DEVELOPMENT OF A STANDARDISED METHODOLOGY FOR RESOURCE FLOW ANALYSIS AND ITS APPLICATION TO SUB-NATIONAL REGIONS

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ABSTRACT

One outcome from the United Nations Johannesburg 2002 World Summit on Sustainable Development was a commitment to promote sustainable patterns of consumption and production (SCP). In response the UK Government has published a Framework, which includes proposals for indicators to measure progress towards SCP. These include material use, manufacturing output, energy consumption and a range of emissions.

In 1998 Biffaward set up an innovative programme on Sustainable Resource Use to promote resource flow analysis (RFA) studies focusing on specific materials, sectors and geographical areas across the UK. Biffaward recognised that data were not collected systematically in sufficient detail to assess resource efficiency. The RFA studies provide information on resource flows through the economy including material use, water, emissions and waste. The aim of this progressive approach has been to provide comprehensive baseline data, highlight problems with data quality and current data gaps and provide the basis against which changes in resource efficiency can be measured.

Steps taken by practitioners to refine and standardise the RFA methodology since the implementation of the programme are described. Data issues including reproducibility, comparability and quality are discussed. Progress to date is presented in relation to the RFA study of Scotland, which was completed in early 2004. RFA results are given for Scotland on resource use and waste production for a base year of 2001.

The paper discusses how the outcomes of RFA studies support progress towards SCP, including the provision of data to develop SCP indicators.

INTRODUCTION

One outcome from the United Nations Johannesburg 2002 World Summit on Sustainable Development was a commitment to promote sustainable patterns of consumption and production (SCP). In response, the UK Government has published a Framework, which includes proposals for indicators to measure progress towards SCP. These include indicators of material use, manufacturing output, energy consumption and a range of emissions. This paper describes resource flow analysis (RFA), the methodology adopted to create an RFA and the data issues that need to be addressed. The paper goes onto present the results of the Scotland's Footprint study [1] and describes how this type of data can contribute towards SCP.

THE BIFFAWARD PROGRAMME

In 1998 Biffaward set up an innovative programme on sustainable resource use to promote Mass Balance studies focusing on specific materials, sectors and geographical areas across the UK [2]. Viridis/TRL, Best Foot Forward and others have extended this approach to include resource flow and EF analyses. Biffaward recognised that data was not collected systematically in sufficient detail to assess resource efficiency. The resource flow studies provide information on flows through the economy, including total material use, water, emissions and waste. The aim of this progressive approach has been to provide comprehensive baseline data, highlight problems with data quality and current data gaps and provide the basis against which improvements in resource efficiency can be measured. Data generated from a resource flow analysis allows the identification of the inefficient use of resources and therefore allows more focussed management of resources and the development of policies to optimise resource efficiency.

RFA METHODOLOGY

An RFA aims to quantify the flow of resources in terms of mass (tonnes) within a defined geographical area or industry sector over a set period of time (typically a year). Resources are described within a RFA as 'materials' or 'products'. The flow of resources from extraction as 'materials' through to manufacture into 'products' to and then to consumption and final disposal, are associated with the transformation and movement of these resources resulting in waste production and emissions to air, land and water. Therefore, to complete an RFA for a geographical area the following should be quantified:

- Material import, production and export
- Product import, production and export
- Waste production
- Water consumption
- Waste water production
- Emissions to air

An RFA will normally also identify how waste arisings are managed; for example sent to landfill, recycled, reused and/or incinerated. In Scotland's Footprint [1] the general approach taken for the RFA was to identify and break down material and product resource flows by industrial economic sector. The industry sectors were defined according to *Standard Industrial Classifications (SIC)* [3]. Service industries were not included as the basis for collecting data, as they are not directly involved with the extraction or manufacture of materials and products. For each of the sectors included, the RFA quantified import, production and export.

STANDARDISING THE METHODOLOGY

The studies within the Biffaward programme obtained initial guidance on a standardised methodology from the publication of *Mass Balance UK: Mapping UK Resource and Material Flows* [4]. This provided guidance on the format for data collection and helped with boundary setting. The guidelines did not address data sources or data quality. It was recognised by the practitioners within the Biffaward programme that some form of standardisation of data between, as well as within, the studies was vital for a variety of reasons [5]:

- Reproducibility – to enable the studies to be repeated at regular intervals and results compared. This enables an assessment of progress towards greater resource efficiency.
- Comparability – to enable the comparison of results between studies: for instance, between different geographical areas of the UK.
- Stakeholder confidence – for the data to have credibility and to ensure they are acted upon stakeholders must be assured that the results are accurate and representative of the current situation.
- Data quality - resource flow data to the level of detail required are often not available. As a result, a proportion of the data has to be estimated using assumptions and proxy factors, all of which influence data quality.

