described in Section 1. For farms, to show the flow of products and materials between units, for example, the transfer of straw from the arable unit to livestock units, the mass balance categories have been expanded to include subcategories for resources coming into the unit from other units on the farm and from outside the farm. Subcategories have also been used to show specific waste management categories, according to waste management practices identified in farm waste audits. Category 5, ‘material embodied into other products’ has been used where an alternative use was found for a waste product, for example

feed sacks were used for storage, rather than being disposed of immediately.

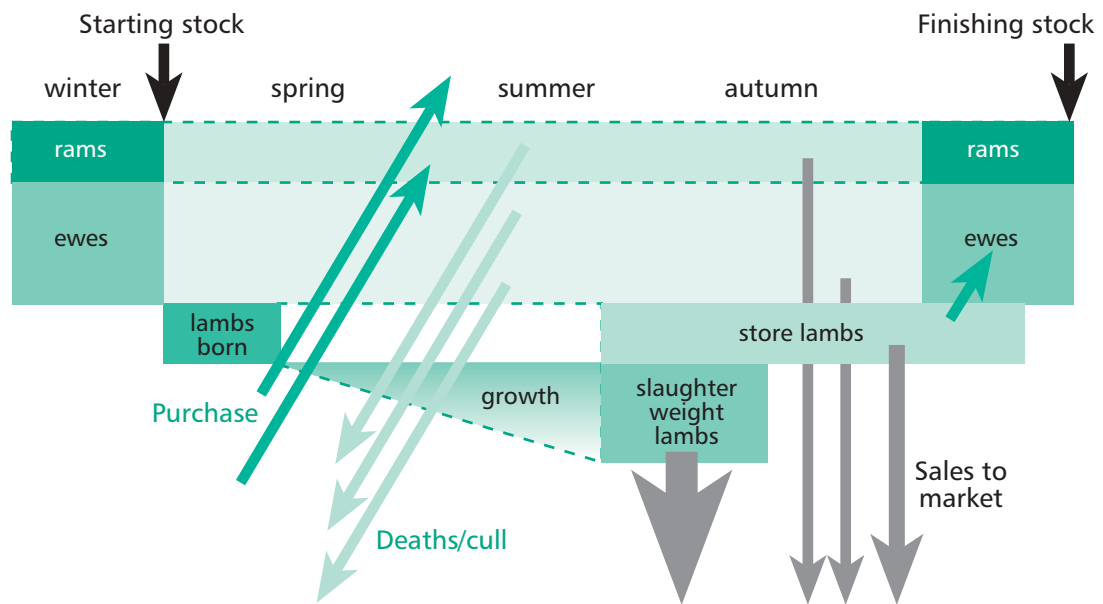
The table overleaf shows mass balance categories at the farm level as well as the information sources that were used to complete data for each resource flow.

Table 4 Mass balance categories at farm level

Mass balance categories at farm level		Information sources available
1 Initial stock		Year end stock figures & valuation figures
2 Inputs/imports	Materials bought into the farm from outside - purchases	Purchase ledger & invoices
	Materials from other enterprises within the farm – transfers	Estimation or records for transfers between enterprises
3 Produced/extracted		Production records Standard figures Waste audit for waste figures
4 Outputs/exports	Materials leaving the farm - sales	Sales records
	Materials going to other enterprises within the farm – transfers	Estimation or records for transfers between enterprises
5 Embodied		Waste audit
6 Transformed/used		Field application records Feed records
7 Recycled/recovered	Waste to recycling collection Waste to composting Waste taken back by supplier Waste to scrap dealer	Waste audit
8 Final disposal	Livestock culled	Livestock records
	Waste materials burned	Waste audit
	Waste to landfill Waste buried on farm	
9 Emissions		CO ₂ only - standard figures – calculations
10 Final stock	Materials in store	Year end stock records and valuation figures
	Waste stockpiled	

For livestock units, the mass of livestock falling into each mass balance category is illustrated in the following diagram showing a sheep unit over one year. This also illustrates the effect of different accounting timescales on the masses present on the farm at any one time, with much higher numbers of livestock present on the farm at certain times of the year.

Figure 7 Example of flux in sheep masses throughout a year



Stock at start and end of period = rams, ewes and any store lambs still in flock

Imports = any rams or ewes purchased

Produced = growth over the year, including those rams, ewes, lambs died or culled

Exports = Sales to market

Final disposal = deaths and culls

2.3.4 Standard figures

Stage 1 Examining farm resource flows

Stage 2 Defining boundaries

Stage 3 Stocks and flows

Stage 4 Standard figures

In addition to information sources available directly from farms, a range of standard figures from other sources have been used to calculate masses of resources, and to add further value to mass-based information. These figures have informed the development of the Farm Mass Balance Tool that is described at the end of this section.²⁰

Standard figures relating to arable units and forage and grazing units

- **Inorganic fertiliser use** can be shown as a total mass as well as a breakdown of nutrients contained within the fertiliser applied. The

quantity of nutrients applied per hectare is a useful indicator at the farm level and this data is included in the mass balance.

- **Inputs of fungicides, growth regulators, herbicides and insecticides:** as well as including total mass of sprays applied, an additional indicator of resource use intensity is to include the amount of active ingredient, expressed as grams of active ingredient applied per hectare.

Standard figures relating to livestock units

- **Livestock masses** for individual types of livestock depend on age and breed, and average figures are not always reflective of individual animal weights.

²⁰ Detailed standard figures which have been used in the mass balance tool are available from Forum for the Future, see back cover for contact details.

- Standard figures for **grazing intake** and **excreta output** are available, for example manure output per animal from Defra figures. Average livestock weights, excreta output and grazing intake for different ages of livestock have been included in the mass balance tool, with the option to alter figures for each farm, if more specific information is known about particular age classes and weights.
- In order to estimate the total grazing intake or the total excreta output, a detailed account of stock movements month by month could be carried out, or the **average number of livestock** in each livestock class or age group over the accounting period can be used. The mass of grazing intake and excreta output then depends on the number of days that the livestock are outside and how many days they are housed.

Standard figures relating to the whole farm

- **Packaging waste estimates:** packaging waste is estimated using standard masses for packaging units, showing the amount of plastic, paper or card, glass or mixed waste per container. These were developed from direct measurement and specifications from packaging suppliers.
- **Non-packaging waste estimates:** bales of straw and forage are presented with standard sizes and masses. Calculations for the mass of bale twine or net wrap per bale have been used to add masses of non-packaging plastic to the mass balance table.
- **Carbon dioxide emissions:** direct carbon dioxide emissions from fuel use on the farm are included in the mass balance. Carbon dioxide emissions from electricity use are not included, as these are part of the mass balance of the power station where the electricity is produced.
- **Energy use:** a total estimation of kWh is calculated to give an overall figure of farm energy use.
- **Machinery use:** machinery is broken down into self-propelled machinery (e.g. tractors and combines), and non self-propelled machinery and tools (e.g. trailers, ploughs, and sprayers). In order to allocate machinery use to the different farm operational units, a simple percentage allocation is used for each operational unit. Percentages are then used to estimate the mass and horsepower of self-propelled machinery and mass of non self-propelled machinery that is used by each enterprise, and for the farm as a whole. Mass and horsepower information has been taken from specifications for machinery models.

2.4 Results: Farm case studies

This section summarises the results of applying the mass balance tool with the five farms involved in the study, relating these results to indicators of resource use and sustainability.

The mass balance approach has been applied with five farms, with a mix of enterprise types, sizes and locations. As outlined in section 2.3, benchmarking between farms is perhaps limited to a few key points, as a result of different accounting periods. Presented here is a summary of the mass balance figures for two farms, followed by some

illustrative results of the key performance indicators that the mass balance approach for farms can deliver. Masses shown for livestock are the live weight of animals entering and leaving the farm.

Figure 8 Farm A – mixed organic farm, 800ha

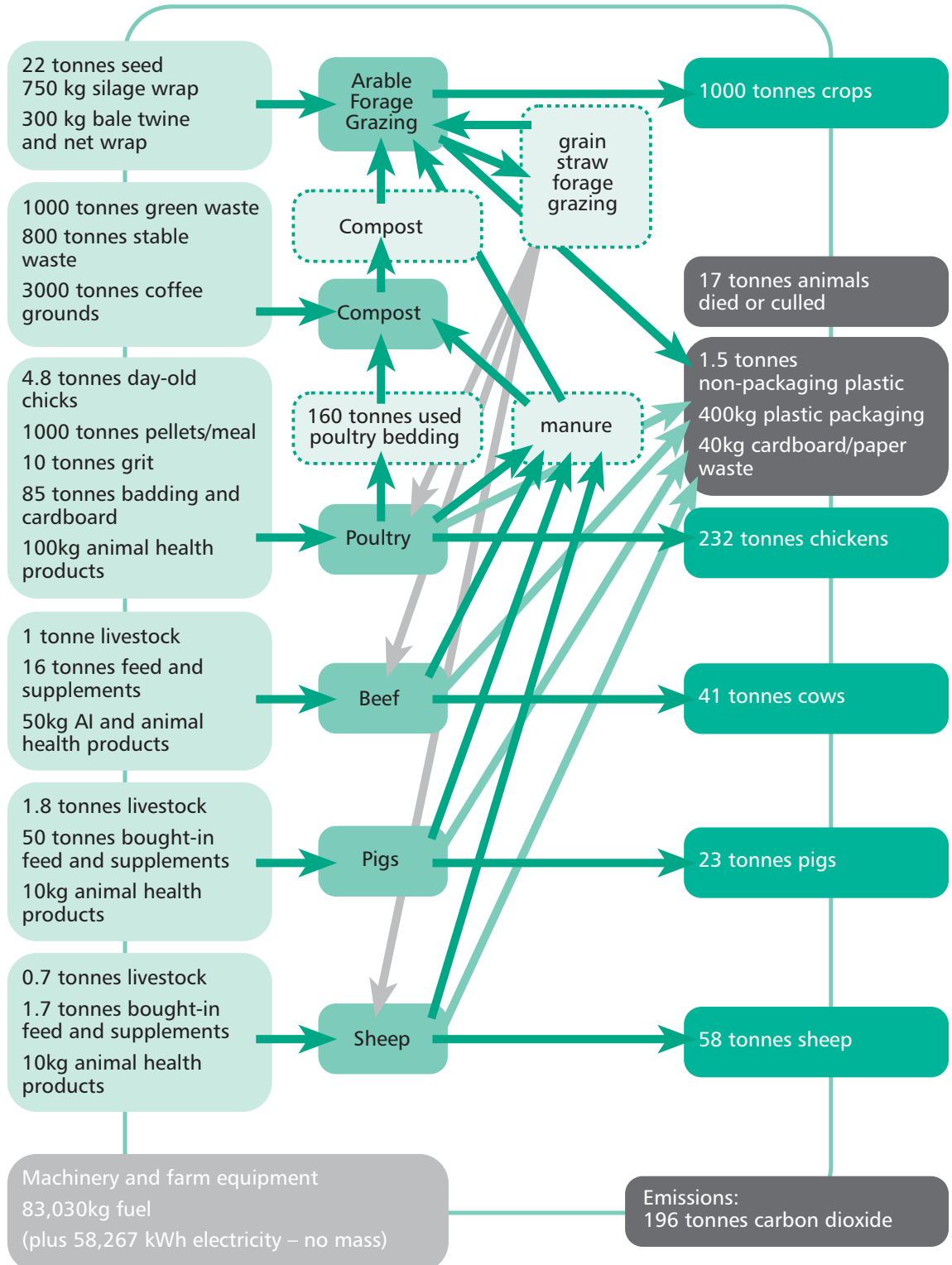
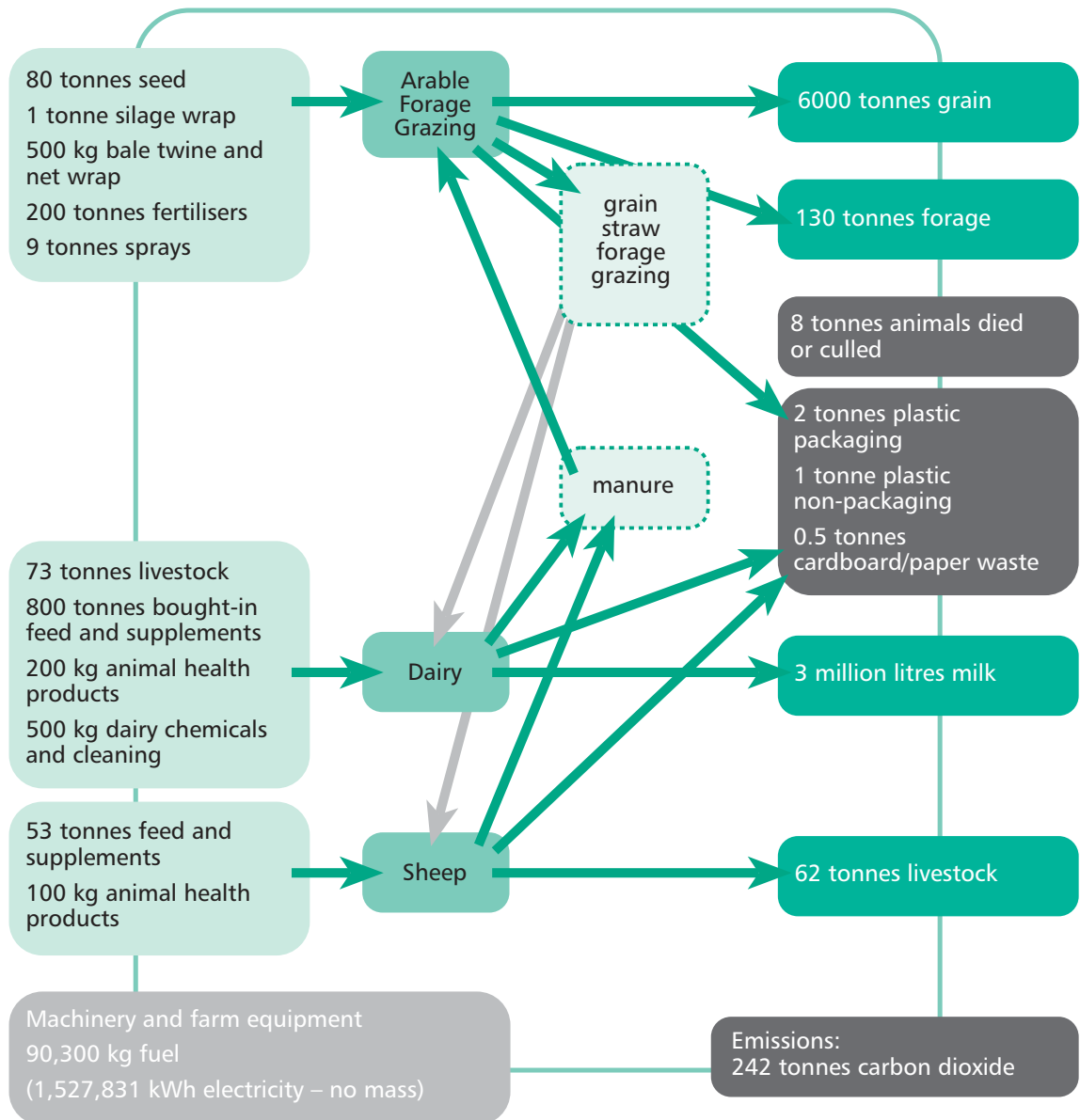


