



A Consumption Approach for Emissions Accounting - the REAP Tool and REAP Data for 2006

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Support Documentation

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1 The REAP tool and data are provided by the Stockholm Environment Institute at the University of York:
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PURPOSE OF THIS DOCUMENT

This document has been prepared to support users of the Stockholm Environment Institute's REAP tool. It has been developed to respond to some of the common queries relating to the methodology and the application of the REAP tool. The document groups queries into common themes allowing tool users to find information relevant to their query.

1 REAP AND THE CONSUMPTION BASED APPROACH

1.1 WHAT IS REAP?

REAP stands for the Resources and Energy Analysis Programme and has been developed to support decision making and policy development. The REAP tool is a software tool designed by the Stockholm Environment Institute (SEI) at the University of York. It provides a database and scenario modelling of the emissions generated as a result of the consumption of goods and services by UK residents.

The software tool is one of the outputs of a 10 year research programme into consumption based carbon and GHG emissions accounting at SEI. It was originally developed to make our data and research at SEI accessible to policy makers and highlight the importance of consumption based approach to emissions accounting.

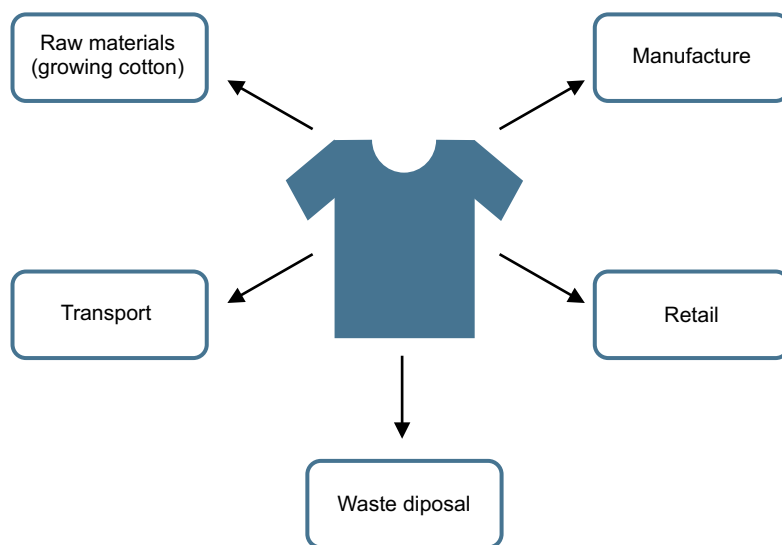
1.2 WHAT IS CONSUMPTION BASED EMISSIONS ACCOUNTING?

Consumption based emissions accounting is an alternative perspective to the more commonly

reported territorial emissions accounting. Carbon and GHG emissions are more often reported according to territorial boundaries, where all of the emissions generated from industrial processes or fuel burning in that location are added together. Consumption based emissions accounting considers not what a country or area emits directly from their industry, but the emissions that occurred from the products and services that people who live in that area have bought. It is an approach that allocates emissions to the consumers of products and services, rather than the original producer of those emissions. It uses the same total emissions, but has a different allocation system.

The territorial emissions tell us where the emissions occur, but the consumption approach tells us why the emissions occur. Increasing demand for products and services drives up emissions across the world. Increasing demand in the UK may increase emissions, not necessarily territorially in the UK, but wherever those goods are produced. In order to gain a full understanding of emissions, in the UK and across the world, it is important to explore not only where emissions occur, but the drivers behind them. The UK





may reduce its emissions within the boundaries of the country, but this can easily be negated by emissions in other countries that are generated in order to satisfy consumer demand in the UK.

The majority of products and services will have generated emissions at some point in their supply chain, whether this is at raw material extraction, factory processing, transportation or packaging. This is mainly due to the reliance on fossil fuels for energy which generate carbon emissions when burnt. In addition, sectors such as agriculture or waste disposal release other greenhouse gases.

