ECO-REGION NW

Measuring regional sustainable development – a review of modeling tools in the UK

Title:	Measuring regional sustainable development – a review of modeling tools in the UK
Author:	Joe Ravetz
Status:	Draft 0.7 position paper
Date:	23-08-04

A Biffaward project on Sustainable Resource Use

1. Introduction

While 'sustainable development' becomes a universal mantra for policy-makers, is it also becoming a cynical public relations exercise? The new apparatus of regional governance in the UK should be an opportunity for making new policy connections between the local and national level, and for integrating the economic, social and environmental agendas.[1]

The current spread of 'integrated appraisal' tools is one attempt to bring a first stage assessment of social, economic and environmental factors into one common framework.[2] In practice the results are not always very helpful – almost any answer can be justified, depending on how policy responsibilities are drawn, how long term trends are built in, and how social trade-offs are handled.

Over-riding this is the sense that much policy for 'regional sustainable development' ('RSD') is a case of 'deckchairs on the Titanic' – that while half of the world population lives in absolute or relative poverty, fine tuning the greening of the UK is almost missing the point.

This is shown by the evidence on the most fundamental impact of all, on the global climate. So far we have been tracking only the emissions within the UK and each of its regions. This measure would show progress if we moved our heavy industries to overseas, and then imported the same products back again. The reality is that imported goods are likely to come from less efficient plants, travel longer distances and cause more emissions.

The results of modelling so far shows that for most regions of the UK, total climate emissions due to the energy embodied in ***consumption***, are 2.5-3 times the direct emissions within the region due to ***production***. While the UK congratulates itself on its hesitant progress towards the Kyoto targets, its real impact on the global climate continues to rise.

Hence there is an urgent need to focus on the real issues, to quantify and measure, to analyse global impacts and life-cycle effects, and to build models of more complex systems. Of course this brings its own pitfalls. It is easy to mistake what can be measured for the whole picture, and the model for the reality. It also runs the risk of divorcing the technical models from their uses and users – often found by researchers who deliver their results to 'policy-makers', only to find that policy has a very different kind of logic.

In this review we look at some current activity in the UK on measuring 'regional sustainable development' (RSD), and ask the question – what does it mean, and where next?

A range of tools

RSD being a many layered agenda, there are different approaches, with different tools for each. Broadly, such tools are either ***technical***, focused on quantitative information processing systems, or ***communicative***, focused on users and the decision making process. Between these are an emerging breed of ***integrated*** tools which aim to link both sides in a more holistic mode of operation.

Integration of policy and analysis is a perennial problem. Policy makers in the expanding agenda of RSD, are surrounded by new 'tools', often demanding large amounts of data, with uncertain quality, and uncoordinated with others. The greater the difficulty of using complex and disorganized information, the more the policy-makers will revert to a procedural approach, simply playing the game of politics and budgets.

At the same time the logic of sustainable development, makes the challenge unavoidable. The issues of inter-generational effects of present actions, of global effects of local actions, and distributional effects of policies, are all complex, inter-dependent, and uncertain.

[1] This paper refers to 'regional' in the UK as the 9 regional administrations: it also includes Wales, Scotland, and Northern Ireland, although these are technically known as 'devolved administrations'.
[2] ODPM 2003: Integrated Appraisal Toolkit

For issues such as air quality or transport network modelling, there is a long history of quite sophisticated technical tools. These by definition work with engineering-type problems which are quantified, where internal interactions are understood, and the range of variables or scenario inputs is not too wide.

Meanwhile for issues which are more qualitative, more uncertain, more inter-dependent and more controversial, then a purely technical approach is not enough. For example, a transport network model may predict the traffic on a new road link: but the wider debate on regional transport, economic development, climate change, road pricing and the psychology of car ownership, needs a wider kind of information base (Ravetz, 1998).

Each of the examples in this paper shows this inter-dependence between technical and communicative approaches:

- Modelling of economic development and its environmental pressure within the region, mainly with a focus on production. The example here is the ***REWARD*** programme and its ***REEIO*** model.
- Modeling of the direct and indirect material flow through a region as a 'mass balance', and the total environmental impacts as accounted by the 'eco-footprint': mainly with a focus on consumption. The example here is the ***Eco-Budget UK*** project, and spin-offs such as the ***Eco-Region NW*** with a more dedicated business-environment focus.
- Modeling of regional development as a 'system' of inter-connected parts, where intangible factors are at least as significant as more measurable factors. The example here is the EU-funded ***INSURE*** project.

Each of these projects has a version or demonstration which is active or current in the North West of England. There are also related methods and tools which are described elsewhere, which could be a long list:

- Modelling of spatial development as a results of policy / lifestyle choices, with its environmental impacts: (the Atlas NW model and its family of QUEST models.[3]
- Accounting in balance sheet / profit and loss form of a regional economy, including for direct economic balances, direct environmental balances, or some combination of these.
- 'Integrated appraisal toolkit', as trialled in some regions and also developed at the national level.
- 'Policy impact assessment' as now being implemented across the EU.[4]

UK & regional policy context

The general policy context for such tools is the UK Sustainable Production & Consumption strategy, as interpreted at the regional level. At present this is a very high level initiative and it is not clear what mechanisms may be put into action.[5]
While the theme of resource efficiency is generally accepted in terms of energy efficiency and waste minimization, the goal of reducing material inputs is quite novel. Meanwhile on the consumption agenda, reducing material inputs from the demand side, there is much aspiration but very few policy levers to engage with. At the regional level of policies, programmes, plans, there are a few specific policy drivers:

- SEA (EC Directive 42/2001): in the UK this is generally being enlarged to cover some form of 'sustainability appraisal' or 'integrated appraisal'.
- EC Landfill Directive & other national waste policies devolved to the regional level.
- Climate emissions / energy targets at the regional level
- Other non-statutory initiatives include the ecological budget and ecological footprint, under development as one of the key indicators.