Figure 9 Farm B – mixed farm, 500ha



These examples of two farms – one organic and one conventional, one with more enterprises, one with greater production leaving the farm – illustrate some mass balance figures, and flows taking place within the farms. These figures also demonstrate some of the limitations of the mass balance approach at the farm level, for example:

- Physical parameters of the farms (size, location, and management approach) need to be known before any conclusions can be drawn. For farms in different regions and with different histories and management there may be few parallels that can be drawn.
- The unquantifiable social impacts of the farms cannot be shown in the mass balance, nor can their financial sustainability. The cost of inputs and the value of the products that are sold will greatly affect overall sustainability of the business.
- The impact of investment in agri-environment schemes or conservation by the farm, for example in building up biodiversity, is not reflected in these figures, although it may be significant in the financial accounts of the farm.

The following are possible indicators that can be obtained from the mass balance, allowing a degree of benchmarking between farms and between enterprises on the same farm. The results presented here are to demonstrate the variation in the different indicators, rather than showing an absolute measure of what good looks like or what a particular farm practice may result in.

Direct resource use

- Inorganic fertiliser applied per ha
- Sprays applied per ha
- Amount of production used on farm, degree of self-sufficiency

Energy

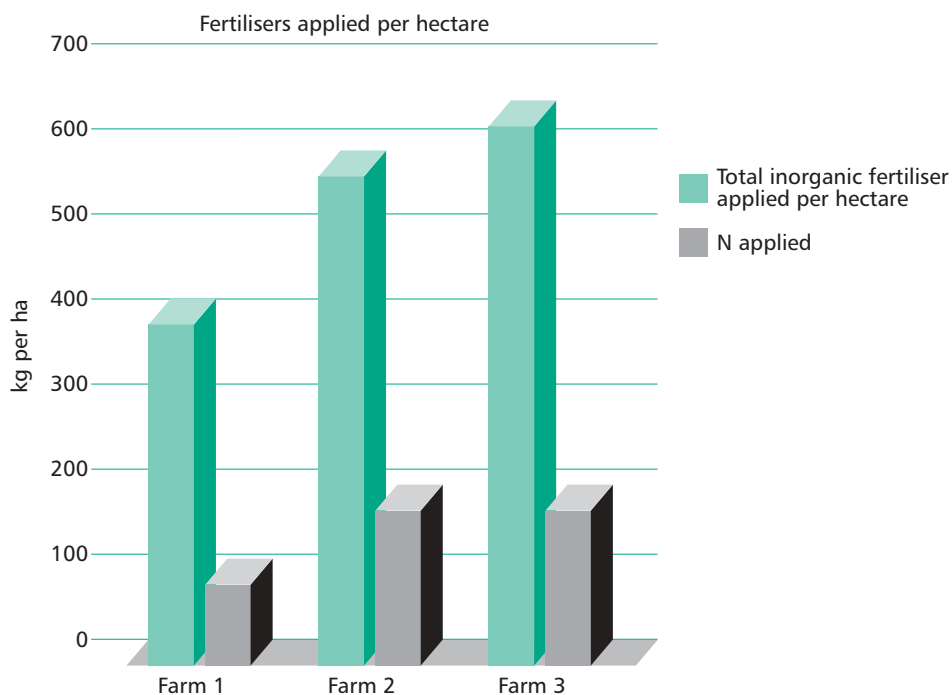
- Fuel use and kWh use per farm, per enterprise, per ha, per unit of output
- Machinery use: kg of machinery per ha, hp per ha
- Carbon footprint – per farm, per ha, per unit of output

Waste

- Waste produced, per enterprise, per unit of output, e.g. plastic waste produced per kg of product
- Cost of waste disposal
- Effect of changing practices on waste disposal costs

Examples of results from the farms included in the study are shown below as bar charts. These are presented on a per hectare basis to show comparison between the farms.

Figure 10 Direct resource use – Application of inorganic fertiliser



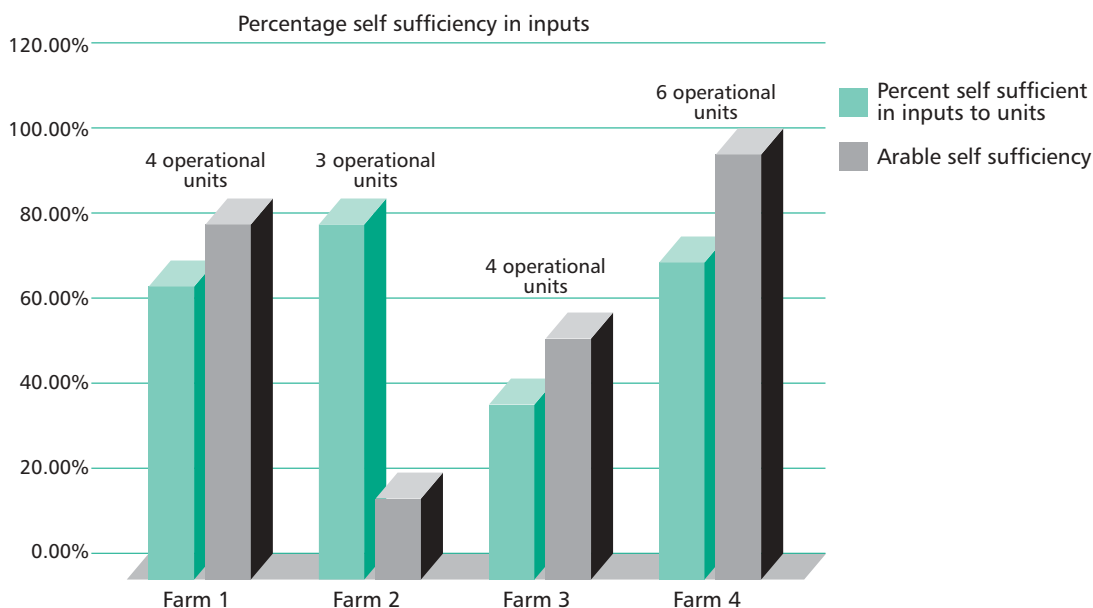
The second column for each farm shows the amount of nitrogen applied as kg per hectare. Farm 3 has a greater overall fertiliser application over all crops per hectare but a similar amount of N application per hectare as Farm 2. To carry out an accurate comparison, the application figures for each crop should be looked at, for comparison with recommended fertiliser application figures. The figures presented here may also reflect some inaccuracy in splitting applications of fertilisers between the arable unit and the forage and grazing unit, which is a result of creating a mass balance based on operational units.

Other results include comparison of:

- Sprays applied per hectare
- Grams of active ingredient applied per hectare
- Crop yields per hectare

Figure 11 Direct resource use - Percentage self-sufficiency in inputs

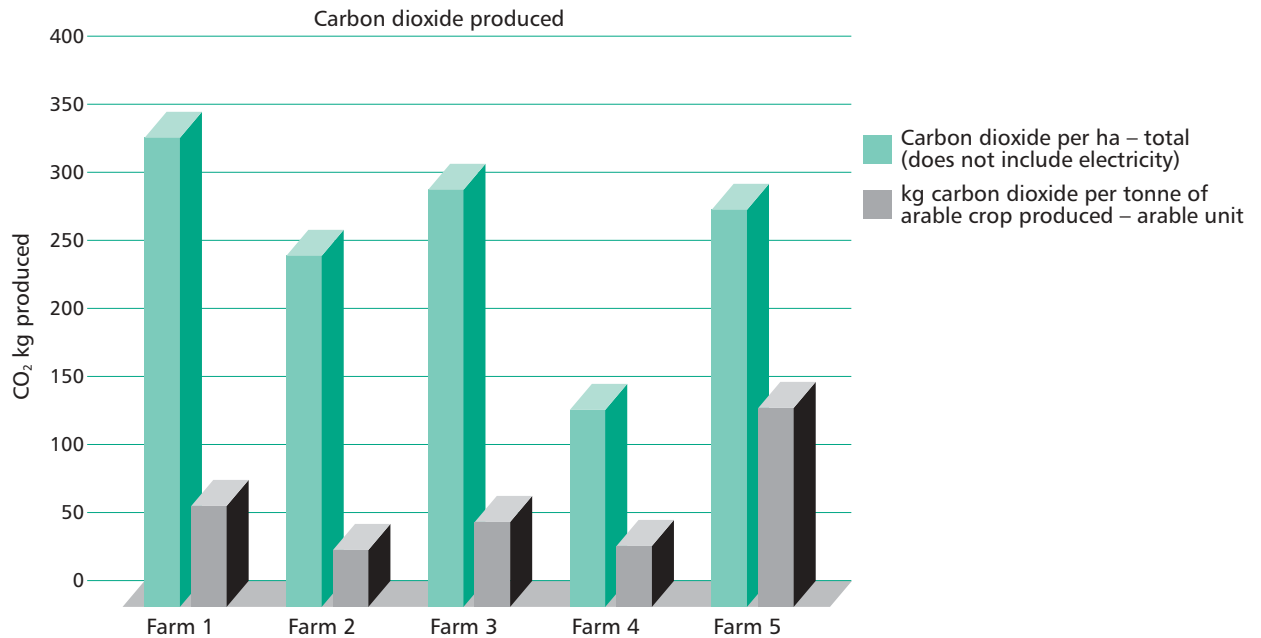
This chart shows a summary of inputs coming from outside of the farm compared to resources that are used within the farm, for the whole farm, and for the arable unit (as the unit which is present on all farms included in the study).