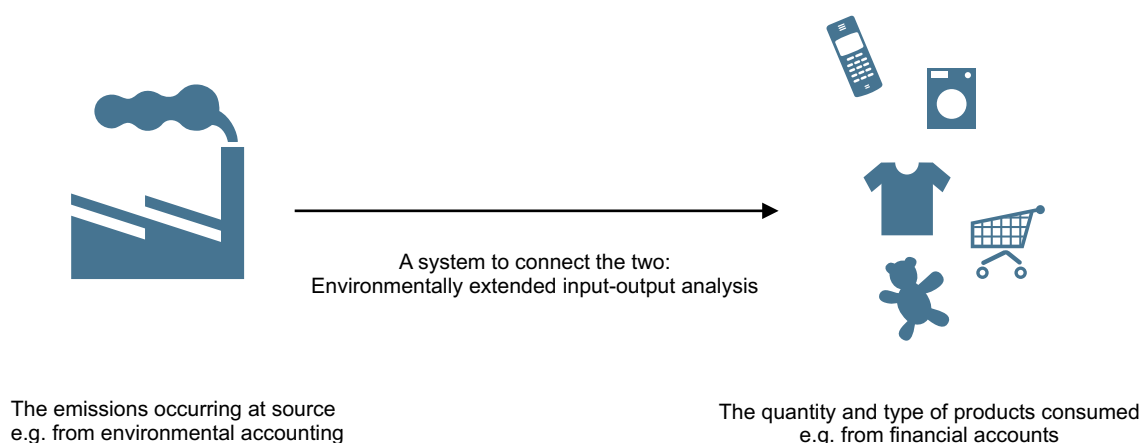
Calculating embedded emissions

In order to calculate the emissions embedded in the supply chains of a single product we could use a detailed bottom-up approach which looks at as much of the supply chain as possible and attempts

to estimate the emissions generated at each stage (known as process life-cycle analysis, PLCA).

If wanted to calculate the emissions associated with all consumption in the UK it would not be possible to do this type of detailed PLCA for every single product. There are far too many different products to examine and maintaining a consistent approach across all of them would be extremely difficult. Calculating the emissions embedded in a whole country's or region's consumption therefore requires a different approach and this is what REAP and the Sustainable Consumption and Production team at SEI specialise in.

SEI's approach is a top-down accounting system, giving an overall picture of the emissions embedded in the products and services consumed. In the most simplified terms, SEI takes data about the emissions



generated data by industry from statistical tables like the Environmental Accounts (ONS) and then statistics on the quantity and type of products and services consumed from national financial accounts. These two datasets sit independently and are analysed for different purposes. However, they can be brought together using structural economics and input-output analysis. This technique is usually used to analyse the economic structure of a country, but it has been extended to incorporate other datasets, including environmental data. This extension allows the emissions generated by industries to be mapped to the products/services that they produce and can follow intermediate products all the way through the economic system to their point of final consumption.

In practice this extended input-output analysis is a very data intensive procedure, requiring information about products, household and government consumption in different areas, the structure of the economy, the number of goods and services imported and exported and the emissions intensity of industry domestically and abroad. A more technical explanation of how the consumption based emissions are calculated is explained in the “*REAP and the Use of Input-Output Analysis*” section on page 10.

The output of the modelling is an estimate of the emissions embedded in the products and services consumed by residents across the UK which is often called a carbon or GHG footprint.

Where do direct household emissions fit in?

Direct householder emissions are those that are emitted by consumers at the point of use, for example, burning petrol in a car engine, or gas in a boiler. These emissions are collected in the Environmental Accounts at a national level and are disaggregated using statistics on energy use and travel. These make up part of both territorial and consumption based emissions accounting and are the same in both approaches.

The chart below shows the breakdown of indirect and direct GHG emissions on a per capita basis for the UK in 2006. It demonstrates the significance of the emissions embedded in the consumption of goods and services compared to the emissions directly emitted from householders at the point of use. Direct household emissions make up just below 10 per cent of the total GHG footprint.

1.3 WHAT CAN REAP DO?

The REAP software tool is an environmentally extended input-output model, the basis of which is explained in the *Calculating Embedded Emissions* section and in more detail in the “*REAP and the Use of Input-Output Analysis*” section on page 10.

The tool itself has two main parts: a database that contains all of the consumption based emissions for local authorities across the UK and a future scenario generator that can model the impact of changes in consumption.