At the regional level in the UK, there is also an emerging level of Regional Sustainable Development Frameworks or Integrated Regional Strategies. These were constructed partly from regional initiatives,

[3] Lindley 2001
[4] EU PIA papers
[5] Sustainable Production & Consumption: DEFRA 2003

partly with government guidance.[6] This comes from the experience of conflict and mismatch between the two main items of regional strategy:

- Regional Economic Strategies, produced by the Regional Development Agencies: generally contain innovation strategies, cultural strategies etc.
- Regional Spatial Strategies, produced by the Regional Assemblies of Local Authorities: generally contain transport strategies, minerals & waste strategies etc.

The UK regional context for RSD is set out in the paper to the REGIONET 'thematic network' project on best practices in RSD structural funding, multi-level governance, and evaluation method.[7] This identifies how the emerging policy apparatus at the regional level is challenged by the inter-dependency of the RSD agenda. The implication is a need for continuous interaction between different modes of knowledge production and consumption:

- Civic debate & dialogue – values, needs, aspirations
- Strategic & future studies – scenarios, trends, targets
- Public policy & programmes – implementation, evaluation
- Evidence & analysis base – modeling, assessment,

This then points towards new possibilities for communications and decision support processes: on the communicative side, there is a great experimentation with ICT approaches:

- Visualization
- Survey and feedback
- Mapping, priorities, values

These all feed into different points on the policy cycle (given that in reality policy is a complex set of overlapping cycles at different levels):

- Baselines, monitoring / reporting, system understanding
- Futures studies, trend projection, scenario studies, strategic planning
- Evaluation, appraisal, assessment etc.

2. Econometric approach

The conventional approach to regional science has at its core an economic or econometric base. This is now interpreted in a current regional programme in England and Wales.

The REWARD programme ('*Regional and Welsh Appraisal of Resource Productivity & Development*[8]*)* provides an information base for resource productivity initiatives at the regional level. It was formed by a partnership of Regional Development Agencies and similar bodies over the last 3 years, and the results are being launched in November 2004. The REWARD programme has focused on three objectives:

- 1) Development of a computer model - the REEIO ('Regional Economy-Environment Input-Output model'). This provides a greater level of detail than ever before, for analysing the effects of economic trends and policies on resources and the environment.

[6] ODPM, 2002
[7] www.iccr-international.org/REGIONET/nationalreports
[8] As of August 2004, the partnership includes: Environment Agency; North West Development Agency (NWDA); North East Regional Assembly (NERA); South East England Development Agency (SEEDA); East Midlands Development Agency (EMDA); East of England Development Agency (EEDA); and the National Assembly of Wales (NAW). Other contributors include Cambridge Econometrics, AEA Technology, Caleb Management Services Ltd, and the Centre for Urban & Regional Ecology.

- 2) A research programme and database on the resource productivity of the regions of England and Wales, and the implications for policy and business. (The concept of resource productivity itself is not simple: recent work looks at the counterpart theme of 'resource consumptivity'.[9]
- 3) An applications and capacity building programme in each of the regions of England and Wales – enhancing strategic intelligence through workshops, training, toolkits, information systems, analysis and communications.

The REEIO software model is the key output from the REWARD project, and is a powerful computer tool for regional strategy and policy appraisal. While it can only provide a numerical summary of any region, and certainly not a complete picture, it does aim to provide a solid technical foundation for other analysis, especially when linked to other technical models and information systems.

The REEIO is based on a detailed econometric 'input-output' model of each regional economy, based on the widely used 'Local Economy Forecasting Model':

- The ***economy*** is arranged in 50 sectors, each of which makes transactions with each other sector.
- The ***labour market*** is shown in 6 types of employment and 25 types of occupation.

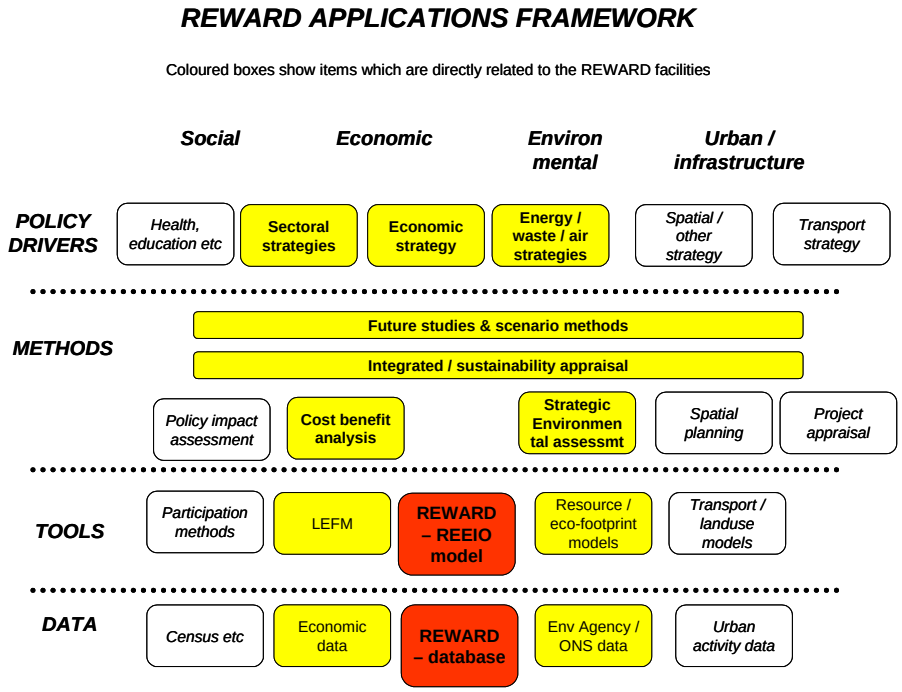
The REEIO then links economic and employment changes with key environmental and resource pressures:

- ***Waste sector***: arisings from household, industrial / commercial, construction, agriculture etc: disposal to landfill, incineration, recycling / re-use.
- ***Energy sector***: demand from households, transport, industrial / commercial activity: energy supply is by 13 sectors and 6 fuels.
- ***Air emissions***: including greenhouse gases, SO_x, $N0_x$, VOCs, PM etc:
- ***Water sector***: demand related to households / economic activity:

The user inputs are arranged in a series of 'what-if' scenario assumptions, from overall population trends to the details of waste or energy management. These are generally arranged as policy inputs or technological change, but short term interventions, projects and shocks can also be simulated. The outputs can be taken to spreadsheets for charting, and further analysis on policy or business implications.