The lowest figure here is just over 40% self-sufficiency for Farm 3, showing that most inputs come from outside of the farm. This farm includes a high yielding dairy unit, with large amounts of feed and minerals bought into the farm. Farm 2 shows a low self-sufficiency for the arable unit, with a small amount of manure being transferred from sheep housing, with only a few days when sheep are housed per year. This illustrates one of the limitations of the mass balance in accounting over one year, where a rotation may utilise inputs from previously grazed ground, and the amount of manures being transferred between units within the accounting year may not reflect nutrient transfers within the calendar year or the cropping year.

Figure 12 Energy - Carbon dioxide emissions

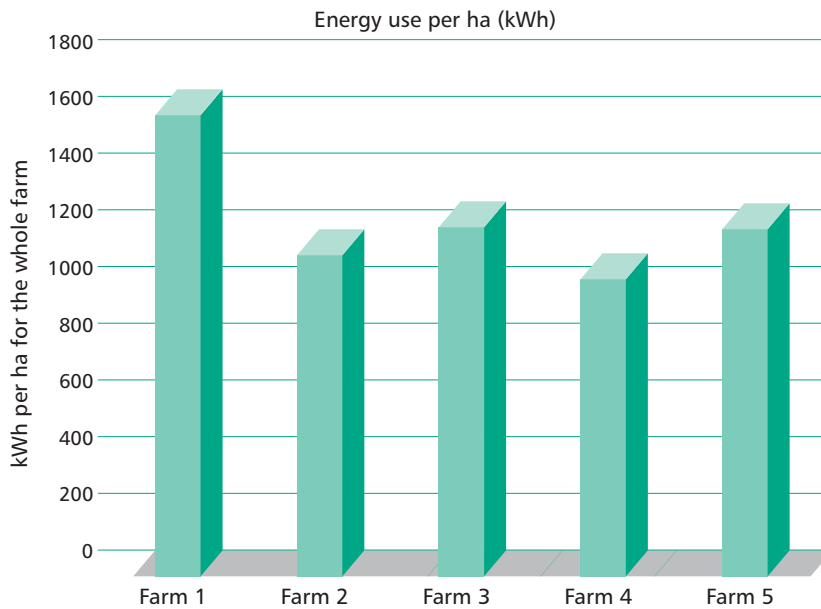
This shows emissions directly related to farm energy use. The farm mass balance only includes carbon dioxide emissions directly from fuel use, and not electricity (as these emissions are part of the mass balance of the power station where the electricity is created).



The chart shows per hectare emissions of CO₂ for the whole farm and for the arable unit of the farm. Farm 1 has the highest overall energy use per hectare, probably as a result of the energy-intensive dairy unit. This could also reflect a split-site operation, which, as discussed in section 2.3.2 may result in higher overall use of fuel if machinery needs to be transported. Farm 5 however shows the highest carbon dioxide emissions per hectare for the arable unit of the farm. Farm 5 is the only organic farm included in the study so this may reflect a greater reliance on mechanical cultivation to maintain an input-free system, for example for weed removal.

Figure 13 Energy - Total energy used per hectare for the farm

As electricity use is not reflected in carbon dioxide emissions, another indicator that may be useful is to look at total energy consumption for the farm in the form of total kWh, converting all fuels to their kWh equivalent.



Again, Farm 1, with two dairy units as well as split sites and use of a grain dryer in the year studied, results in the highest energy use per hectare across the farm.

In order to accurately assess the reasons for these different figures, the indicators of the machinery use intensity across the farm should also be considered:

- Horsepower per hectare
- Mass of self-propelled machinery used across the whole farm, for each unit, and kWh for each tonne of output from each unit.

Figure 14 Waste produced per hectare over whole farm

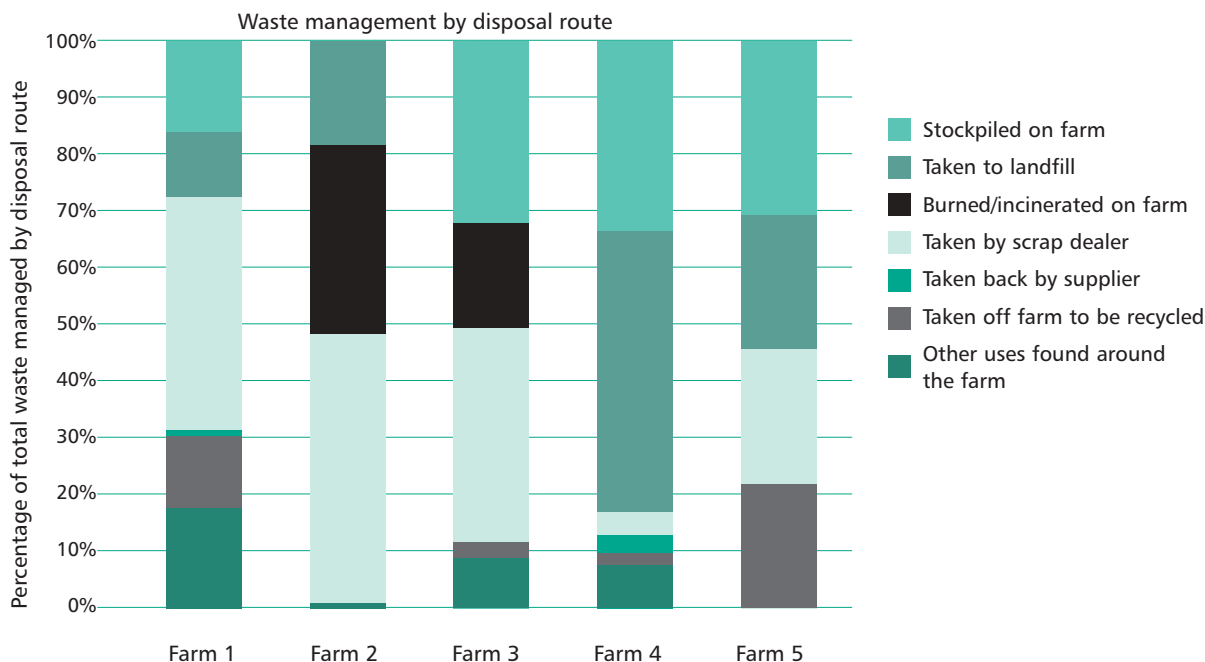
For an individual farm using the mass balance approach, amounts of waste are shown as specific mass flows within the system. The effect of changing farm practices on waste figures can be gauged, and the cost of waste management factored in to provide a figure for overall waste management costs, which are likely to increase under the new farm waste regulations.



Farm 3 shows a greater amount of packaging plastics, mainly composed of fertiliser bags and spray cans, particularly in comparison to Farm 4, which is the organic farm with no input of fertiliser or sprays.

Figure 15 Waste - management and costs of waste disposal

This diagram shows waste management practices depend on the farm’s location, the location of nearby waste disposal or recycling facilities, or farm groupings where centralised waste collection may be possible.



In this study, none of the farms were involved in burning wastes on the farm. The total cost of waste disposal ranged from £0.03 per hectare to £0.27 per hectare. The lowest cost per hectare appeared to be where there were low packaging amounts and high machinery amounts, receiving income from scrap dealers.

These results highlight some of the opportunities for further investigation using the mass balance approach as well as some of the limitations of the approach. For an individual farm, useful management information can be obtained from the mass balance approach, particularly in relation to energy use, carbon dioxide emissions, and waste management. However, the reasons behind the different figures cannot be known by examining the mass flows, without going into the details of the farm and its management.

2.5 Waste management on farms

This section discusses some of the wider implications of these results relating to waste flows, waste management and the new farm waste regulations.

The farm waste audit that was carried out across the Forum Farm Network and the detailed mass balance study reflects the general patterns of waste management that is found across farms in the UK. Some farms will be affected by the new waste regulations more than others, but generally, all farms will face some increased costs for waste disposal, as they pay for collections, and have to spend more time collecting, sorting and storing waste items.

Looking at waste on a weight basis may not give an accurate indication of the relative time taken to manage the different wastes, as some of them are more problematic due to their bulkiness and difficulty in handling them, for example spray containers and fertiliser and seed bags. For one arable farm of 2,600 acres, the time involvement for managing wastes was estimated at an average of half a day a week, for one person, throughout the year.

The actual tonnages of waste involved in collection schemes may be quite small, particularly since many of the waste streams are relatively light plastics. Another factor affecting the cost of plastic collection and recycling is the amount of contamination with silage residue, mud and water, and this can seriously decrease the potential value of the plastic to a recycling company and increase the costs of collection.

Practical waste management under the new regulations

As farm dumps are closed and current waste management practices are phased out over 2006, national collection schemes for farm plastics are to be put in place, building on existing regional and local schemes.

The table overleaf shows examples of some of the practical issues in farm waste management, for some of the non-natural waste streams included in the mass balance, and practical points which have been raised during farm waste audits:

Table 5 Non-natural waste management issues and possible solutions

Waste stream	Issues for minimisation, reuse and recovery	Possible solutions
Packaging plastics		
Big Bags (500 kg, 600 kg or 1 tonne capacity) used for fertiliser and seeds	<p>Cannot be reused by manufacturers – safety concerns and bags are often cut open</p> <p>Few collection schemes currently available</p> <p>Bulky to store</p> <p>May contain residues of fertilisers</p> <p>Reprocessors may only take inner of fertiliser big bag so needs to be separated and outer still then needs to be dealt with</p>	<p>Bulk delivery of fertilisers although certain infrastructure is needed for this</p> <p>Used bags can be baled or compressed and stored under cover</p> <p>Centralised collection points/take-back by manufacturers for recycling of material to cut down on on-farm storage</p> <p>Bags should be fully emptied and as clean as possible</p>
Small sacks (20 or 25 kg capacity) used for livestock feeds and minerals and seeds	<p>May contain residues</p> <p>Small quantities of a specific plastic type are often not worth collecting</p>	<p>More delivery in bulk though may cause storage problems/deterioration</p> <p>Centralised collection point for several farms to increase quantities</p>
Buckets from livestock feeds/minerals		<p>Often reused around the farm for storage or as water containers etc.</p>
Plastic spray cans and sheep dip/spray cans. Cans from dairy chemicals, cleaning products	<p>Different manufacturers use different sizes/formats/delivery systems so cuts down on reuse possibilities</p> <p>Spray cans must be thoroughly cleaned</p> <p>Different types of plastic may be used for one container</p> <p>Small sizes of containers for safety reasons increases amount of packaging used</p>	<p>Agreement between manufacturers to use same sizes and format for cans</p> <p>Centralised collection points for several farms to increase quantities for collection</p> <p>Cans can be crushed to take up less space</p>
Plastic containers from veterinary products	<p>Small amounts</p> <p>Could contain residues</p> <p>May involve different types of plastics so difficult to recycle</p>	<p>Return to supplier for collection and incineration</p>
Shrink wrap from pallets	<p>Small amounts</p>	<p>Added to other LDPE plastics (films, bags) for collection</p>
Plastic oil containers	<p>Bulk, may be highly flammable if residues are present</p>	<p>As for other rigid plastic containers though oils can often be delivered in reusable metal drums or in bulk, depending on the product and quantities</p>
Non-packaging plastics		
Silage wrap, black plastic	<p>Bales: A single use product - torn when removed from silage so cannot be reused. (Clamp: Is often reused).</p> <p>Used wrap contaminated with mud/silage residues – difficult to clean</p> <p>Bulky to store for collection</p> <p>Few collection schemes in operation</p>	<p>Clamps use less plastic than bales but are less versatile</p> <p>Used wrap can be baled/compressed for collection</p>
Plastic cores from silage wrap		<p>Can be replaced by cardboard cores which are more easily composted or recycled</p>

Waste stream	Issues for minimisation, reuse and recovery	Possible solutions
Packaging paper and cardboard		
Paper feed sacks		Can be reduced with bulk deliveries or larger size containers though may be safety, storage and delivery issues
Cardboard boxes from spray cans	Bulky waste stream – crushing/flattening takes time Must be kept dry	Can be recycled if there is the facility locally
Cardboard cores from silage wrap	Small amounts – not major waste issue	Can be added to compost though may need to be shredded or broken up first
Animal health products outer packaging		
Packaging paper and cardboard		
Wooden pallets & wooden boxes	Low value material – often designed for single use and broken after one use Few suppliers will take back	Can be chipped (though presence of nails/staples may prevent this) or ideally secondary uses found

The next section draws some conclusions about the applicability of the mass balance approach at farm level and how it links to other measures of sustainability at the farm level.