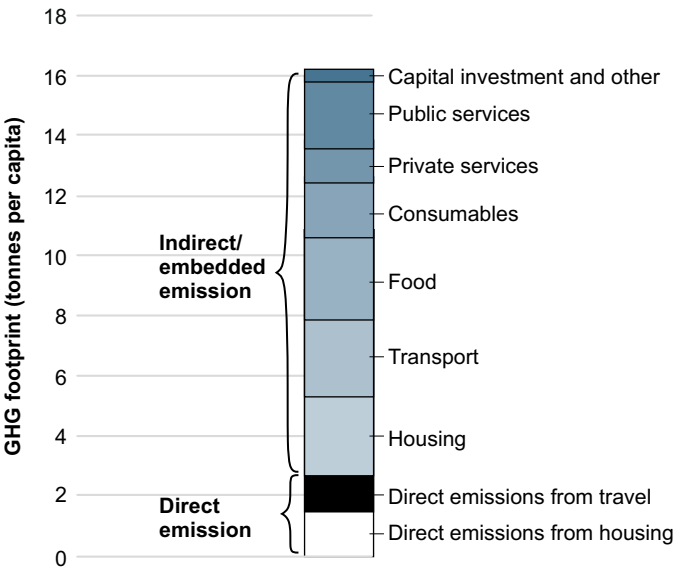


Figure 1: Direct and indirect emissions breakdown of the UK average per capita footprint, by theme, 2006

General functions

The tool provides the following functions (for all local authorities and regions in the UK):

- emissions generated at the point of production;
- emissions generated as a result of consumption by local authority and region;
- time series emissions data from 1992-2006 by region;
- a comparison tool to compare data across geographies;
- a composite region function to join local authorities or regions;
- update data function where baseline data can be changed;
- future scenario creation and analysis;
- evaluation of scenarios and results display.

The data and scenario results can be extracted out of the database at any time, exported into Excel or Word. All results are available as per capita or total values.

Scenario modelling

The scenario functions in REAP enable a policy maker to answer the “What If” question about the effects of policy on the environment helping to formulate strategies for local, regional and national government.

Scenarios can be created across all areas of consumption, allowing the user to see the effects of changes to consumption on the footprint in the local area over time. For example, users can assess the impact of changes to:

- household energy demand;
- distance travelled;
- food consumption;
- consumable goods and services;
- population;
- the efficiency of different production sectors.

All of these areas of consumption can be changed individually or as a group, allowing scenarios to be as simple or complex as required.

What the REAP tool can measure

The REAP tool is suitable only for measuring the footprint of residents in your area. The REAP tool is not suitable for measuring the footprint of local government operations or the footprint of local businesses.

REAP measures the impacts associated with the consumption activities of residents of an area only. This means that a local authority’s results exclude the activities of commuters who work in that local authority but live elsewhere. They also exclude the impact of tourists who may visit the area. The impacts of all visitors and commuters to a local authority are taken into account at their place of residence.

Accounting for waste in the REAP tool

Waste is an industrial sector in REAP, like any other sector providing a product or service and generating emissions as part of their processing. The emissions generated by the treatment of waste are initially allocated to the waste industry and through the input-output framework this is then reallocated to its products or service (for waste industries this is a waste disposal service). The majority of this service is purchased by local authorities or governments or other businesses. It is not largely purchased directly by householders.

If waste services are purchased by businesses then they will be allocated a proportion of the waste treatment emissions, which will be incorporated in the supply chain of the products that they produce. When a consumer buys that product, some of the embedded emissions will include any waste treatment emissions that occurred along the supply chain.

When waste services are purchased by local authorities or governments it is included under local government spend, the emissions of which are allocated across householders equally. Within the footprint breakdown there is always a component for public services. This includes waste treatment, along with other services purchased by governments on behalf of residents such as health or emergency services.

The actual emissions associated with waste treatment are relatively small compared to the emissions associated with generating products in the first place. Even though emissions are produced when waste is treated there are many other emissions

produced from industries along the supply chains of products. The way that household waste is disposed of therefore has quite a small impact on the total footprint of an area.

Only measures taken at the top of the waste hierarchy such as reducing food waste (by planning food purchases) will have a significant impact on the size of an area's footprint because they would reduce embedded emissions by reducing product consumption.

1.4 WHAT IS DIFFERENT ABOUT THE NEW VERSION OF THE REAP TOOL?

The underlying methodology and approach is the same, however there are some small changes to the functionality and additional data has been added:

- all data updated from 2001 to 2006
Greenhouse gas footprint added as a new indicator;
- time series of Ecological Footprint, Carbon and Greenhouse gas emissions for the UK and the regions for 1992 - 2006 incorporated;
- ability to alter percentage of an item produced in the UK for food, goods and services in scenarios;
- ability to look at the energy mix of the electricity sector in more detail to help investigate the effect of decarbonising the electricity sector.

The tool design and functions are very similar to the previous version so if you have received REAP tool training in the past it will not be necessary to have training in the new tool. We do offer training and support packages for new licence holders, which can be tailored to individual requirements. Please contact us at info@resource-accounting.org.uk if you would like more information about training and support.