Certain principles for data collection were agreed between the Biffaward practitioners. These can be summarised as follows:

- Use of standard data sources:
    - ProdCom (products) [6]
    - Minerals Yearbook (abiotic materials & fossil fuels) [7]
    - Forestry Statistics (wood products) [8]
    - FAO food balance sheets (food) [9]
    - DEFRA agricultural census (grass eaten) [10]
    - DUKES (fossil fuels) [11]
    - EA/SEPA/DEFRA (solid waste) [12]
    - NETCEN/NAEI (emissions to air) [13]
    - Local data sets where available.
- Transparent methodology. It was agreed that where data conflicts arise the choice of data used would be documented and justified in final reports.
- Data quality assessment. Data produced by RFA studies varies in quality. It was agreed to assign quality assessments to the data used in the studies in order to support the interpretation of the data presented. The level of data accuracy is influenced by:
    - The data source.
    - The degree of manipulation required to derive the final dataset. For instance applying conversion or proxy factors.
    - Ideally, the availability of comparative sources of data from more than one source.

  In Scotland's Footprint data were assigned a data quality assessment according to the criteria in Table 1.
- Manipulation of ProdCom data. ProdCom is one of the key data sources [6]. ProdCom collects via survey, data from approximately 25,000 businesses annually and 4,500 quarterly. The resulting data relate to the value and volume of UK manufacturers' product sales, imports, exports, net balance (imports – exports) and net supply (apparent consumption) and covers approximately 4,800 products. Currently however the data need considerable manipulation in order to be used including:
    - Data extraction
    - Conversion to mass

- Removing double-counting
- Dealing with ProdCom reliability problems

Although no standard methodology was agreed to deal with these issues it was decided that all actions would be fully declared in the final reports. The Scotland's Footprint study further developed a common approach to dealing with data as described in the next section.

Table 1: Criteria used for assessing data quality in a RFA study

Criteria	**Description**
High	*Data recognised as being accurate and robust, and sources can be established.*
Medium	*Data based on expert judgement or assessment, not necessarily verifiable; or have been subject to analysis, but are accepted by Industry as being reasonable.*
Low	*Best estimates made by the Project Team solely for the purpose of completing the analysis.*

STANDARDISTING DATA MANIPULATION IN RFA

The main data problems faced in RFA studies are described in the following sections in relation to the Scotland's Footprint study.

PROXY DATA

Due to the lack of available primary data, particularly for the products data, the Scotland's Footprint study had to place heavy reliance on data sets covering UK as a whole, and the application of proxy factors to derive estimates for Scotland. Until regional data improves, proxy factors are a necessary tool in obtaining data for this type of study. The proxy factors applied, as closely as possible, reflected the likely activity in Scotland. However, it is very important to recognise that a data set produced in this way is not as legitimate as using primary data and reduces the overall accuracy of the analysis produced.

The most commonly applied proxy factor used was employee numbers by SIC sector. The use of population as a proxy factor was avoided because it would not give any indication of the unique nature of Scotland's manufacturing compared to the UK as a whole. For instance the oil and gas fields lying within Scotland's waters account for approximately 71% of the total UK oil and gas output; whereas Scotland has only approximately 8% of the UK total population. However, the proxy factors more widely applied also have disadvantages associated with them. In particular employee numbers are a good proxy for production and manufacturing, because they reflect the industries of particular importance in Scotland; however, these are less valid when applied to import and export figures.

DOUBLE COUNTING

Double counting of resources was avoided in the Scotland's Footprint study by classifying products as either 'intermediate' or 'final'. This inevitably leads to a simplification of the situation, which meant that many products classified as intermediate products would also be used as final products and *visa versa*. This issue can only be improved by further research and central collation of supply chain analysis.

SENSITIVITY OF CONVERSION FACTORS

ProdCom reports were largely used for product data [6]. A significant proportion of ProdCom data were not available in units of mass. Conversion factors were required to convert the data into tonnes. Conversion factors were found by searching the Internet fro a number of product examples. For example, from manufacturers or retailers web sites, hwere the weight per item or the weight per m2 was expressed. An average was taken for as many different examples as possible and used to make a conversion factor.

Two factors limited the quality of the conversion factors applied. Firstly, within certain ProdCom categories there was potential for considerable variation in the weight (in kilograms per item) between products covered. This meant that data was very sensitive to the conversion factor applied. Secondly, there were cases when appropriate conversion factors, fitting the description of the product, could not be found, or the product description was vague and a conversion factor for a similar product had to be applied. This is the first known study to make use of complete ProdCom data, and as more studies are carried out, data used for the conversion factors will become more refined and the quality of the data improved.