2.6 Conclusions: the farm mass balance and farm sustainability

2.6.1 Measures of farm sustainability from the mass balance approach

The farm mass balance shows indicators of resource use efficiency, for example waste production, carbon footprint and degree of self-sufficiency at the farm level, in terms of quantities of inputs and outputs on a whole farm and per hectare basis. This is related to the type of production system and basic physical factors such as soil type.

In general, there are several principles of sustainable farming which the farm mass balance model helps illustrate and measure, for example:

- Low emissions to environment
- High degree of cycling of nutrients and resources within the system
- Low waste production
- Lower reliance on external inputs

Some measures or indicators of farm sustainability are available by completing the farm mass balance:

- Waste audit and quantification of wastes for individual farms, costs of disposal
- Active ingredients in sprays and nutrients for applied fertilisers
- Total farm carbon footprint
- Basic comparison of machinery use across the farm
- Basic comparison of production figures

Other indicators are presented as estimates, and could be the basis for further development, or general pointers for farm management:

- Energy use and machinery intensity in terms of mass and horsepower between different units of the farm – based on an estimation of machinery use by each enterprise
- Investment in inputs for agri-environment or conservation schemes for the farm – based on mass of inputs, however the outputs from conservation schemes may not be quantifiable as a mass, so this indicator could be further refined.

The farm mass balance in its current form is limited to estimating direct CO₂ emissions from fossil fuel use. As discussed in section 2.3.1, other greenhouse gas emissions could be included in the mass balance but, as with other indicators, a balance needs to be struck between the time investment for farm managers or staff in finding and entering data for the mass balance tool and the benefits that can be gained. Pressure to look more closely at fuel management (and by doing so reduce CO₂ emissions) may increase as the price of fuel increases.

Agri-environment schemes

The mass balance is based on accounting for physical flows to and from the farm system. Under new farm payments, farmers receive area-based payments depending on maintenance of the land in good agricultural and environmental condition and provision of agri-environmental goods. These outputs cannot be easily measured in terms of physical flows, so the mass balance is of limited use to gauge the effectiveness of these payments in providing the desired products.

Encouraging farmers to focus on agri-environmental goods on the farm, such as landscape features or biodiversity cannot be at the expense of sound resource use and production efficiency. Farming systems where sound resource use is encouraged as part of overall sustainability must be enabled and encouraged, and the mass balance approach may assist in achieving this objective.

2.6.2 For future development

There are several areas which have not been covered in this report, which may add further value to the Farm Mass Balance Tool. Most of these issues relate to adding non-mass related data into the tool to maximise the management and environmental impact information that can be gained from the tool.

Direct resource use and emissions to environment

Greenhouse gas emission estimates

- Agriculture contributes 66% of the UK's total nitrous oxide emissions, and 46% of methane emissions²¹. The mass balance model could form the basis of providing more accurate farm level greenhouse gas emission estimates for direct and indirect emissions. These are summarised in table 6, below.

Table 6 Management options for the main greenhouse gases emitted from farms

	Greenhouse gas	Source of emissions	Management options to reduce emissions
Direct emissions	Methane (CH ₄)	Enteric fermentation by ruminant livestock Manure management	Animal diet and productivity Animal housing
	Nitrous oxide (N ₂ O)	Mainly through inorganic fertiliser application Soil emissions	Improving efficiency with which nitrogen is used by crops and livestock, for example through timing of applications and nutrient budgeting
	Carbon dioxide (CO ₂)	Fossil fuel use	Reduced use through appropriate machinery and cultivations
Indirect emissions	Carbon dioxide (CO ₂)	Transport of goods Manufacture of inputs	Reduced transport of inputs and outputs Reduced energy intensity of manufacture Reduced input use

● Sprays and fertilisers

Mass balance information can be linked closely to efficiency of use of inputs such as sprays and fertilisers, for example to enable more accurate nutrient balancing and more accurate estimate of spray run-off, including emissions to environment and efficiency of uptake

Further life cycle analysis of inputs and outputs

● Embodied energy in agricultural inputs

One tonne of nitrogen fertiliser takes 38-50 gigajoules (GJ) of energy to produce, while one tonne of pesticide takes 45-95 GJ to produce.²² These hidden energy costs are known as embodied energy and are useful to examine the impacts of farming systems over the whole lifecycle of the crop.

²¹ National Statistics Office Environmental Accounts Spring 2005.
www.statistics.gov.uk/downloads/theme_environment/EAMay05.pdf

²² Corre, Schroder and Verhagen (2003) *Energy use in conventional and organic farming systems*

- **Transport associated with inputs and outputs**

Inputs to the farm and products from the farm can be tracked from and to source and destination and the likely impact or cost of this transport taken into account in the lifecycle assessment of the production system (e.g. input, waste and food “miles”). For example, a system using imported inputs may be less sustainable than one using local inputs.

- **Nutrient cycling and full environmental account with natural capital flows**

As discussed in section 2.3.1, as well as the issue of greenhouse gas emissions from agriculture, complete modelling of nutrient flows will lead to both savings for the farm and less environmental emissions to air and water. The current tool does not have the capacity to examine air and water emissions fully although these should be included in a full mass balance. This could be an area for further development.

Adding value to farm mass balance information

- **Linking with existing farm tools and software packages**

Nutrient management, accounting and environmental management software is used in a variety of formats by different farms. There may be elements of the mass balance tool that could be transferred to existing software packages in a straightforward way, for example by including packaging estimate figures in farm inputs management computer software.

- **Linking with national datasets**

By using a consistent classification in terms of geographical area, products and materials, farm mass balance information could contribute to refining and ground-truthing national level datasets such as the Environment Agency’s waste estimates model.

- **The basis of a tool for low carbon farming**

Low carbon farming depends upon maximising resource use, minimising machinery and fuel inputs into the farm, and producing renewable energy on farm where possible. The mass balance tool can assist in identifying where there are potential savings in energy efficiency and building up a data set for benchmarking low carbon farms.

2.7 The Farm Mass Balance Tool

The methodology and the stages outlined in section 2.3 has been used to develop a tool, with the aim of presenting a user-friendly interface to allow the application of the mass balance approach at the farm level. The tool is based on a series of Excel worksheets which result in a final mass balance table and a mass balance report for the farm.

Table 7 Summary of different worksheets within the Farm Mass Balance Tool

1 Start		Basic farm information Farm classification and farm size based on national farm classification
2 Arable	Optional sheets depending on whether these units are present	Crop and forage inputs and outputs, with transfers to livestock units Livestock sheets include the numbers of livestock, inputs of feed, forage, veterinary supplies etc. The user is able to alter masses of livestock, grazing intake and manure output according to their farm information.
3 Forage and grazing		
4 Sheep		
5 Beef		
6 Dairy		
7 Poultry		
8 Pigs		
9 Compost		
10 Conservation		If conservation is a separately costed activity, or is a focus of the farm activities, this can be accounted for separately on this sheet
11 Resources & Waste		In previous sheets, wastes are calculated automatically depending on inputs that are used. Machinery use, fuel & electricity use and mains water use, with a percentage allocation to each unit. Waste management practices.
12 Mass balance table for whole farm		Data from unit sheets automatically entered into mass balance table format within the ten mass balance categories
13 Report		Interpretation of the mass balance information as outlined in the key performance indicators

Completion of the tool results in the output of a mass balance report for the farm, which summarises the following information:

Farm level information	Enterprise level information
Total amount of water used	Total amount of inputs bought into the unit
Total amount of electricity used	<ul style="list-style-type: none"> ● Inputs from outside the organisation ● Inputs from within the organisation
Total amount of fuel used	
Total amount of waste produced	Total amount of products leaving the unit
Amount of waste under each waste management practice	<ul style="list-style-type: none"> ● Products leaving the organisation ● Products moving to another unit
CO ₂ produced by whole organisation	Mains water used by the unit
	Electricity used by the unit
CO ₂ produced per kg of product	CO ₂ emissions from the unit
	Waste produced by the unit

A separate briefing on completing the mass balance for farms is included in Appendix 1.

Section 3 University mass balance

This section outlines how Forum for the Future has worked with universities to apply the mass balance approach.

This study with universities has helped to develop a tool for looking at resource flows within any organisation using a mass balance framework.

3.1 Introduction

3.1.1 Higher education and sustainable development

The importance of education to realising a more sustainable society has long been understood. Progress globally and nationally since the 1972 Earth Summit, which formally recognised its contribution, has been variable but now in the UK at least, mechanisms are in place that could start to make a tangible difference. The Department for Education and Skills published its sustainable development action plan in 2003,²³ that required the further and higher education funding councils in England to develop sustainable development strategies.

The Higher Education Funding Council for England's strategy²⁴ is matched in other administrations by a commitment from the Scottish Funding Council, and a draft strategy for sustainable development in higher education from the Welsh Assembly Government.

All these policies recognise the impact that higher education and its institutions make to society beyond teaching and research, including employment, resource use and purchasing decisions.

3.1.2 Drivers for sustainable resource use in the higher education sector

There are significant benefits for universities from employing more sustainable resource use practices and there is no doubt that reducing the use of energy and water on campus is bringing financial savings to most parties. For example:

- Queen's University Belfast makes a saving of £30,000 per year through the use of its Combined Heat and Power system to generate energy on campus (with a five year pay-back period)
- Loughborough University has an energy check list for all new buildings and uses flat screens and self shut down PCs. Campaigns to encourage staff and students to switch off lights and other electrical equipment have also reduced their energy consumption
- University of Aberdeen has reduced their water bills by 7% after installing waterless urinals and flush controls following an audit of consumption and water metreing strategies
- Reducing waste through substitution, more effective use and recycling has also delivered gains to several universities: for example, Sheffield Hallam University is investing in its hardship fund for students with the revenue which is generated from recycling toner cartridges.

²³ DFES (2003) Sustainable Development Action Plan for education and skills

²⁴ Hefce (2005) Sustainable development in higher education: statement of policy 05/28

Higher education is also subject to the Gershon review of public sector efficiency, which scoped out further efficiencies that could be made in the sector's operations, in particular procurement.

So as well as management demands for cost savings generally, there is an obligation from the government, as a major funder of a university to follow best practice in procurement including whole life costing analysis and sustainable purchasing.

3.1.3 Resource use tools for higher education

The Higher Education Partnership for Sustainability (HEPS) was a three-year initiative with a network of 18 universities that produced a number of innovative tools and good practice.²⁵ The HEPS reporting tool highlighted how higher education institutions are responding to government initiatives in public sector efficiency reforms that support sustainable development.²⁶ HEPS illustrated how sustainability can be achieved in three areas that any university operates across:

- As a business where efficient management of resources not only saves money but also safeguards reputations
- As a provider of learning and research, forming and informing leaders and decision-makers of the future
- As a significant member of the community, e.g. employer, purchaser, amenity provider.

A previous Biffaward Mass Balance project for the UK education sector has provided some valuable insights into aspects of resource usage across further and higher education and highlighted where good practice already exists.²⁷

3.2 Aims of this study

This study has aimed to apply the mass balance approach with a number of universities, examining how useful the approach is at this organisational level, and what the issues are for universities specifically. The study wanted to determine whether the mass balance tool could provide useful information for resource managers within universities, and whether it is possible to use this information for more sustainable resource management.

Ideally, a mass balance would look at resource flows for a whole organisation. However, Forum for the Future's previous experience of universities indicated the unlikelihood of any university possessing a complete dataset of inputs and outputs in mass form for an institution – or indeed for a set of buildings. Therefore, the final aim of the university mass balance study was to test different elements of the mass balance approach, with the intention of joining these figures together to form a picture of resource flows for a model university.