1.5 THE BEST WAYS TO USE REAP

REAP can be used as a database and the data held within it can be easily extracted and analysed. It is also a scenario tool and can be used to look at the potential impacts of different policies in a local area. The tool can provide powerful messages about the extent of change required to achieve reductions or the potential impacts of policy measures. It can also be

used to ask “what if” questions, such as what would be the impact if people in my local area reduced their meat consumption.

The REAP tool is most appropriate for strategic level analysis, looking at the changes that could be made to the local authority or region as a whole in order to affect the average for that area. It can measure small changes, but in order to considerably reduce the footprint of an area it needs to affect quite a large number of people. For example, it would be difficult for the REAP tool to show the impact of 10 people changing their lifestyles. We have developed another tool called REAP Petite (see The REAP tool suite section) which could identify these small scale changes.

The REAP tool is designed to encourage cross-theme action. It demonstrates that in order to successfully reduce the footprint you need to tackle housing, travel, food and the consumption of other goods and services, as well as technological efficiency and the carbon intensity of the national grid. In order to reduce the footprint changes are required in all of these areas, whether it is through behavioural change or infrastructural developments. The REAP tool does not include pre-defined policies, so any type of policy that leads to a change can be included within a scenario.

1.6 GENERATING A SCENARIO

We have developed a 6-page guide to scenario modelling in the REAP tool. This explains how to begin creating a scenario and the type of variables to include and exclude. If you would like this guide please contact info@resource-accounting.org.uk and we will send you a copy.

1.7 ACCESSING THE DATA OUTSIDE REAP

The 2006 footprint results for local authorities and regions are available on request and will soon be downloadable from the *Resource Accounting* website (www.resource-accounting.org.uk). These spreadsheets include a breakdown of the ecological, carbon and GHG footprints for every local authority in the UK and regions, with both per capita and total values. There are also individual pdf reports available for each LA and region, with explanations of the results and data for that area.

1.8 USING REAP DATA AS AN INDICATOR MEASURE OVER TIME

The REAP Tool and the free data that are available to download from the website (www.resource-accounting.org.uk) are not fully funded for regular updates. We update the data as frequently as possible and use the most up-to-date data available, however we cannot guarantee that the datasets will be updated at regular intervals due to the nature of the funding. In addition we always strive to improve and develop our methodology and therefore cannot guarantee comparability of data between releases. We therefore recommend that our data are not used as an indicator measure that is monitored overtime.

We have produced a historical time series of the carbon, ecological and GHG Footprint from 1992-2006. This is available in the REAP tool for all of the regions in the UK, but not down to local authority level.

1.9 REAP TOOL GEOGRAPHIES

The REAP Tool includes UK totals and results for all individual regions and local authorities in the UK. It also has the capacity to create combined footprint results and scenarios for a number of local authorities together (such as a city region) within the composite region function.

The REAP datasets are available at much smaller geographies; postcode, output areas (OAs) and super output areas (SOAs) etc. but due to the size of these datasets they are not included in the tool or published on the website. SEI is currently developing a research programme based on the small area datasets.

1.10 REAP AND OTHER CARBON ACCOUNTING APPROACHES

REAP calculates the emissions generated as a result of consumption of products and services. It is an area based approach, allocating emissions to the consumption of residents rather than the territory in which they were produced. As explained in the *Calculating Embedded Emissions* section, it is a top-down approach that combines emissions and consumption data.

REAP contains data about the emissions generated by the consumption of residents in an area. It is designed for policy makers, rather than individuals

or businesses. In theory an individual or a business could calculate emissions from their own individual consumption pattern, but REAP does not do this. REAP provides a higher level estimate of the emissions generated from all residents consumption in an entire area.

The REAP tool applies the consumption emissions accounting approach to residents in an area. The consumption based approach could be applied in other ways and we often do this at SEI. For example, we have calculated the emissions associated with the consumption patterns of a government department.

There are a number of methods for calculating emissions, the majority of these will focus on direct emissions, rather than embedded emissions. REAP is quite unique in that respect; there are few other systems in the UK that have modelled the consumption based emissions and can provide a consistent approach for calculating the embedded emissions in different products and services.

Direct emissions are easily calculated using standard conversion factors of CO₂ per kWh used or fuel burnt. Defra provide full lists of these factors and update them regularly, this includes transport fuels and estimates for the indirect emissions of electricity from the national grid.