To cover more detailed questions such as economic clusters, transport strategy or environmental technologies, there are a series of 'off-model' components in the form of smaller spreadsheets. A key resource is a comprehensive database of economic and environmental indicators, trends, projections, and scenario inputs for each region. One of the components is the 'linking-up' study, which looks in detail at the policy applications of the model, in terms of future studies, strategic planning, and evaluation / appraisal. One of the route maps produced by the linking up study is shown below.

[9] Ravetz J (forthcoming), 'Regional industrial ecology and resource productivity – new approaches to analysis and communication' In: Randles S & Green K (Eds) *Industrial Ecology & Spaces of Innovation*: Ashgate



The model so far has been applied in the North West region, to the agenda for resource productivity and commercial/industrial waste minimization[10]. This aimed to quantify the opportunities for waste minimization by increasing the scale of activity in business-environment work. The process included a regional workshop, a detailed report on modelling and regional initiatives, and the setting up of a forum to take it forward. This also aimed to link the REEIO system to the mass-balance approach of the Eco-Region NW as in the next section, although this turned out to be difficult before the full datasets were available. The modelling itself was not greatly detailed, as waste management data is particularly patchy, but the exercise served its purpose of stimulating and informing debate and commitment to a resource efficiency forum.

The REEIO was also used in a strategy exercise for the East of England Development Agency. This quantified the environmental effects of the Regional Economic Strategy under 4 scenarios.

3. Material flow & eco-footprint approach

Regional material flow analysis

An assessment of material and energy flows within a defined boundary is termed a ***Material Flow Analysis (MFA)***. This looks at the material inputs to a region in terms of raw materials and products, and at outputs in terms of waste and emissions, plus any changes in stocks. The analysis focuses on the consumption of goods and services by households and the commercial sector, including materials directly used and consumed. It may also look at 'hidden' material flows including ores and wastes from extraction or harvesting, energy used for extracting, transporting and producing materials: and greenhouse gas emissions from energy use. This kind of data is arranged in terms of 'consumption

[10] NWDA report: CURE / CE / Caleb 2004

sectors', i.e. the functional requirements of consumer needs, rather than the detailed breakdown of economic 'production sectors' in the REWARD system and most economic accounts. As a result of these two kinds of analysis a number of key physical indicators can be generated:

- ***Direct Material Consumption*** (DMC) that is the total amount of materials directly used in the regional economy and consumed in the region, i.e. excluding exports.
- ***Total Material Consumption*** (TMC) that is the total material use associated with the regional consumption activities, including DMC and the indirect or 'hidden' material flows associated with it. Again, this excludes exports and their associated indirect flows.
- ***Carbon dioxide emissions*** (CO_2) as the largest single cause of climate change.
- ***Ecological footprint*** (EF), usually measured in 'global hectares per person'. This is calculated from the CO_2 emissions, plus other impacts on land use. This is allocated on the 'consumer responsibility' basis, i.e. an aggregate measure of all impacts from all flows which are implicated in the delivery of products to the final demand from households.

Current development of the mass balance method in the UK is based on two key challenges.

One is the adaptation of standard economic input-output tables, to a material flow format which enables detailed stock-flow models to be assembled for each material stream, as in the following:

					X			M	C	G	I			
PRIMARY	MANUFACTURING	FACTORS	SERVICES	TOTAL PRODUCTION	EXPORTS	*total production - exports = total consumption - imports*	TOTAL DIRECT CONSUMPTIO	IMPORTS	Households	Government	Investment	Stock change	To waste	To recycling

The second challenge is the adaptation of monetary input-output tables (MIOT) to a physical input-output tables (PIOT): this then enables the calculation of both direct effects and indirect effects of final demand (consumption), based on patterns of inter-industry trading. To overcome this, a new set of 'physical input-output tables' are being constructed for the UK economy and its regions, by SEI and CURE under the 'Eco-Budget UK' project.

Mass balance models in the UK

Over the last 5 years, a large scale research programme has been coordinated through the 'mass balance club', sponsored by the Biffa waste company, with the opportunity of funding by the UK Landfill Tax Credit Scheme. This has focused a range of industrial sectors: a range of substances and products: and a selection of regions or sub-regions.[11] A coordination unit has set up a common classification system using the European CN system (Classification Nomenclature). There are two main approaches to doing this:

- Production-centred balance: this focuses on raw materials and manufacturing within the region, and includes exports plus regional final demand. This is more compatible with the REEIO analysis and database.
- Consumption-centred balance: this focuses on the products and services delivered to final consumers, and traces the direct and indirect material consumption along product supply chains, with their impacts, which could be anywhere in the world. This approach is suited to a LCA method, and its simplified version the Ecological Footprint.