The factors discussed above affect the quality of the data produced, reducing stakeholder confidence in the results. In addition the data manipulation currently required also means that RFA studies are extremely time consuming. As a result RFA studies are less likely to be repeated on a regular basis. Data quality and availability therefore needs to be addressed. As well as producing more authoritative results, this would greatly reduce the amount of time needed for data analysis.

IMPROVING DATA QUALITY / AVAILABILITY

Scotland's Footprint made a series of recommendations to improve data quality and availability:

- Ensure production data is collated in terms of mass to allow easy supply chain analysis.
- Office of National Statistics (ONS) to:
    - Provide ProdCom data at a regional level.
    - Examine if aggregated data could be made available. This would allow data currently not published due to commercial confidentiality reasons to be presented.
    - Ensure that industries report in terms of mass, or alternatively, ONS and other stakeholders carry out research and agree on a set of defined conversion factors to mass.
- Data on import and export between UK regions and other countries should be collected in more detail and made more transparent. For example:
    - Air freight data were not available in enough detail to enable the extraction of UK import and export from world import and export.
    - Some road freight data were not included because they were not broken down into enough detail. For example, agricultural products included both primary crops and processed foods.

- Currently, the examination of flows of resources throughout Scotland is limited. This is mainly due to very little data being available on the end use of materials and the location of this use. However, some good data are available, such as that published by the Forestry Commission. Examples such as this can be used as a basis to improve data collection in other sectors.
- It is recommended that Government and Industry work together to improve the data available: for example improved research on supply chain analysis, would aid and provide a better understanding of resource use and of the flows between manufacturing sectors.

The final report on the Biffaward programme [14] also made recommendations to improve the availability and quality of resource flow data. These recommendations are given in Table 2. These bring together the problems encountered in all the RFA / mass balance studies with regards to data collection, and they help to structure a way forward.

Table 2 Biffaward programme recommendations

1. Detailed information from the Annual Business Inquiry and PRODCOM should be integrated by DTI/ONS/Defra on an experimental basis to provide a detailed understanding of resource flows between sectors.
2. The above analysis should be married with geographic information from the interdepartmental register (IDBR) to add regional and if possible local information on resource flows and emissions.
3. The Environment Agency and ONS should collaborate to introduce IDBR identifiers onto the inventory of sources and releases (ISR) to allow each emission source to be integrated to its corresponding economic data series. The fact that this can be a significant pollution pathway for outputs from some sectors (e.g. nitrates and phosphates in the case of agriculture).
4. The Government should undertake a regular cycle of surveys of waste arisings and water use for different industrial and commercial sectors to improve the information base for mass balance and environmental accounts.
5. Firms should be made responsible for chemically sampling their waste streams and reporting the information. If the chemical composition of the waste is highly variable this too should be communicated and more regular sampling undertaken.
6. Official data should be incorporated into the mass balance database including all the potential new sources described in earlier recommendations. Biffaward projects should continue to be added to the database as they are completed.
7. The Government and other stakeholders in industry and the voluntary sector should review the Biffaward mass balance programme with a view to carrying forward the development and ensuring that the database meets the needs of its potential users.

SCOTLAND RFA RESULTS

Some of the key results from the Scotland's Footprint RFA for 2001 were as follows:

- 112 million tonnes of materials consumed.
- 30 million tonnes of products manufactured.
- 6.9 tonnes of final products per capita consumed.
- 3 million tonnes of food consumed.
- 15 million tonnes of solid waste generated including:
    - 8 million tonnes by the commercial sector.

    - 2 million tonnes was household waste.
- 2.7 million megalitres of water consumed.
- 62 million tonnes of emissions to air generated.

The material consumption by the main industrial sectors in Scotland is given in Table 3. The waste data results are given in Table 4. These data illustrate the more detailed level of results that were obtained.

Table 3: Material flows through Scotland in 2001 ('000s of tonnes)

	Production	**Import**	**Export**	**Stock change***	**Apparent consumption**	**% of total materials consumed**
	A	**B**	**C**	**D**	**=A+B+C+D**	
Agricultural materials	14,119	1,593	979	48	14,780	13
Forestry	5,306	67	289	**	5,084	5
Fishing	441	72	228	**	285	0.3
Extraction of coal, lignite and peat	7,980	4,079	395	-282	11,383	10
Extraction of petroleum and natural gas	124,925	0	75,640	-449	48,836	44
Extraction of metal ores	0	348	0	**	348	0.3
Other mining and quarrying	36,085	323	5,085	**	31,322	28
Total materials	**188,855**	**6,482**	**82,615**	**-684**	**112,038**	

Note: totals may differ due to rounding.
* (-) equals an addition to stock
** No data available
*** This category includes stone for construction, limestone, gravel, sand and clay.