Over recent years the number of standards and targets for carbon or GHG footprint has increased substantially. The UK Government has implemented standards, emissions reduction targets or work programmes for its departments and agencies, products, businesses and communities. These often have a prescribed method for calculating the emissions impacts or savings. Increasingly, government departments and governing bodies are looking to estimate the emissions impact of their different policies and programmes and the methods and approaches can vary. Whether the approach looks at just direct emissions, or indirect emissions as well, is often a useful way to distinguish them. It is then valuable to examine the conversion factors applied and the scope of the calculation.

SEI has completed a number of research projects on the different carbon, GHG and Ecological Footprint calculation methods, along with generating a number of our own tools for different calculation purposes. The term footprint is usually used to describe a full direct and indirect emissions assessment; however, there is no official definition so its meaning can vary.

1.11 THE REAP TOOL SUITE

The flexibility of the approach used at SEI means that the outputs of the modelling can be applied in a number of ways. Once the embedded emissions impact of a product of service is known it can be combined with any level of expenditure data to calculate the indirect emissions that would be generated as a result of demand for that product.

The original REAP tool provided the consumption based emissions accounts of residents in local authorities, regions and the UK. SEI has now developed a number of complementary tools to look at the consumption emissions of other groups – including tourist, communities, individuals and government departments.

REAP Petite is a tool for calculating the emissions associated with the consumption patterns of a community.

REAP Tourism provides the consumption based emissions of tourists, comparing different tourist types and patterns of expenditure.

The **Housing Calculator** is a tool for translating housing policy options, such as insulation or boiler improvements into average kWh demand for an area which can then be analysed in the REAP Tool for Local Authorities and Regions.

REAPSweden and **REAPBasque** are two international variations of the original REAP tool; designed for local authorities in those areas.

EUREAPA is a tool currently under development. It is a 27 region version of the REAP UK tool, containing data for 27 countries in Europe.

The **Yorkshire Regional Econometric Model** has been adapted to calculate emissions from consumption in the same way that REAP UK does, but for the Yorkshire and the Humber region.

The **WWF** and **Bioregional footprint** calculator are two on-line tools that individuals can use to calculate their own footprints, using a full consumption based approach.

The South West Regional Development Agency **Carbon Compass** is a framework for calculating the direct and indirect emissions impact of the SWRDA's investments.

The **NHS Calculator** and **Schools Calculator** were designed for internal departmental use to help determine the direct and embedded emissions of procurement for the NHS and Schools.

1.12 REAP TECHNICAL COMPUTER SPECIFICATION

Once you have a REAP licence you can download and run the software tool on any number of PCs within your organisation. There is no restriction on the number of PCs that have the tool.

REAP runs on a computer (not a server), it is an .exe file.

REAP has the ability to update itself via the internet when SEI releases bug fixes or updates to the baseline data. REAP downloads its updates via FTP from the ftp site: <ftp://ftp.sei.se> Please ensure this site is visible to programs on the user's machine.

Supported operating systems for REAP are Windows 2000, Windows 2003, Windows XP (all versions) and Windows Vista (all versions). Windows 98 and NT4 should work fine but are untested.

REAP is very flexible with regards to processing speeds and any processor that can run the host operating system will happily run REAP. In practice, REAP will operate comfortably on a 600Mhz CPU, but 1GHz will make evaluating scenarios quicker. REAP is not multi-threaded and will not benefit from a dual-core / multi-core CPU.

128MB of system memory is recommended to run REAP, but 64MB will be sufficient.

The base REAP installation consumes 12MB of hard disk space but needs a further 10MB for temporary storage. Allowing 40MB for REAP will ensure it has space to operate, even when working on very complex projects.

Your display hardware should support a screen resolution of 800 x 600 or above.

REAP operates best when it is installed and executed on the local machine. Network delivery systems (such as Citrix Metaframe) are supported, however it is advised that you consult with SEI to check how the specifics of your infrastructure will affect REAP.



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An internet connection is required to use automatic updates. REAP connects to the SEI FTP server to check for, and download, any new updates. FTP traffic should be allowed to pass through your firewall.

1.13 THE STOCKHOLM ENVIRONMENT INSTITUTE AND REAP DEVELOPMENT FUND

The Stockholm Environment Institute (SEI) is a not-for-profit, independent, international research institute specialising in sustainable development and environment issues. It has been engaged in these issues for a quarter of a century. SEI's mission is to support decision-making and induce change towards sustainable development by providing integrative knowledge that bridges science and policy.