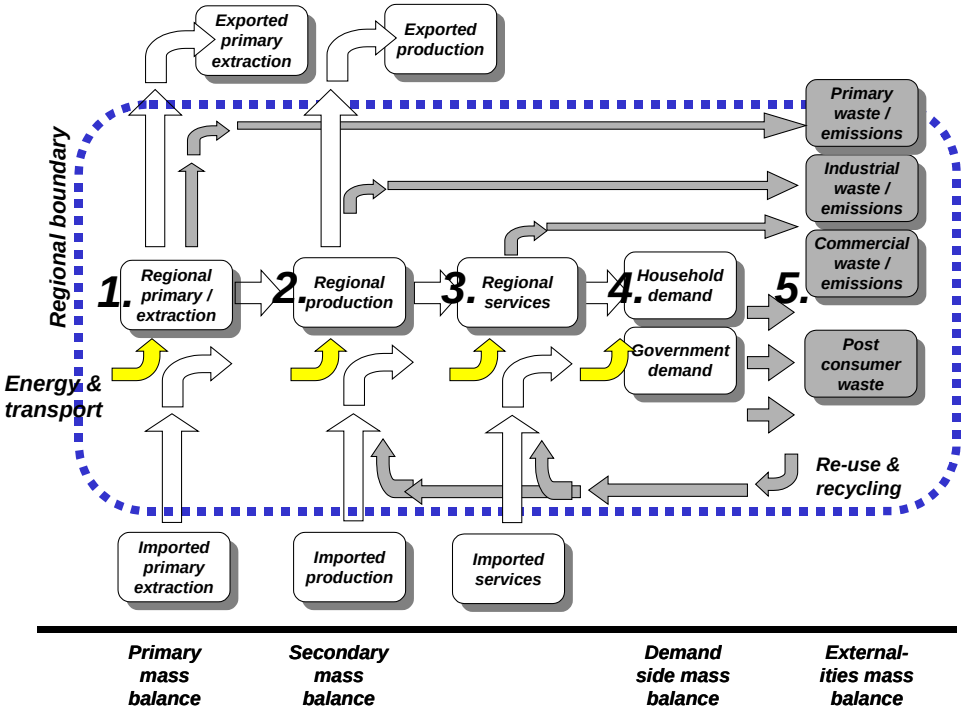
In principle a combined and integrated system should be developed with both production and consumption as part of a whole. However, existing data is not very adequate to make detailed links between one approach and the other. For instance waste data, particularly C&I waste, does not have

[11] www.biffaward.org.uk: www.massbalance.org

details of its material content or its industry source. The consumption data now being assembled from a variety of databases including PRODCOM, COICOP and the IVEM energy database, does not have detailed information on the waste arising from each stage in the supply chain, or its material content, or the inter-industry transfers of materials and waste. The diagram below shows this challenge graphically:

MATERIAL FLOW & MASS BALANCE:

Concept framework for 5-stage model



- The framework is organized in a 5 stage process, corresponding roughly to the primary, secondary, tertiary, demand and 'externalities' classification of economic sectors.
- Various kinds of waste streams are shown by the shaded boxes on the right hand side, coming off each of the stages.
- Various inputs of energy and transport are also shown at each of the 5 stages.
- Mass balances of production & consumption are shown at each stage in the production-consumption chain, including for exports and imports.
- This diagram can then provide a template to be further detailed for each product or sector, where the width of the arrows would represent the volume of material flow.
- ***Resource efficiency*** or ***resource productivity,*** i.e the useful outputs per unit of input, can be measured in various ways at each stage of the production chain.

Although this chart contains many types of material flows and linkages, it is very simplified compared to the reality, where many materials are used to make many products, at many intermediate stages, in many sectors, with many environmental inputs and outputs. We also know that there are few data available in any coordinated form, for these many interactions! There would be several ways to deal with this through modelling in a mass balance perspective.

- One is a stock-flow model that aims to capture for each industry and each main type of product, a very simplified picture of material inputs, stocks, outputs and waste streams. This works well for

the case of simple products which are consumed directly by householders: but this is more difficult with complex products and services, where indirect and cumulative effects are large.
- This issue could in theory be overcome with input-output methods, except that most of the data does not exist. Using a proxy approach with environmental multipliers on economic supply-use tables, a basic physical input-output table for the UK and its regions is now being constructed. The above mass balance framework can then be fitted to the sectoral divisions of the PIOT, with appropriate satellite accounts for energy inputs, waste / emissions outputs and so on.

Eco-Budget UK project

The Eco-Budget UK project is the coordinating mechanism for the regional level of the Mass Balance UK programme. It aims to provide a comprehensive database on the flow of materials and their environmental impacts, for each of the regions of the UK. This will enable questions to be asked on the strategic assessment of regional strategy: on the resource efficiency of particular sectors: the comparison of different products or materials: and the true resource costs of waste disposal. The methodology has been developed over a series of regional studies in the South East, Wales and the North West. It will be closely linked to the information systems of government data providers, the Mass Balance UK framework, and parallel projects at regional and national scale. The main results will include:

- Resources and Energy Analysis Programme (REAP): a scenario-based integrated resource/energy-environment modelling system.
- Physical input-output tables / database for the UK regions: this is organized in 76 sectors, and over 1000 material / product types from the PRODCOM database.
- A demonstration 'Green Budget' for the UK economy, setting out the policies and market measures needed to steer the UK towards environmental sustainability within 50 years.

REAP model

The REAP model is an adaptation of the LEAP model (Long range Energy Analysis Programme) developed by the Stockholm Environment Institute Boston, and used in over 40 countries around the world. Its methodology is based on a comprehensive accounting of how energy and materials are consumed, converted and produced in the regions of the UK. It then identifies trends, projections and alternative scenarios, and policy options for economic development or environmental management under a range of alternative assumptions on population, economic development, technology, price and so on.

The REAP scenario modelling system is arranged around a 'functional' concept, with four types of components:

- ***Population and demand***: factors that affect the overall size of the economy, labour force and consumption: regional migration, demographic factors, and household incomes / savings.
- ***Technology and production***: factors that affect the share between economic sectors, and the transactions between each of the sectors: e.g. the size of the waste management sector, and its use of transport services.
- ***Productivity and eco-efficiency***: the resource intensity or the amount of waste / emissions produced for each £ of turnover in each sector: e.g. the waste from construction activity.
- ***Environmental management***: for some topics, there are further choices to be made: e.g. waste disposal / recycling methods.