The process of applying the mass balance approach with universities has been used to

²⁵ Forum for the Future (2004) On course for sustainability: final report of the Higher Education Partnership for Sustainability www.heps.org.uk

²⁶ Forum for the Future (2004) Reporting for Sustainability: guidance for HEIs

²⁷ Waste Watch (2004) Resource management in the education sector: key findings from a study

inform the development of a mass balance tool for organisations, which can be used with any organisation to examine mass flows. This is introduced at the end of this section, with further details in Appendix 2.

Universities involved in the study

Universities were chosen for their previous commitment to sustainable development, and for their capacity to produce data for a particular department. Geographical location was also a consideration, Edinburgh and Greenwich selected for their contrasting location, and Sheffield Hallam and Sheffield University in order to compare organisations in a shared locality. The universities chosen were:

University of Edinburgh

University of Greenwich

University of Sheffield

Sheffield Hallam University

The partners worked together on identifying data and on possible solutions to tough emerging issues and established their own specific aims for the project:

- To determine if the mass balance approach is useful/possible in higher education
- To improve resource efficiency and effectiveness at institution/faculty level
- To identify useful data sources and gaps
- To target resource intensive parts of institutions
- To identify relationships between financial (profit), environmental and social resource flows and their impacts
- To uncover the links between administrative resource flows and academic outputs.

Section 3.3 discusses how the mass balance approach has been adapted for application with universities, and how the information that is available from a university is useful for a mass balance application.

3.3 Methodology: developing the mass balance tool for higher education

There were four main stages to developing the mass balance approach for universities. The result of this process is a tool which can be used with any organisation to categorise the organisation's resource flows into the mass balance framework. This is a development from the Farm Mass Balance Tool for farms, which is a more rigid approach with defined inputs and outputs.

Stage 1 All possible resources and materials

Examining university resource flows within different departments and for the university as a whole

What materials should be included in the mass balance?

Stage 2 University mass balance categories

How do university departments relate to mass balance operational units?

How are university accounts and records arranged in order to facilitate the collection of mass balance information?

Stage 3 University operational units

How do university resources fit into the ten mass balance categories?

For example, how does the mass balance definition of 'products' fit with an organisation that is not based on the production of physical products?

Stage 4 Standard figures

Is mass based information available from other sources that would be useful for a university mass balance?

3.3.1 University resources and materials

Stage 1
All possible resources and materials

Stage 2
University mass balance categories

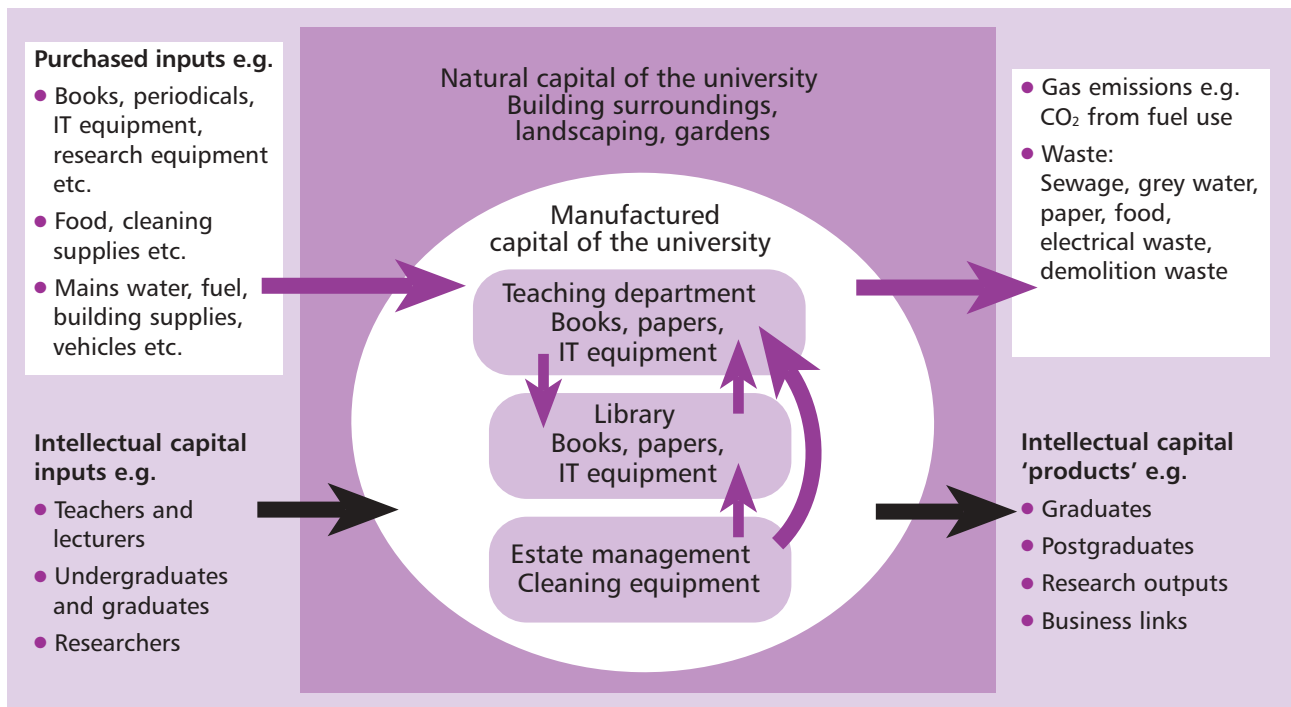
Stage 3
University operational units

Stage 4
Standard figures

The type of data used in previous applications of mass balance (predominantly in the manufacturing industry) do not readily match higher education, where there is no tangible 'product' created by a manufacturing process. The main products, or outputs, of a university cannot be measured as a mass as they take the form of contributions that the knowledge and skills of their graduates and research make to society. In addition, these outputs are dependent on inputs like teaching, research, mentoring etc, which are not things that can be measured in mass form. Universities find themselves outside of the traditional scope of the mass balance.

The boundaries of a university mass balance are outlined in the diagram opposite, with the purple arrows indicating the resources that have been researched.

Figure 16 Example resource flows in a university



3.3.2 University mass balance categories

- Stage 1**
All possible resources and materials
- Stage 2**
University mass balance categories
- Stage 3**
University operational units
- Stage 4**
Standard figures

Of the ten types of data identified in the Mass Balance UK framework (see figure 1) only three were deemed suitable for higher education. These are outlined below, with a discussion of how the partners derived this data from their university department.

Inputs

Research with the partners showed that resources flowing in to institutions are fairly well controlled through the finance and purchasing systems and data that was fairly easily accessible. Reports produced from the Greenwich University purchasing and finance systems showed spend on each item by department listed under the generic commodity codes developed by Proc-HE. Proc-HE (www.proc-he.ac.uk) is the body

responsible for developing and implementing the procurement strategy for higher education in the UK.

These reports only showed expenditure that was linked to contracts. Off-contract expenditure was less easy to track. The group agreed to look at on contract expenditure first and identify main spends. It was agreed that no minimum would be set for inclusion in the spend data at this point, but once that data had been compiled it was agreed that a minimum spend figure of £100K pa per institution would isolate the significant spend categories.

Stocks

The partner group agreed the importance of knowing what actually happens to resources once they have entered the system, in order to identify how much mass is circulating in the system. This proved to be a hard task as the data was very difficult to obtain, because

there was a lot of low value mass about which little or no data was kept, e.g. computers moving from academics to researchers or test equipment being given to students to use.

Movement of resources around a university appeared to be quite haphazard. A lot of mass is not procured by the university itself, but brought onto campus by students, staff or visitors and then disposed of on campus. At the same time, mass procured by the university might be taken away, for example by students in the form of lecture notes, and disposed of away from the university. The group concluded that it was not possible to generate useful data on stocks.

Outputs

General waste is fairly well recorded by weight and data was available for some discrete units.

Table 8 Summary of the mass balance categories and the information sources that have been used within the universities

Mass balance categories at organisation level		Information sources available within universities
1 Initial stock		Category not useful to include at university level
2 Inputs/imports	Materials from outside the organisation, e.g. purchases	Finance and purchasing data, ledgers available for each department, with varying levels of detail
	Materials from other units within the organisation	Category not applicable to universities
3 Produced/extracted		Amount of waste produced, from waste estimates
4 Outputs/exports	Materials going to outside the organisation, apart from waste	Categories not applicable to universities
	Materials going to other units within the organisation	
5 Embodied		
6 Transformed/used		Category not applicable to universities
7 Recycled/recovered	Materials to recycling collection	Waste estimates Waste studies carried out within universities Waste disposal invoicing
	Materials recovered through composting	
	Materials taken back by supplier	
	Materials to scrap dealer	
8 Final disposal	Final disposal: materials burned or incinerated	
	Final disposal: materials to landfill	
9 Emissions		CO ₂ emissions calculated from fuel use
10 Final stock		Category not useful to include at university level

3.3.3 University operational units

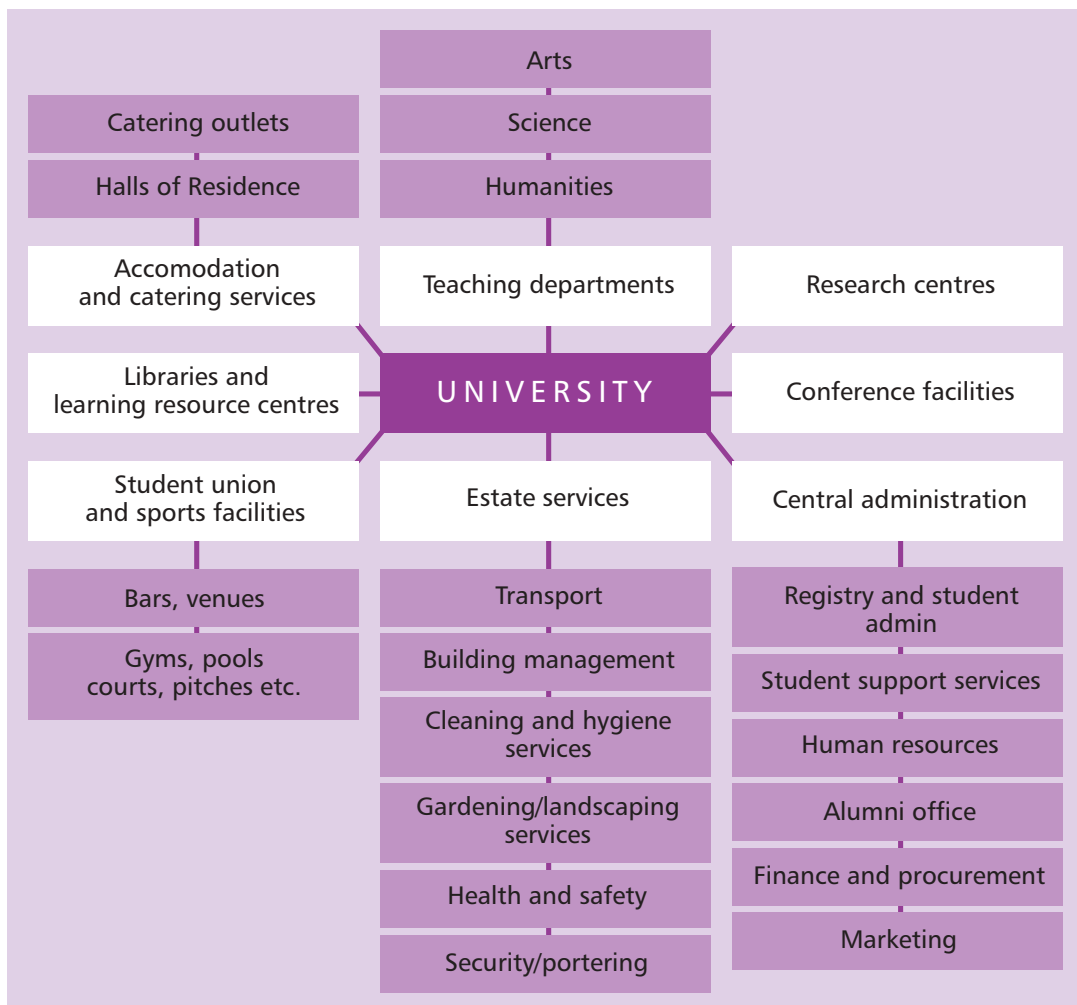
- Stage 1**
All possible resources and materials
- Stage 2**
University mass balance categories
- Stage 3**
University operational units
- Stage 4**
Standard figures

Based on the fact that a complete dataset of inputs and outputs for a whole institution did not exist, the project group felt that the results would benefit from doing a mass balance on particular units within the institutions. The study looked at an academic faculty and an administrative or commercial function of the university, in order to meet the aim of exploring the links between administrative resource flows and academic outputs:

- University of Edinburgh:** Charles Stewart House (administrative unit) and Joseph Black building (houses the school of chemistry)
- University of Greenwich:** Maths and computer science department
- Sheffield Hallam University:** Stoddart Building (housing the School of business and Finance and Computing and Management Sciences)
- University of Sheffield:** Print unit

The initial scoping for the study with universities highlighted that there may be at least nine or ten main operational units and many more sub-units, comprised of individual buildings or departments within the university. This is illustrated below in figure 17.