In order to enable the ongoing and future development of REAP, the full REAP Licence is transferred to the REAP Development Fund (RDF). 100 per cent of resources from this fund go into the amendment and improvement of the REAP tool. The REAP Development Panel (guided by feedback from REAP users) decides on the focus of future development work.

The REAP tool and the free data that are available to download from the website (www.resource-accounting.org.uk) are not fully funded for regular updates. We update the data as frequently as possible and use the most up-to-date data available, however we cannot guarantee that the datasets will be updated at regular intervals due to the nature of the funding.

2 A COMPARISON OF THE 2004 AND 2006 DATA RELEASE

2.1 DATA PROVISION

At SEI we update our data as regularly as possible, but are constrained by the availability of national datasets. We are always working to provide the most up-to-date information.

The REAP Tool and the free data that are available to download from the website (www.resource-accounting.org.uk) are not fully funded for regular updates. We update the data as frequently as possible; however we cannot guarantee that the datasets will be updated at regular intervals due to the nature of the funding. In addition we always strive to improve and develop our methodology and therefore cannot guarantee comparability of data between releases.

2.2 COMPARISON OF THE 2004 DATA AND THE 2006 RELEASE

Results for all greenhouse gases and the carbon footprint show a high level of agreement between 2004 and 2006. The UK average figures differ by less than 1 per cent. This reflects the fact that SEI's methodology and the data underpinning it for these indicators has

remained much the same. However, we have updated the national datasets between releases and improved different components of the model. It is therefore not possible to compare the data from each year.

In order to analyse how the footprint has changed over time we have produced a historical time series of the carbon, ecological and GHG Footprint from 1992-2006. This is available in the REAP tool for all of the regions in the UK, but not down to local authority level due to lack of data availability.

The ecological footprint results are reliant on national datasets which are subject to revision; this means that footprint estimates can vary between publications. This ecological footprint dataset has been calculated using the revised National Footprint Accounts (NFA) 2008 from the Global Footprint Network (GFN). A change in this input data has resulted in a change in our results compared to previous releases. However, the underlying model remains the same and the NFA have been improved. This is explained in greater detail, with a full comparison of results and methods in the "*Changes to the Ecological Footprint results in REAP 2006*" section on page 14.



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3 TECHNICAL DETAILS: METHODOLOGICAL APPROACH

3.1 REAP AND THE USE OF INPUT-OUTPUT ANALYSIS

The SEI REAP methodology is based on structural economics, in particular input-output analysis. This is a standard economic modelling tool usually used by governments to understand the interactions of an economy. The reason that this type of economic modelling is used is because calculating embedded emissions requires an understanding of supply chains of products. The input-output tables described all of the interactions of industry and services in the UK economy, so it is a very valuable tool.

In the 1930s Leontief first used input-output analysis to look at how demand for products influenced different sectors of the economy through their supply chain linkages (for a full guide to input-output analysis see Miller and Blair, 2009¹; Leontief, 1970²; Leontief, 1986³.) This modelling was then extended to explore how demand for products affected other things such as labour or carbon emissions. SEI is one of the few organisations that have extended this type of analysis to incorporate carbon emissions for the UK.

In simplified terms, SEI takes data on direct emissions by industry from Environmental Accounts and uses the input-output framework of the economy, with all its supply chain detail, to reallocate the direct emissions to end use products. It is essentially a reallocation system, from emissions source, to final product.

Input-output analysis effectively describes the supply chain of all product groups and services in the economy. The tables show what inputs are required to each industrial sector to make the outputs from that sector. As a result the supply chain of a number of products is immediately available and can be analysed, even if the input products

are imported. This type of economic framework is therefore an ideal place to analyse complete, and often very complex, product supply chains. It would be very difficult to achieve consistent and complete supply chain picture from bottom-up life cycle analysis. Even if you can identify all of the inputs to make one product many of those inputs will have their own complex supply chains and it is difficult to know where the boundaries should be drawn. The data will always come in different units and quantities and even more difficulties arise if one process produces more than one output.

Input-output analysis removes these problems by using the whole economy expenditure approach that has consistent units and covers all economic interactions. It also produces results that are comparable across product groups, which is something that can be difficult to achieve in life cycle assessments of individual products. This system offers accuracy, system completeness, scalability, expandability, scientific credibility and the possibility to combine the model with other economic or econometric modelling to develop scenarios. The decision by SEI to use input-output analysis as the basic methodology for calculating emissions embedded in products was guided by this knowledge.