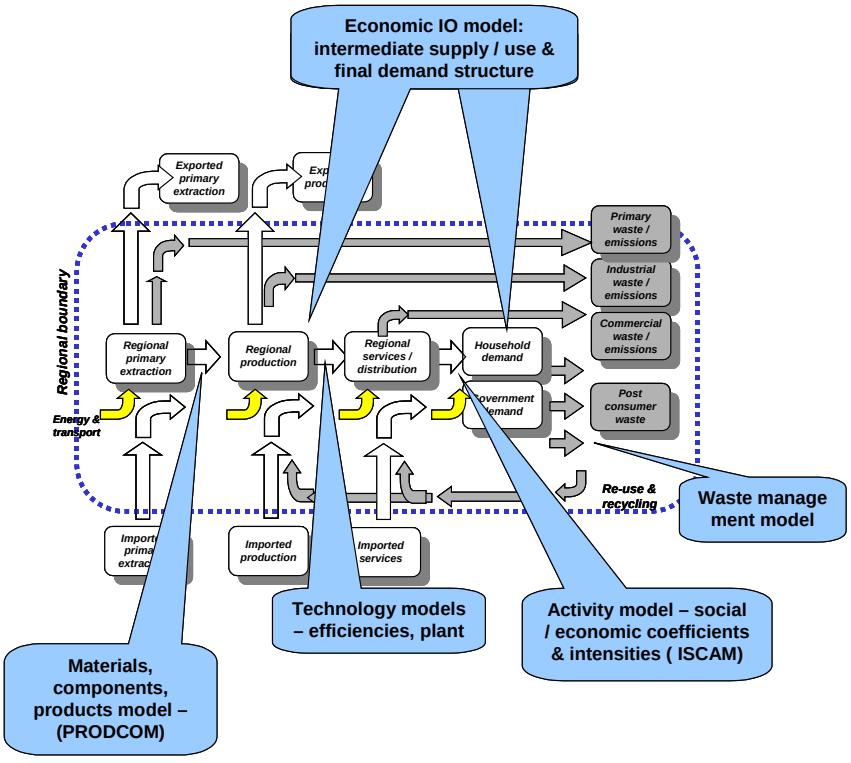
The modelling system now under development starts with the form of a simple environmental accounting model, organized in principle around the mass balance framework in the Figure 1 above. However in practice the data at each stage are in different types of units – raw materials at the primary stage, products at secondary stage, composite items and services such as floorspace or transport kilometres at the tertiary and demand stage. Also, to design scenario settings with policy relevance involves a wider set of parameters than a purely MFA- mass balance model can deliver.

The way forward is seen as a loose-coupled modelling framework, as in Figure 2 below. The core mass balance model is linked to a range of other models with compatible formats:

- Econometric-based physical IO model, which provides the environmental multipliers
- Materials, products, components and environmental coefficients model / database, adapted from the PRODCOM system
- Activity sectors and policy issues at the regional & urban level, including urban development, land use, housing, transport etc. This is based on the ISCAM flexible modeling framework which provides a consistent format for the 'off-model' calculations which are needed to link policy inputs with the mass balance information. This may also involve or link with other models for waste management or for technological change.

INTEGRATED RESOURCE FLOW MODEL

Concept framework for combined model



Physical IO tables

At the core of the REAP is the PIOT: this follows the approach of the UK Office for National Statistics to compile the Input-Output Annual Supply and Use Tables[12] and applies it to physical flows within the

[12] Office for National Statistics (2003) United Kingdom Input-Output Analyses, 2003 Edition; Editor: Sanjiv Mahajan, London, www.statistics.gov.uk/inputoutput

economy. As a 'supply table' we use the ProdCom[13] list of production and import volumes on a 4-digit SIC level after conversion to mass units throughout. This results in about 700 entries for volumes of products that are supplied by the whole of the UK industry. Each of these numbers is then allocated to one of 76 economic sectors reflecting the use of these products by those sectors. This task is being performed by using all available information from previous sectorial and regional mass balance studies done in the UK.[14] The matrix shows the tonnage of goods exchanged between each industrial sector and the tonnages that reach final demand or ends up as waste. It can be seen as the combined 'use table' of materials and products in the UK economy.

This 'physical use table' (PUT) is not yet a complete physical input-output table (PIOT) as has been constructed by some countries before[15]. Nevertheless, it can be seen as the major and crucial step in that direction. Because of its level of detail – in terms of sectorial (76) as well as product breakdown (ca. 700) – the PUT is even more useful in answering certain questions. It provides an understanding the intermediate flows of materials between industrial sectors, and the final demand by households and government. An example would be the decision to build a great number of new houses in the UK. The PUT will be used to trace back the flow of construction materials through the whole economy right to the very inputs of raw materials. Combined with other information such as embodied energies and specific emission factors a number of output indicators can be created to assess the environmental effects of the house building endeavour. This relies on a similar method explored by ONS in Environmental Input-Ouput Tables in 1997[16] and published in Economic Trends.

Eco-Budget UK

The UK Budget is a key event in the political & economic calendar, where the national fiscal strategy is set out. This is generally organized around (a) economic growth & stability, and (b) social welfare and distribution. However, while there is consideration of environmental issues, these are often too little to counter the effects of material economic growth. There is a range of basic ecological taxes such as fuel duty, but these are organized firstly around political agendas and public finances, and secondly around environmental concerns. The government's aviation strategy is one example, where the exponential growth in air travel and climate emissions is hardly affected by the current proposals for small aviation taxes. The outcome is that the global ecological damage and expropriation of resources continues, as directly or indirectly responsible for global poverty and international conflict.

This Ecological Budget presents an alternative which meets in full the goals and aspirations of the government and the community for longer term environmental sustainability. It is based on the best available analysis and modelling of the UK economy and environment over the short-medium term and up to 2050. The Ecological Budget is presented in macro-economy and sectoral terms in order to establish its feasibility. It is also presented in terms of environmental / energy resources and impacts, for a more complete picture of the UK 'real world' physical budget.