Figure 17 Potential operational units for a university



3.3.4 Standard figures

Stage 1
All possible resources
and materials

Stage 2
University mass
balance categories

Stage 3
University
operational units

Stage 4
Standard figures

An analysis was done for a 'model' university to show what mass balance might look like when applied to a whole university. This section goes into some detail about how the standard figures that formed a model university mass balance were reached from the information available from the partners on resources, plus established conversion factors for determining how cost is converted into waste. The figures cover:

Inputs

- 1** General material input
- 2** Water
- 3** Electricity
- 4** Other fuels
- 5** Stationery items, printing and computer consumables
- 6** Books
- 7** Furniture
- 8** Cleaning products

Outputs

- 9** Waste
- 10** Waste management

Standard figures in detail:

1 General material input

Information available

Edinburgh University provided a report on a waste audit and utilities consumption of six buildings. Greenwich provided total expenditure and per department expenditure on stationery items and printing and computer consumables. Sheffield Hallam provided a student mass balance project on the catering unit of the Stoddart Building. Sheffield University provided expenditure on materials purchased in their printing unit. In addition, the Estates Management Statistics (EMS) database provided information on residential and non-residential cleaning costs for universities and the floor area of each partner university.

Conversions

Volume to weight conversions for furniture, paper and household items was used based on conversion factors from the DETR's Waste Classification Scheme.

2 Water

Information available

Water consumption data was available for the Stoddart Building at Sheffield Hallam and the print unit at Sheffield University. The EMS statistics gave total water consumption data for all the partner universities. Water consumption is given in cubic metres. One cubic metre = one tonne.

Conversions

Data was available from Sheffield Hallam, Edinburgh University and Sheffield University. Because of the different source data available, two different methods were used to estimate department level data. For Greenwich University it was possible to derive figures for departmental water consumption or it was possible to derive average figures of water use per building. Each perspective is potentially useful and ideally both should be used to gain a complete picture whilst avoiding double counting.

For Greenwich University there were figures for university water consumption, total departmental spend and total university spend on all things. The proportion of departmental spend was taken to indicate the size of the department. It was assumed that water consumption would follow departmental size proportionally. Total water consumption multiplied by proportional department spend is equal to the departmental water consumption. Another method of calculation that can be used is a division of the university's total water consumption by the number of departments within it. This would give average water consumption per department.

3 Electricity

Information available

Sheffield Hallam, Edinburgh and Sheffield University provided data on electricity consumption taken as operational units. Greenwich University gave the expenditure on electricity by department. The EMS statistics were able to give information on the gross internal area of the universities and total energy consumption.

Conversions

The area of the Stoddart building was divided by the amount of electricity it consumes in order to have a figure on the amount of electricity used per square metre. Since the EMS statistics gave information on the total area of each university, this figure was used as a conversion to show an approximate amount of electricity used per university.

$$\frac{\text{Stoddart building area}}{\text{Stoddart building electricity consumption}} = 123.69 \text{ kWh/square metre}$$

For the purposes of the model university mass balance, it was necessary to establish the electricity consumption per department or per building. The fuel consumption per department has been derived from this figure. For Edinburgh University it was not necessary to make conversions because the energy consumption data for each building was already available.

4 Other fuels

Information available

Sheffield Hallam provided figures for consumption of heat and gas in their unit, and Sheffield University gave the consumption of Onyx-CHP – their combined heat and power plant – for the printing unit. Edinburgh University gave information on the gas consumption of the buildings used as operational units. For the buildings where gas is consumed it has been assumed that it is the only fuel consumed apart from electricity. The EMS provided information on the amount of total energy and total electricity consumption of universities.

Conversions

Electricity consumption was subtracted from energy consumption and it was assumed that the result equalled to the total fuel consumption.

$$\text{Energy consumption} - \text{Electricity consumption} = \text{Other fuel consumption}$$

The following figures had no standard conversion rates, and so mass conversions were calculated by the project team.

5 Stationery items, printing and computer consumables

By examining office supplies catalogues it was possible to establish an average price for each product category which, when divided by the total expenditure on the product category, gives the average number of items purchased.

$$\frac{\text{Total expenditure}}{\text{Price per product}} = \text{N. products}$$

$$\text{N. products} * \text{Weight average product} = \text{Total mass}$$

6 Books

Greenwich University provided information on the amount spent on books. A consultation settled on £50 as an average price of a book. The total expenditure divided by the average price gives the number of books purchased. The average weight of a book (0.5 kg) was reached by taking a random sample of books in a library. The number of books purchased multiplied by the average weight give the total mass of books.

7 Furniture

Greenwich University provided figures for spend on furniture, which together with figures from office supplies catalogues enabled the calculation of the average price of furniture. Dividing the expenditure on furniture by the average price of a piece of furniture gave the average number of furniture items purchased. The DETR conversion factor for household items (mainly furniture) is 270kg per cubic metre. Measurements were made of desks and workstations and converted to mass.

$$\frac{\text{Tot expenditure}}{\text{Price per product}} = \text{N. products}$$

$$\text{N. products} * \text{Volume per product} = \text{Total volume of products}$$

$$\text{Total volume of products} * \text{Product conversion factor} = \text{Total mass of products}$$

Some figures like the weight of printing machines, foods and kitchen materials have been estimated using partner's estimates.

8 Cleaning products

Information from the SHU Stoddart building catering stock mass balance calculated the weight of cleaning products the catering unit purchased and it was assumed that that amount was used by the whole of the Stoddart building. The area of the Stoddart building was known, and by dividing the amount of cleaning products used by the area of the

building a figure was obtained that would enabled conversion of square metres into kilograms of cleaning products.

$$\frac{\text{Total weight cleaning products}}{\text{Area Stoddart building}} = 0.0054 \text{ kg cleaning products/square metre}$$

9 Waste

Information available

The Edinburgh University Waste Composition Study gave the amount of waste produced by six buildings and the total landfill waste produced annually from 2001–2003.

Edinburgh University also provided information on the amount of clinical waste and general waste produced and the amount of waste recycled.

The EMS report gives the staff and student headcount in each university. The Environment Agency Waste Production Survey indicates the total waste tonnage per service sector unit, including the education sector, and the amounts of waste used for each waste management method.

Conversions

Conversions were used to calculate the total waste of those universities from which information was missing. Figures for the types of waste produced and the amount recycled in Edinburgh University was used to calculate the total waste produced. The EMS statistics were used to find out the number of people using the university facilities (staff plus students) and the proportion of total headcount between Edinburgh University and the other universities was calculated. The proportion was used to calculate the total waste produced by the other universities.

Headcount proportion Greenwich: 59.7%
 Sheffield: 111.8%
 SHU: 106.2%

10 Waste disposal options

Information available

The Environment Agency Waste Production Survey indicates the total waste tonnage per service sector unit, including the education unit, and the destination of that waste (landfill, incineration, recycling etc). Edinburgh University also provided data on the management of their waste.

Conversions

The waste management figures from Defra and Edinburgh University were converted into percentages and compared to see which would best fit the purpose of the mass balance. As the DEFRA figures date as far back as 1998 and include waste management options that are unlikely to be used by higher education institutions, it was decided to base calculations on Edinburgh University's figures. Despite only showing the information on waste that would be sent to landfill, the figures are very useful and are displayed in the report section of each worksheet.

Categorisations of data and assumptions

The categorisations for data were predominantly based on the expenditure analysis provided by Greenwich University that categorised certain products under specific headings. These categorisations included usually more than one type of product and included non-mass related expenditures such as services. To calculate the weight of the goods included in these categories a series of assumptions were made to categorise them in consultation with partners.

Section 3.4 summarises the results of applying the mass balance framework and suggests what the flows within the 'model' university look like. These results are discussed in relation to indicators of resource use and sustainability for universities.

3.4 Results of the university mass balance

At the heart of a mass balance is the identification and calculation of resource flows in and out of an organisation. The following diagrams show how the data established by the standard figures and conversion factors might translate for the model university, with five separate departments.

Figure 18 Mass balance model university

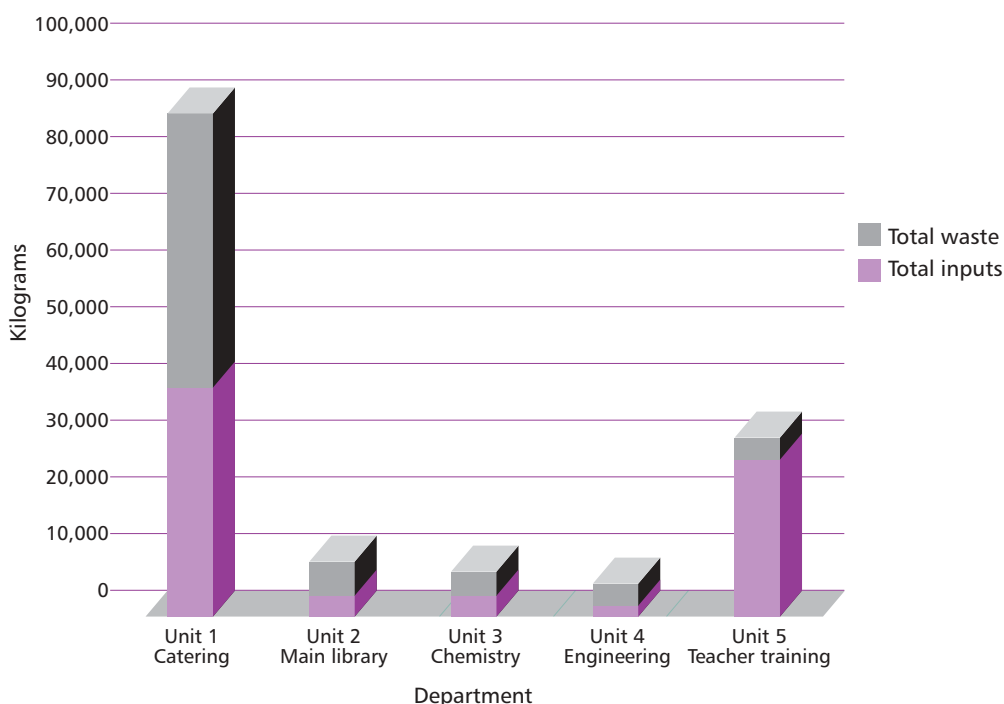


Figure 18 shows that the balance between inputs and waste is close enough to have confidence in the assumptions that built them, with the exception of the teacher training facility where a significant amount of furniture had been procured that year which has skewed the results. The clear indication from Figure 18 is that the mass consumption and waste from the teaching functions is small compared to catering.

Figure 19 Waste composition of model university

Having established the big picture, the mass balance method then allows for a more thorough interrogation of the information.