The main compromise with using the economy-wide input-output approach is the level of product and service disaggregation. The tables cannot include every single product or service purchased and consequently they are grouped into similar categories using the Standard Industrial Classification.

In order to calculate the emissions embedded in products and services using input-output analysis the following steps are taken.

- The Input-output tables are formulated from national datasets held by the Office of National Statistics, making adjustments for taxes and differing trading margins. A diagram of the resultant input-output framework is shown in figure 2.
- Data on direct (industrial) emissions generated by different sectors of the economy are added to the basic input-output framework.

-
- 1 Miller, R. E. and Blair, P. D. (2009) *Input-Output Analysis: Foundations and Extensions*. 2nd edition, 31 May 2009. Cambridge University Press, UK.
 - 2 Leontief, W (1970), taken from Kurz, H.D., Dietzenbacher, E. And Lager, C (1998), *Input-output analysis Volume II*, Cheltenham, Edward Elgar Publishing Ltd.
 - 3 Leontief, W (1986), *Input-output economics*, New York, Oxford University Press.

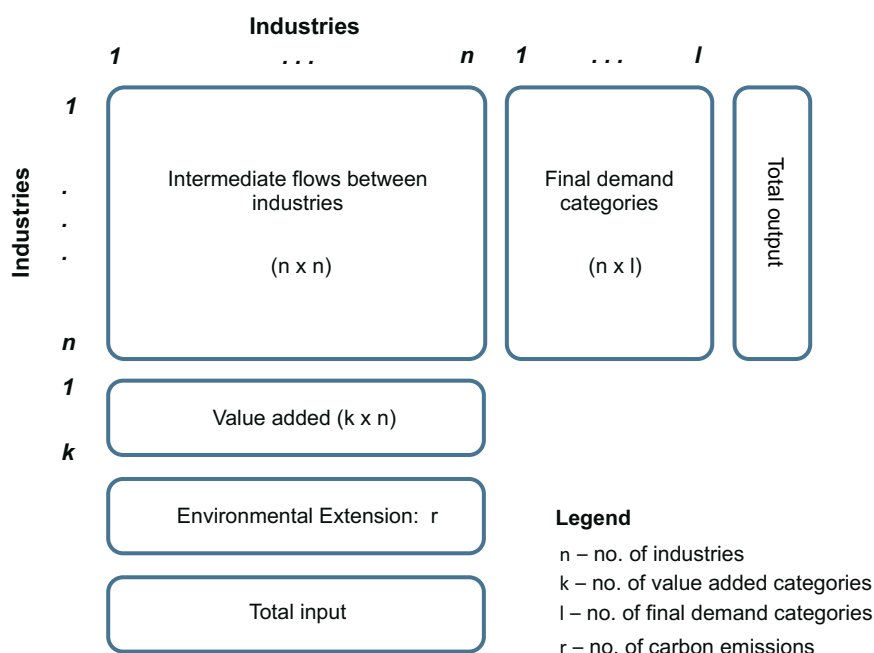


Figure 2: General structure of an input-output table

- The emissions data by sector is re-allocated to products and services depending on the economic interactions described by the input-output table.
- The resultant output is the indirect (or embedded) emissions of a product or service that are generated throughout supply chain of that product or service. The conversion factors do not include emissions that are generated at the point of use of a product (e.g. the emissions from a car exhaust when fuel is burnt).

Figure 2 shows how an input-output table is presented, with the main component being a transactions matrix of the industrial sectors. Each row of the table indicates the distribution (sale) of an industries output to other domestic industries (intermediate demand) and to end consumers, such as households or government (final demand). Each column shows the amounts of inputs purchased from other industries and value added categories.

The result of this process is a full account of the emissions embedded in products and services across complete supply chains, which can be then used to determine the embedded carbon in a product or service per pound spent on that product or service.

3.2 ECOLOGICAL FOOTPRINT COMPARISON OF METHODOLOGIES

At SEI we also calculate the ecological footprint of consumption activities. The modelling approach we use is the same as the carbon/GHG method, but the input data is different. For modelling ecological footprint you need to understand the direct land use by industry, rather than the direct emissions output of industry. This direct land use is then reallocated in the same way as carbon and GHGs – from source to final products.

One of the main features of an ecological footprint indicator is that it is based on consumption, not just domestic production. It takes into account the impact of all products that are consumed, whether they are produced in the country of consumption, or elsewhere in the world. This means that any methodology for calculating a footprint must take trade into account.