The Eco-Region NW project

Within the Eco-Budget UK framework there are a number of trial regions with related regional mass balance or eco-footprint projects. The foremost is the Eco-Region North West. This is developing a 'joined up' information system to measure environmental performance, not only at the regional level

---

[13] Products of the European Community, PRODCOM Annual Industry Reports; Office for National Statistics, London, www.statistics.gov.uk

[14] See www.massbalance.org

[15] For example: 1) Stahmer C, Kuhn M, Braun N (1998), Physical Input-Output Tables for Germany 1990, Eurostat Working Papers 2/1998/b/1, Luxemburg: Eurostat. 2) Gravgaard Pederson O, (1999). Physical input/output tables for Denmark. Products and Materials 1990. Air Emissions 1990/92. Statistics Denmark, Kopenhagen. 3) Weisz H, Schandl H, Fischer-Kowalski M (1999) OMEN – An Operating Matrix for material interrelations between the Economy and Nature. In: Kleijn R, Fischer-Kowalski M, Palm V (Eds.) Ecologizing Societal Metabolism: Designing Scenarios for Sustainable Materials Management

[16] For further information on the work undertaken by Prashant Vase, refer to: http://www.statistics.gov.uk/StatBase/ssdataset.asp?vlnk=5412&More=Y

but for sectors and firms. The Eco-Region NW extends the scope of the Eco-Budget UK and the REAP model, with a particular focus:

- Waste management sector: focus on total impact assessment of waste disposal:
- Construction industries: key performance indicators for firms, building types, design options and building elements.
- General business applications
- Regional policy applications: indepth analysis

The Eco-Region NW information system then makes links between the flows of resources and wastes, and their causes in production and consumption. It also connects a 'top-down' analysis at the regional level, with a 'bottom-up' environmental reporting system at the firm level. This will be both a basis for further development of waste management information systems: and a template for wider application across the UK and EU. The project objectives include:

- ***Databasing***: develop a comprehensive data system on regional resource and waste flows: including sources, destinations, balances and ecological footprints.
- ***Modelling***: develop an integrated model to analyse future trends and scenarios, in resource flows, strategic waste management, and assessment of BPEO.
- ***Benchmarking***: develop and test a benchmarking / reporting system for waste minimization and resource productivity in sectors, firms and products.
- ***Business applications***: apply the model / database system to waste / resource management in business strategy, focusing on the construction industry as a main case study.
- ***Policy & public applications***: use the database / modelling system to analyse regional policy for their effect on the ecological footprint and resource productivity.

Sample regional data

Below are some preliminary results based on current work in the NW region (SEI & CURE, 2004): here they focus on material flows rather that the ecological footprint:

- The **Direct Material Consumption** (DMC) for the North West region in 2000 was 66 million tonnes, which equates to 9.5 tonnes per person.
- The largest single component of the DMC is the construction sector, with 35 million tonnes per year of bulk materials. This is allocated as below to domestic, commercial services, transport, and industrial construction (the latter being included indirectly in the consumption accounts).
- The **Total Material Consumption** was 160 million tonnes, or 23 tonnes per person, approx 2.5 times the DMC. This corresponds to recent UK data (Wuppertal Institute 2002).

These figures per person in the NW region can be compared with overall waste production per person:

- Industrial waste: 0.87 tonnes per person
- Commercial waste: 0.5 tonnes per person
- MSW, household & other: 0.6 tonnes per person
- Construction: 1.5 tonnes per person

The overall total of all waste streams including agriculture and mining is 5.4 tonnes per person/y, i.e. over half the total DMC per person of 9.5 tonnes/y. This suggests a material economy which is working at only 40% overall resource efficiency: i.e. out of every 10 tonnes brought into the economy, only 4 tonnes is utilized.

Eco-region NW extensions

- 'Visualization of Regional Material Flow using Over-flow Potential Maps': this is a spatial modeling of the material flow from construction and demolition waste. Based on current methods in Japan this tracks the material metabolism of a conurbation through space and time.[17]
- ***Sustainable Transport for Resources And Waste*** (STRAW): this explores the agenda for an integrated waste resource management infrastructure: the mix of facilities required in terms of type and scale; potential locations for these facilities, in the light of environmental clusters, industrial symbiosis: the movement of materials between these facilities, in terms of intermodal transport.
- ***Manchester Eco-Schools***: a demonstration application of the Eco-Region NW construction sector to a pilot school in Manchester. The aim is to provide a framework for the assessment of the schools portfolio as a whole.
- ***Footprint NW*** – a preliminary study for the NWRA for the AFS (Action For Sustainability) framework.
- ***Assess***: an online business benchmarking system for environment & waste minimization. This is being currently expanded to include more detailed information on material flows.

There is also the Atlas NW modeling / visualization system, a prototype spatial modeling system with a detailed analysis of urban development policy options and impacts. Design work is in progress for the linking of this to the Eco-Region NW through a web interface.

4. Systems dynamic approach

Each of the above REWARD and REAP systems is complementary, but each has severe limitations. Each of them assumes certain 'exogenous' factors such as population growth, technological change and availability of natural resources. In contrast, in real situations these factors are often linked and inter-dependent. The modeling approach which puts inter-dependency at the center of the picture is known as ***system dynamics***. This first achieved worldwide attention with the 'Limits to Growth' world model (Forrester: Meadows et al).

The INSURE ('A flexible framework for indicators for sustainability in regions using system dynamics modelling') is a EU-funded information system for enhancing intelligence on RSD.

INSURE uses ***system dynamics*** concepts and modelling tools for SD indicators. This helps to represent underlying trends in RSD, and to link the indicators with policy options. This also helps with many problems of indicators - lack of integration, lack of data, sectoral barriers, lack of consensus between stakeholders, and lack of comparability between regions. Hence, INSURE will contribute to increased awareness of the issues and choices of RSD among stakeholders at all levels.