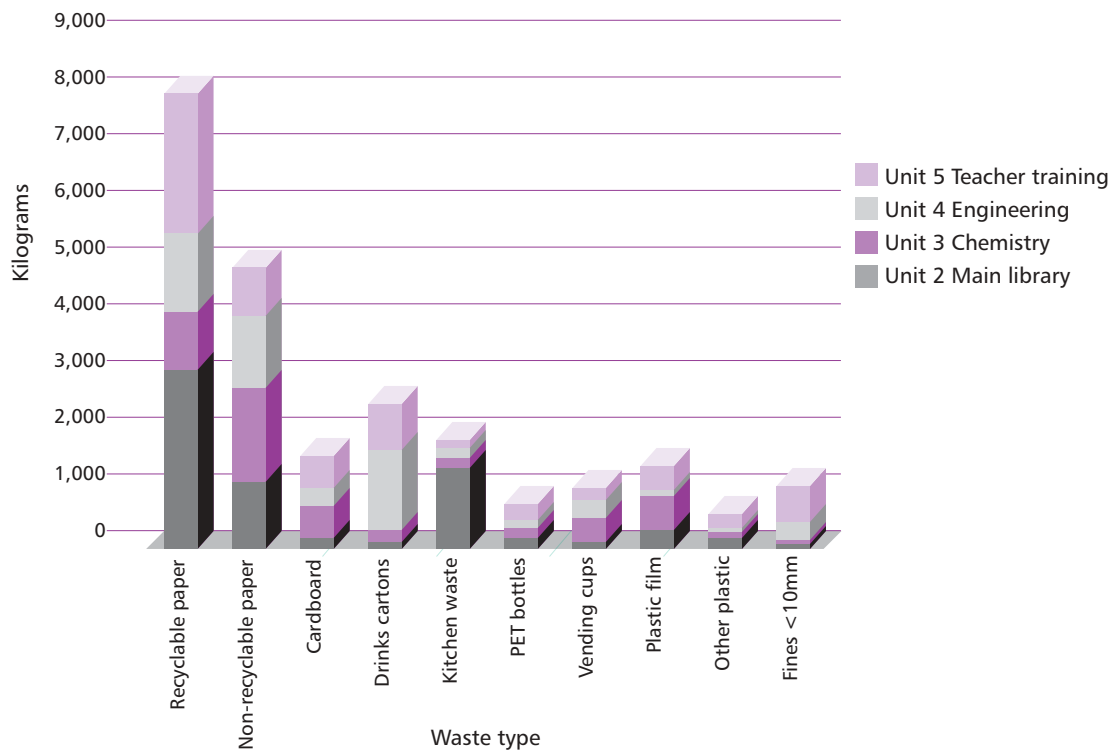
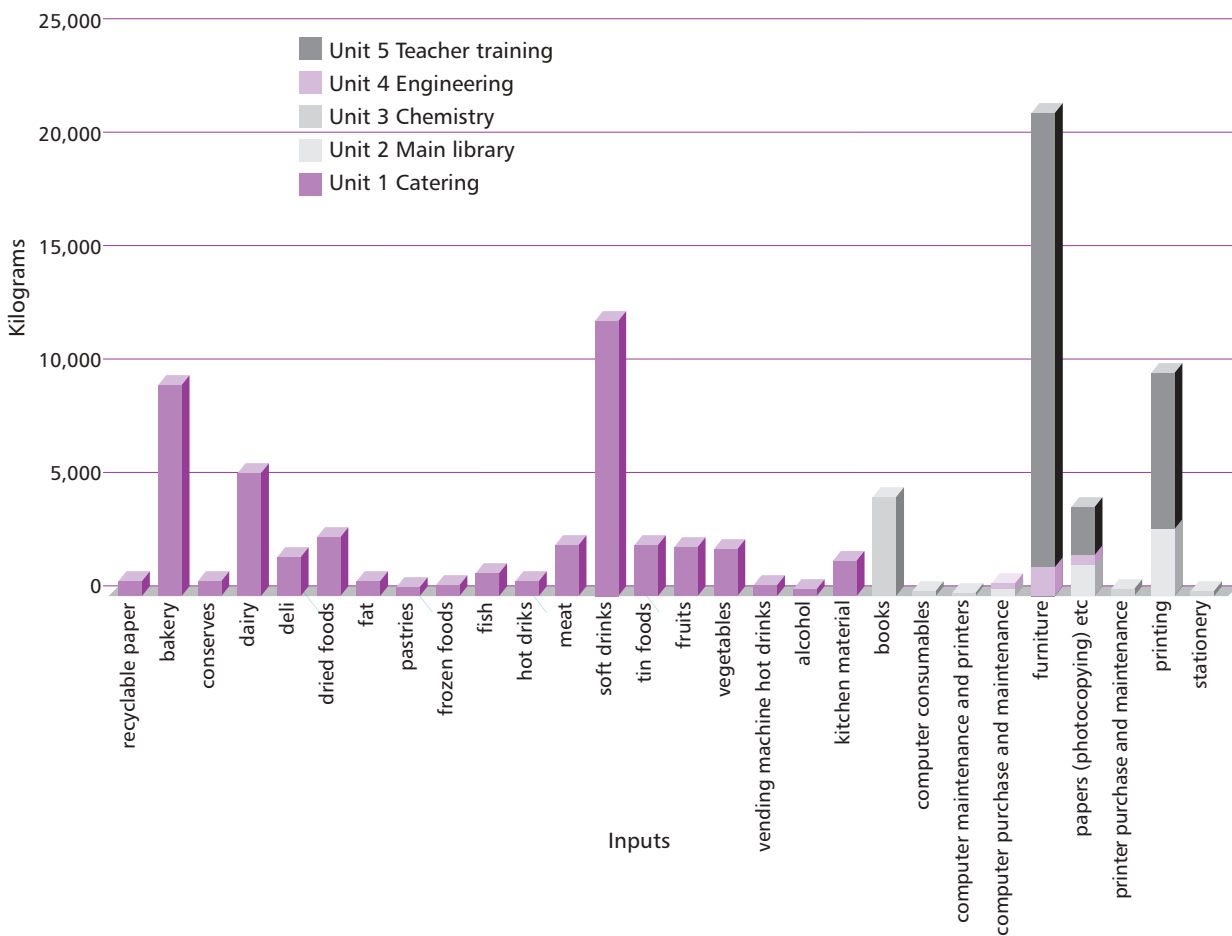


Figure 19 shows the composition of the waste in each of the operational units in the model except catering. It is evident that paper both recyclable and non recyclable are the big challenges. The third ranked waste stream was drinks cartons.

Figure 20 Total inputs to model university by department and category



As would be expected, water and energy constitute the majority of the mass balance. Analysis at the next level down shows that the significant inputs are soft drinks, books, printing, paper and furniture.

It would be difficult to argue that a university should cut down on the number of books that it orders, but there are opportunities in reducing consumption of soft drinks and examining the life cycle of furniture purchased. Paper is a perennial concern for environmental managers requiring constant vigilance to keep under control but efforts to reduce consumption in the higher education sector have not to date been outstandingly successful or long lived.

The following diagrams illustrate the flows of resources of Sheffield Hallam University's Stoddart Building catering unit and of the model university.

Figure 21 Resource flows of Sheffield Hallam University Stoddart Building catering unit

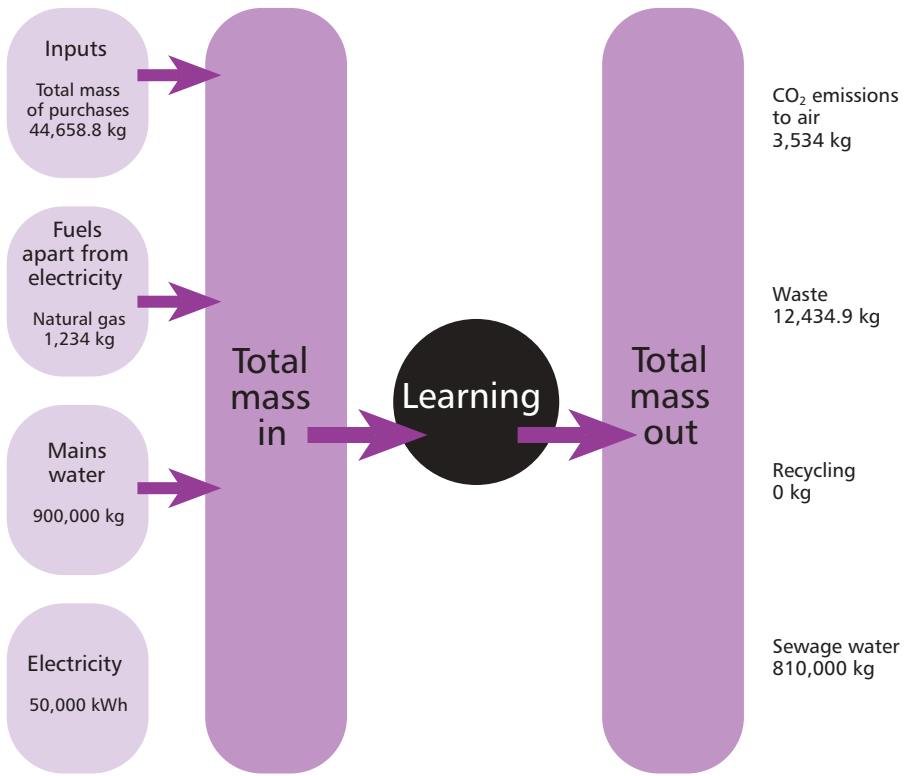
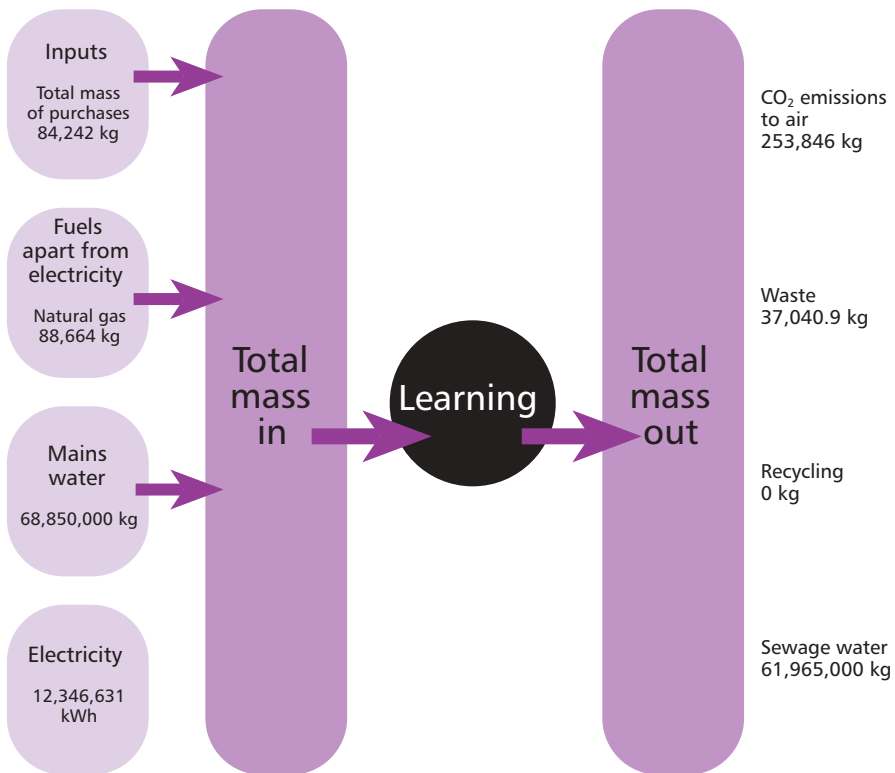


Figure 22 Resource Flows of Model University



3.5 Conclusions: the mass balance approach and sustainability at university level

As analysis of the data went on it became clear that the potential errors were quite large and would have an adverse effect on the usefulness of the tool as a support to a manager in making decisions about resource use.

This does not necessarily mean that the concept is flawed for use in higher education, but rather that the natural resource data necessary for mass balance is incomplete and skewed towards financial information. However, there are two causes for optimism on this point.

Firstly the trends towards more complete reporting in the future. Increasingly, universities are establishing environmental management and reporting systems. The University of Gloucester has just become the first university to be accredited with ISO 14001 status, and many other further education colleges already carry this accreditation. These have traditionally been concerned solely with waste and energy but the government's recent emphasis on sustainable consumption and production will mean that higher education will be expected to know more clearly what natural resources it is consuming.