Table 4 Waste generated in Scotland, by sector and management method in 2001 ('000 tonnes)

Sector	**Total**	**Landfill**	**Incineration with energy recovery**	**Reused**	**Recycled**	**Composted**	**Other**
Municipal	3,211	3,003	45	**	110	43	11
Commercial	8,011	3,724	0	1,362	2,875	0	50
Industrial	3,535	3,078	2	0	348	4	103
Total	**14,757**	**9,806**	**47**	**1,362**	**3,333**	**47**	**163**

Note: the 'other' category covers circumstances where waste streams could not fit under any of the other categories.
Note: the totals may differ due to rounding.
** no data available

USING THE DATA TO MEASURE SUSTAINABLE PATTERNS OF CONSUMPTION AND PRODUCTION

The goal of collecting resource flow data is to support decision-making and promote sustainable patterns of consumption and production. Understanding the flows helps the design of policies that can effectively improve the sustainability of current resource use, predict the impact of policy changes or monitor the effects of changes in policy. This understanding is vital to inform the Government's sustainable production and consumption programme [14]. The data cannot stand alone, but need to be used to construct indicators and be compared at regular intervals to measure progress.

The Government's Framework for Sustainable Consumption and Production [15] identifies four key objectives:

- To 'decouple' economic growth from environmental degradation;
- To focus policy on the most important environmental impacts associated with the use of particular resources, rather than on the total level of all resource use;

- To increase the productivity of material and energy use, as part of the broader Government commitment to increase the productivity of the nation;
- Encouraging and enabling active and informed individual and corporate consumers who practice more sustainable consumption.

Resource flow data are key to realising these objectives by aiding the identification of the most significant environmental impacts and allowing progress towards resource efficiency to be monitored. Some key ways in which data from RFA can be applied to achieve these aims are given below.

ECOLOGICAL FOOTPRINTING

In the Scotland's Footprint study the RFA data were used to produce an Ecological Footprint (EF) for Scotland. The EF is a natural follow on from a resource flow analysis. Some additional data are required however, as the EF shifts the focus away from the economy, to the consumption of resources by residents. The EF can also highlight resource efficiency as well as indicate the level of environmental sustainability of a population. By manipulating data to represent achievement of future policy targets, scenarios can be created to show the impact of such policies. Equally, EF can also highlight the scale of the targets that would be needed for the population to become environmentally sustainable.

MASS BALANCE

RFA data can be used to generate a mass balance. The underlying principle of a mass balance is the physical law that within a closed system the total mass is constant. The concept of balancing resource use with outputs can provide a robust methodology for analysing resource flows.

ECO-EFFICIENCY

The World Business Council on Sustainable Development (WBCSD) describes eco-efficiency as, '…progressively reducing the ecological impacts and resource intensity throughout the life cycle, to a level in line with the earth's estimated carrying capacity [16]. Eco-efficiency can be calculated by dividing a product service value by its environmental influence [17]. The eco-efficiency of Scotland was calculated using the results from the RFA by dividing the resources remaining in the economy (product and service value) by the resources consumed (environmental influence).

Scotland's eco-efficiency was calculated at 79% for use of materials and products. In comparison the eco-efficiency of Greater London was found to be 46% [17] and 76% for the Isle of Wight [18]. As well as permitting comparisons between geographic areas, the results from the RFA can also be compared year on year to measure progress in resource efficiency.

OTHER INDICATORS

The SCP framework has proposed indicators [19] intended to support the framework by focusing on the key areas of concern and monitoring progress on a systematic basis. The most relevant of these in relation to RFA are the indicators of material use. The indicators used of total material requirement (TMR), direct material input (DMI), and domestic material consumption (DMC) are derived from the UK Material Flows Account [20]. These indicators are widely used across the European Union [21]. Data

from an RFA study can be used to collate these indicators in relation to a more refined unit than the whole of the UK.

CONCLUSION

RFA applied at different levels provides the data required by stakeholders to move the economy towards more sustainable patterns of production and consumption. For the data to be meaningful it must be widely accepted as being robust and representative. In addition time series data must be available in order to monitor progress and to ensure policy is focused. The Biffaward programme has provided important baseline data. In particular, it has highlighted both the data gaps and problems with data accuracy. _Steps have been made during the Scotland's Footprint study and other studies within the Biffaward programme to standardise RFA data. Recommendations made by both the Scotland's Footprint study and the final report by from the Biffaward programme have identified the steps that need to be taken to move the data forward to the next level.

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