The system dynamics approach which underpins INSURE has potential as a unifying and scientific representation of SD at the regional level. The basic concept is very simple. Instead of just measuring the 'symptoms' through RSD indicators, we should look at the 'causes' with a more fundamental understanding of the region as a whole system. This shows how economic sectors, spatial development, environmental pressures and social trends are all inter-linked and inter-dependent. Policies and programmes can then begin to address the causes – deep-rooted problems, rather than the symptoms on the surface.

The system dynamics approach

There are three features that make system dynamics suitable for analysis of SD: the study of trends and dynamics; the inter-dependence of different factors; and the integration of local and universal

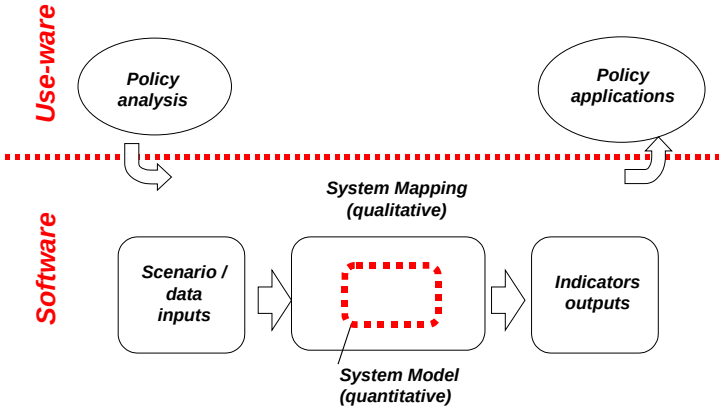
[17] Hiroki Tanikawa and Hidefumi Imura, Quantification and evaluation of total material requirement related to urban construction: case study for residential development, Journal of Environmental Systems and Engineering, No.671, VII-18, pp.35-48, 2001.

knowledge. The use of system dynamics modelling tools enables a focus on the underlying logic of regional development more than in the indicators themselves. The analysis of SD indicators as 'metrics' of a system will emphasise the evolution over time of its overall 'shape' and its 'development pathway'. The focus on the fundamentals of SD will then enable comparability between different regions, which are each approaching SD in their own way.

INSURE main results & products

The practical results from INSURE (due in late 2006) is a flexible 'system dynamics framework'. This framework comprises both ***software*** components and ***'use-ware'*** components:

SYSTEM MODEL / MAPPING - CONCEPT



The ***Software*** components are in the form of a system dynamics modelling toolkit, titled the ***Systems Model / Mapping***:

- The ***Systems Model*** is a quantitative model of the regional system
- The ***Systems Mapping*** is a qualitative representation of the regional system. While these have different functions, they will be integrated as far as possible.
- To operate this System Model / Mapping, there are ***user inputs,*** which translate ***regional policy*** issues into the system dynamics format in terms of ***scenario settings and datasets***.
- To interpret and apply the results of the System Model / Mapping, there are ***user outputs***, in the form of ***SD indicators***, in a format for analysing, reporting and communicating the results.

The ***Use-ware components*** are the policy processes, methods and applications, which will enable the software to function and be used more effectively:

- ***Policy analysis*** inputs: the methods and procedures which enable policy issues, debates, targets and data to be translated into a format suitable for the Systems Model / Mapping.
- ***Policy outputs***: the methods and procedures which enable the System Model / Mapping outputs, the Sustainable Development indicators, to be applied to future studies, strategic planning, and policy evaluation.

The main ***applications*** of the INSURE products include:

- Policy impact assessment:
- SD Indicators studies:
- Scenario development:

The main ***users*** of the INSURE products will include:

- The European Commission, in the management of policies and programmes for regional development and other horizontal measures.
- Regional and national authorities, at the strategic level of regional policies and programmes.
- Other regional stakeholders, researchers and consultants.

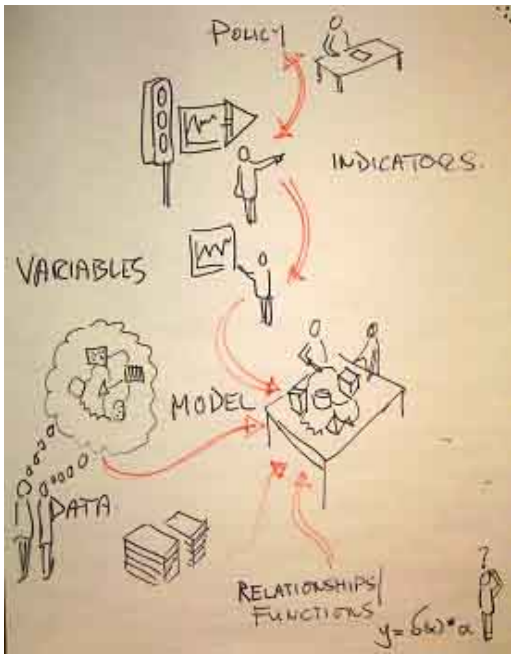
Behind the INSURE project is the result of a decade of experience in working with RSD indicators and indices, decision support systems, technical models and so on. This shows how most policy issues contain some quantitative elements (e.g. 20% reduction in road transport), and some qualitative elements (e.g. the psychological addiction to cars). Even the most detailed transport models cannot deal directly with these wider factors, but they may find effective ways to manage them. This suggests that the INSURE approach of structured enquiry may be very effective – the quantitative parts can be pushed as far as the data allows, while the qualitative parts enable more in-depth debate on the issues.

The system dynamics framework will bring several benefits to the problem of common versus individual SD indicators for the regions. It will help to link different indicators in cause-effect chains: it will help to bridge over missing data: it will define indicators in relation to the underlying system and SD values: and it will help to define which are the most sensitive or the most policy relevant indicators for each region, or for different types of regions. In this way it will contribute to the evaluation of EC regional policy and other horizontal measures. It will also help to define a regional-level European Common Indicators initiative.