Secondly from finance to mass, cost efficiency is not going to go away as a driver for environmental management in higher education however, it is getting harder and harder to make significant cost savings and managers are turning their attention to environmental benefits in the wider sense, reflecting the progress already made in business and local government. The most powerful way of demonstrating those benefits is in terms of the reduction in use of natural resources and if you are reporting that reduction the unit that makes the most sense is mass. So the need for something like mass balance will remain but there has to be confidence in the data quality first.

However, regardless of its application in a mass balance the data generated as a result of this project will be useful in helping managers to better understand the flows of natural resources within universities, and the impact of different departments or units on total resource use. Amongst the partners already, there are four different reporting methods in use: the balanced scorecard, the European Foundation for Quality Management (EFQM) standard, the Business in the Environment (BiE) Index of Corporate Environmental Engagement and an environmental management system, which could benefit from being joined up by the mass balance framework.

In order to demonstrate that public funds are being spent wisely, universities regularly report to the funding councils and government on their performance. There are two dominant data gathering exercises – the Estates Management Statistics (EMS) and the Higher Education Statistics Agency (HESA) returns. The HESA return records data on things such as student ethnic background, staff responsibilities and enrolments. The Estates Management Statistics record data on floor area utilisation, energy use and water use on an institution wide basis. There is obvious potential for a greater integration of mass balance data into the EMS, and the inclusion of a waste indicator has been suggested.

3.6 Organisational Mass Balance Tool

The process of examining resource flows within universities has involved the development of a simple tool that performs the basic function of accounting for resource flows, in terms of mass at an organisational level. The tool is capable of being used by any organisation, and differs from the Farm Mass Balance Tool as it enables the user to define the operational units, inputs to and outputs from the organisation.

The tool is based on a series of worksheets within an MS Excel spreadsheet. By allowing an unlimited number of operational units to be assimilated into the tool, a small or large organisation can apply the tool with equal effectiveness. The tool generates a report, with the following information:

For the whole organisation	For each defined operational unit within the organisation
Resources and waste	Total amount of inputs bought in
Total amount of water used	Inputs from outside the organisation (%)
Total amount of electricity used	Inputs from within the organisation (%)
Total amount of fuel used	Total amount of products leaving the unit
Waste management	Products leaving the organisation (%)
Total amount of waste produce	Products moving to another unit (%)
Breakdown of waste management used	Mains water used by this unit
Carbon footprint	Electricity used by this unit
CO ₂ produced by whole organisation	Carbon dioxide emission from this unit
CO ₂ produced per kg of product	Waste produced by this unit

By entering data on input flows for set categories, managers will be able to measure and better manage mass flows within their organisation. It is flexible enough to allow users to examine specific resource flows to enable these to be managed separately, but also present data in a simple format.

Which indicators of resource use will be useful to them depend on the aims of the organisation, e.g. whether it is a mass-dependent production system like a farm or a non-mass-dependent production system like a university, with the aim of producing social capital rather than manufactured capital.

The Mass Balance Tools are available from www.forumforthefuture.org.uk

A 'how to' guide to using the organisation and university mass balance is in appendix 2 and on the website.

Appendix 1 Farm Mass Balance Tool

The mass balance tool for farms comprises a series of MS Excel worksheets, based on the different enterprises that are present on the farm and that are being included in the farm mass balance. Each sheet is structured to show what information is required to complete the farm mass balance.

- 1 Start** Basic information is entered about the farm, including name and size, as well as the dates which are the start and end date for the accounting period. Options show which enterprises are included on the farm – the relevant sheets will become visible.

<ol style="list-style-type: none"> 2 Arable Forage & grazing Sheep Beef Dairy Poultry Pigs Compost 	<p>Optional sheets depending on whether the farm includes these units</p>	<p>For each relevant enterprise, enter figures for inputs used, production figures and transfers to other units on the farm. The classification presented in the drop-down list for inputs and products is the mass balance classification (used in other mass balance projects) and for waste is the UK waste classification</p>
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- 3 Conservation** Information can be entered to show the inputs and energy used in carrying out conservation activities on the farm, in line with Entry Level or Higher Level Scheme options. This sheet can be left blank if there is not separate information available.
- 4 Resources and waste** The machinery owned by the farm is inputted, including self-propelled and non self-propelled. Machinery use is allocated to the different farm enterprises based on a percentage of total use. If the machinery owned by the farm is used for contract or rented land, this can be included in the total percentage.

This sheet also asks for details of waste management practices. Waste quantities are calculated from each enterprise so these figures should accurately reflect the total waste

Appendix 2 Organisational Mass Balance Tool

The mass balance tool for organisations is based on a series of Excel worksheets, corresponding to the different operational units within the organisation, as defined by the user at the start of the process.

- 1 Start** Basic information is entered about the organisation, including the sector, and the timescales that are being used. A sheet is created for each operational unit within the organisation, as the name of each unit is entered.

Mass Balance tool for organisations

Name of organisation:

What sector is this organisation?:

What time period is the mass balance for?

From:

To:

Name of operational units to include in the mass balance?

Name of unit 1:

Notes for completing the mass balance spreadsheets

1. For each unit, input details of inputs, fuel, products and wastes, clicking the appropriate button after each line is entered. Each time a button is clicked, the mass balance table is updated. Ensure that data entry for that line is complete before the button is clicked. When a button is clicked, ensure the last line to be updated is selected.
2. On completing details for one unit, use the tabs to move to the next unit.
3. The final sheet 'Report' uses information from the Mass Balance table and presents this as indicators which may be used for benchmarking.

- 2 Units** The user then works through each sheet, entering information for each operational unit, such as inputs, fuels, products and wastes, with the name of the material and the quantity. Any number of these resources can be included for each unit. In order to make this tool relevant to the wider suite of mass balance projects, a list of materials including the mass balance classification is offered. If this classification is useful, this can be selected from, otherwise the user can enter alternative material names. As materials are entered, the mass balance table is updated with the relevant figures in each category.

Unit 0

What are the inputs to this unit? (apart from fuel, electricity and water)	Amount in stock at the start	Amount bought in	From (source) (including other units within the organisation)	Amount in stock at the end	Click when input added
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
What fuels are used (excluding electricity)	Amount in stock at the start	Amount bought in	From (source) (including other units within the organisation)	Amount in stock at the end	Click when fuel added
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
Carbon dioxide emissions from direct fuel use		Amount emitted			
		<input type="text" value="0.0 kg"/>			
How much electricity was used during this time?		Amount used			
<input type="text"/>		<input type="text"/>			
How much mains water was used during this time?		Amount used			
<input type="text"/>		<input type="text"/>			
What are the products from this unit? (apart from waste products)	Amount in stock at the start	Amount leaving unit	Going to (destination) (including other units within the organisation)	Amount in stock at the end	Click when product added
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	
What are the wastes produced from this unit?	Amount of waste produced		How do you manage this waste?		Click when waste added
<input type="text"/>	<input type="text"/>		<input type="text"/>		

Fuels are entered in the units and quantities in which they are used, e.g. litres of diesel and cubic metres of natural gas. These figures are converted to kilograms automatically after they are entered. Likewise, fuel use is converted to a direct carbon dioxide emission as the information is entered, and this is presented on the sheet for the unit.

- 3 Mass balance sheet** Figures from each operational unit worksheet are updated in the mass balance spreadsheet, according to category. The user can view the table to show the ten main mass balance categories or to show subcategories of different waste management methods.

	(1) Initial stock	(2) Imports - materials/products flow in	From outside organisation	From other units within the organisation	(3) Produced/extracted	(4) Total flow out	To outside organisation	To other units within organisation	(5) Embedded materials/products	(6) Transformed/used	(7) Materials to re-employment	Materials to recycling collection	Materials recovered through composting	Materials back to supplier
	0	0			0	0					0			
	0	0			0	0					0			
	0	0			0	0					0			

- 4 Report** A report is then produced as the last sheet in the workbook. This presents a summary for the whole organisation of fuel and water use and waste management. Each operational unit is summarised in terms of the quantity of resources entering and leaving the unit from within the organisation and from outside the organisation.

Appendix 3 Mass balance projects across the UK sponsored by Biffaward

More details available at www.massbalance.org

Organisation	Project Name
SNW	RIFAS
Environ Trust	Zero Emissions
WWF-UK	Tourism Mass Balance
FIET	Evaluation of waste production, utilisation and brokerage potential in UK furniture industry
Southampton Environment Centre	Waste Management for Schools
Heads, Teachers and Industry	Education for Sustainability – 'e4s'
West Country Rivers	National Strategy for Agri-Waste Management
University of Leeds	Analysis of Packaging Flows in the UK: Phase II Study – Data Collection and application
Imperial College	Island State
Viridis	Mass Balance Study of Tyres – Extension for Education and Dissemination Activities
ISDG (Oxford University)	Carbon balance evaluation
Viridis	Mass Balance of the Construction Industry
FIET	Furniture Packaging Optimisation
TIET	Sustainable Timber Waste
SWEET	Paper Industry Mass Balance
BFM Ltd	Benchmarking solvent waste in the UK furniture manufacturing industry
HRI Ltd	Mass Balance Model of Nitrogen Flows in the UK
National Centre for Business and Sustainability	Sustainable Markets for Waste Glass from Fluorescent Tubes and Lamps
British Glass Foundation	A fundamental appraisal of the environmental impact of large-scale glass manufacture
SWEET	Ceramics Industry Mass Balance
Waste Watch	The Environmental Footprint for the Public Sector
Royal Society of Wildlife Trusts	Dissemination of resource flows in UK Economy (Phase 3)
Waste Watch	Research and Development to Identify and Evaluate the Environmental Footprint for the Financial Sector
The Castings Development Centre	Mass Balance Study for the Foundry Sector
West Country Rivers	Mass balance study into Agricultural Waste...
SWEET	Chemicals Industry Mass Balance
The Midlands Environmental Business Club Ltd	Exhibition Industry – Sustainable Waste Management Best Practice Guide
Royal Society of Wildlife Trusts	Mass Balance Ecological Footprint of the NHS
RACEEnvironment Ltd	Resource Flow Analysis of the British Poultry Industry
Bioregional development group	Reclaimed Materials in Construction: BedZed Mass Balance
Institute of Waste Management (EB)	'City Limits' – A resource flow and ecological footprint analysis of Greater London
West Country Rivers	Sustainable management of organic materials in agriculture
Viridis	Sustainable Resource Use in the Motor Industry

Organisation	Project Name
University of Surrey	Material Flow Analysis for Iron, Steel and Aluminium in the UK
Ecosys	Sustainable Waste Management in the South East – Resource Flow Mapping
University of Surrey	Economic Dimensions of UK Material Flows of Iron, Steel and Aluminium
University of Leeds Environmental Trust	Mass Flow Analysis for the Periodical Publishers Sector in the UK
Sustainability North West	ECO-REGION – resource flow and ecological footprint analysis of the NW region
British Furniture Manufacturers Ltd	Benchmarking wood combustion
C-Tech Environmental Group	MB study into thermal methods of waste treatment
Viridis	Resource flow and ecological footprint of Scotland
National Centre for Clean Air	A Mass Balance of the UK Newspaper Industry
Arena Network Northern Ireland	Mass Balance of Northern Ireland
SWEET	Resource Flow and Ecological Footprint of the South West Region
WWF-UK	Reducing Wales' Ecological Footprint
RACEenvironment Ltd	Resource Flow Analysis of the British Pig Industry
C-Tech Environmental Group	Mass Balance Study into Electricity Generation Including a Critical Review of New and Emerging Technologies
Waste Watch	Resource Management in the Education Sector
Forum for the Future	Organisation level application of mass balance analysis to farms and universities, using concept and methodology to design transferable resource management tools
National Centre for Business & Sustainability	STRAW
Timber Industry Environment Trust (TIET)	Embodied Wood: The UK mass balance and efficiency of use
C-Tech Environmental Group	Mass balance study into waste arisings from the food and drink processing industries
University of Cambridge	Mass balance & scenario analysis for UK clothing and textiles
WWF-UK	Ecological Budget UK

If you would like to receive a copy of the mass balance tool for organisations or farms, please contact us.

If you would like further information about Forum for the Future's involvement in the Biffaward Mass Balance projects, or details of the methodology used in the report, please contact the relevant people below.

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