5. Review & ways forward

Which tool?

The table below is a summary of the 3 modeling approaches discussed here. It should provide some guidance as to which tool is best suited to which application.

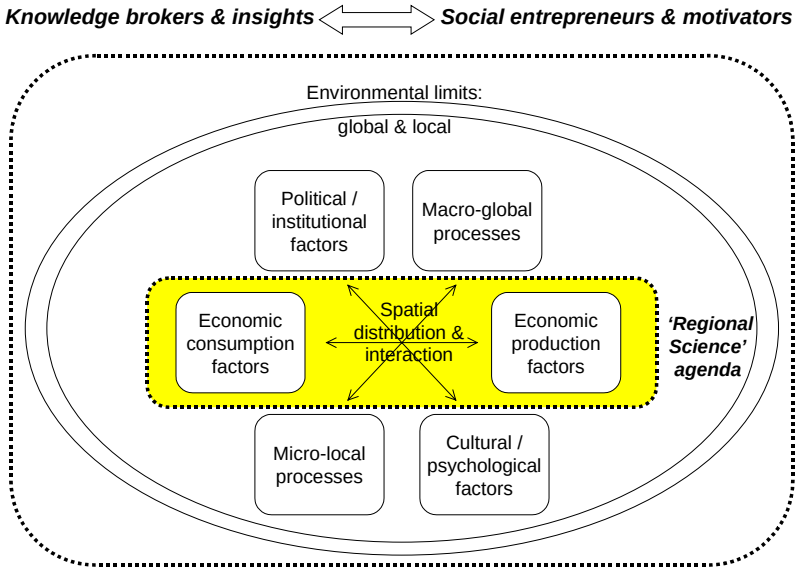


	Economy-environment	Material flow	Systems dynamic
	REWARD	**REAP**	**INSURE**
Model approach	Based on production	Based on consumption	inter-dependent system with quantitative & qualitative factors
Main focus	Environmental impact within the region of economic activity, including exports (excludes travel abroad).	Environmental impact locally / globally of consumption within the region, including imports (excludes commuters)	Interactions between energy, emissions, technology, economy and population
Spatial level	England region / Wales	UK National, regional and LA level	NUTS 3 level across the EC25 + Turkey
Time frame	10-15 years	50 years	25 years (tbc)
Methodology	a) Regional economic scenario: b) env pressures are calculated from activity in 49 sectors.	Key environmental pressures: material consumption, ecological footprint, GHG emissions	Systems dynamic approach: includes regional templates & scenario templates
Scope of model	a) 49 x 49 economic IO table with employment data: b) energy, emissions, waste, water, in ~ 50 categories	a) Direct / indirect material consumption b) eco-footprint & GHG c) activity model d) business-environment benchmarks	Under development
Limitations	No account of material flow or global impacts	No account of economic processes or transfers	Only a generic version supplied, with each region to develop its own detail
Main applications	SEA on economic strategies & programmes	Policy scenarios (based on policy proxies)	Comparison between regions: strategic studies within the region.
Main users	Environment Agency, Regional Development Agencies etc	Main partners/clients: LA's, Regional Governments, RDA's	DG Regio: DG Environnement
Main orientation	Policy orientated	Populist orientated	EC & regional policy oriented
General output	Very specific quantitative output for policy analysts	Good visualising tool aimed at public relations and campaigns.	Good learning tool for exploring regional issues & scenarios
Funding	Partnership of EA with RDAs and NAW.	Biffaward Landfill Tax Credit Scheme, plus other 10% funders.	100% EU funded at the development stage
Availability	CD access strictly to subscriber organizations only. Available late 2004	CD Available late 2005, at nominal cost. Web access through regional projects e.g. Eco-Region NW	Availability via CD not yet finalized; prototype available late 2006.

Towards a new 'regional science'

One way to apply this thinking is to take the established body of theory and evidence in 'regional science' from the last 50 years, and to work through the implications of the RSD concept. This 'RSD science' shows how the former neo-classical approach to regional economics, shifts towards a more evolutionary, process based, and complex systems approach to economy, environment and society. It focuses on the interfaces and linkages between different sectors, between different sciences, and different worldviews. (Bailey: Funtowicz: Rotmans etc). Such a regional science is identified as 'poly-valent', in the sense it does not focus only on a positivist economic dimension, but considers other dimensions where a single predictive theory is not the sole objective. A mapping of the scope of such a '***regional poly-valent science'*** agenda is shown in Fig…

REGIONAL POLY-VALENT SCIENCE AGENDA



The 'RSD science' concept also helps to enlarge the perspective on evaluation, which in turn confirms the case study experience in this paper. This enlarged evaluation agenda concerns not only 'objective' evaluators who analyse government programmes in search of measurable inputs and outputs. It is also about evaluation as a continuous process of mutual learning, capacity building, strategic intelligence and reflexive knowledge, in and around a wider circle of policy and governance in civil society. (Batterbury: O'Connor).

This is of course a huge intellectual challenge, as such a poly-valent and process-based evaluation agenda may then appear fuzzy and subjective. It may lead in opposite directions from the government modernization agenda of rational management, evidence-based policy, and fiduciary accountability, as summarized in the UK by the 'Best Value' and SMART (specific, measurable, achievable, rational and targettable) approach to public policy. It may even be more open to political and professional misuse and abuse.

Conclusions

Clearly each of the 3 tools above only shows a very simple and partial version of the RSD agenda. They are at an early stage of development, and it is too soon to say how they will mature over time. There is an obvious need to connect them together, yet we find from experience that this is likely to be too complex and impractical for use by policy makers. Therefore we might concentrate our efforts on providing a 'route map' for guidance in between one tool and the next. The chart below shows the 'quantitative' part of a larger picture which combines this with the 'qualitative' and communicative tools (Ravetz 2004).

Quantitative 'systems' model