There are a number of organisations that calculate ecological footprints including Best Foot Forward (BFF), SEI and the Global Footprint Network (GFN).

As there is no internationally agreed method for national footprint calculation, the estimates by different organisations can vary. It is important to understand the differences between the methods,

Table 1 Comparison of methodologies

SEI (REAP)	Global Footprint Network	Best Foot Forward
Input-output methodology: • Direct ecological footprint land reallocated from generating sector to products using IO framework. • Ecological footprint land from sectors are linked to the products produced. Generated by the model, using actual UK data. • These supply chain (embodied emissions) are specific to the UK.	Life cycle analysis (LCA) and physical flows: • LCA information is collected on different products. This LCA data is not necessarily UK specific. • LCA data provides embodied emissions estimates. • Embodied emissions coefficients multiplied by trade volumes for that country.	Resource flow analysis and mass balance: • Physical quantities for production import and export of energy, materials, products and transport and production of waste used as a proxy for material consumption. • GFN coefficients applied to resource flows, supplemented by other LCA coefficients when required.

the basic assumptions made by the models and the strengths and weaknesses associated with each.

Table 1 is a summary of the different methodologies used by the main footprint organisations.

A detailed comparison of the GFN method and REAP is available in the peer-reviewed paper by Wiedmann, 2008⁴. Please refer to this paper for a full comparison of the two models, a summary is provided in the following paragraphs.

In the latest release of GFN data (2008 edition) GFN estimate the UK footprint to be between 5 per cent and 15 per cent higher than SEI's figures between 1992 and 2005. The UK footprints calculated by SEI range from 4.2 (in 1994) and 5 gha/capita (in 2002). Those estimated by GFN range from 4.8 (in 1993) and 5.5 gha/capita (in 2001). This discrepancy between footprint estimates reflects the different calculation methods used by each organisation; the main reason for the varied estimates is the way that the models treat trade.

From a methodological perspective there are two ways that the trade impact can be taken into account:

- using financial information (trade values) and multipliers derived from economic input-output analysis;

- using physical information (trade volumes) in combination with life cycle coefficients that identify the impact of these traded goods.

The SEI model takes the first approach, using financial information and multipliers derived from input-output analysis. Input-output analysis is a standard economic framework used to analyse the interdependencies between industries in the economy. It can be extended to incorporate environmental impacts such as pollution, resource or water use for example (a full description of the methodology has been published in the journal *Ecological Economics*: Wiedmann *et al.*, 2006⁵). The SEI model extends the input-output analysis to include GHGs and land use (ecological footprint). All the footprint results that are generated by SEI have this same underlying methodological framework.

A simplified explanation of how the methodology works is as follows: data on direct emissions generated by different sectors of the economy (for the CO₂ and GHG footprint) or data on land and resources required for production (ecological footprint) are taken into the model and re-allocated, from the generating sector to the goods or services produced. The input-output model is the tool used to complete this re-allocation. It is a representation of the UK economy, which shows how all of the

4 Wiedmann, T. (2008) A first empirical comparison of energy Footprints embodied in trade - MRIO versus PLUM. *Ecological Economics*, 68(7), 1975-1990. <http://dx.doi.org/10.1016/j.ecolecon.2008.06.023>.

5 Wiedmann, T., Minx, J., Barrett, J. and Wackernagel, M. (2006) Allocating ecological footprints to final consumption categories with input-output analysis. *Ecological Economics*, 56(1), 28-48. <http://dx.doi.org/10.1016/j.ecolecon.2005.05.012>.



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different sectors interact – which manufactures buy from which producers (both in the UK and abroad). The direct emissions (or land areas) are re-distributed to products adding up all the emissions across their whole supply chains. This means emissions (or land required) that are embodied in the final product are generated by the model itself, based on the sectors that were required to produce the product and their associated emissions (or land requirements).

GFN uses the second approach in a trade volume and life cycle coefficients model called PLUM – a “product and land use matrix” accounting framework. These types of models don’t calculate impacts embodied in different products within the models. They do not link direct emissions from sectors and the products produced. They therefore need a way of converting the amount of goods purchased (trade volumes) into a quantity of emissions or land area. For this they use estimates of the impact (emissions or land) of goods based on lifecycle analysis. The factors that are used may come from a variety of sources, not necessarily specific to individual countries, unlike the input-output framework which calculates factors specific to the country and with consistency across products. For example, the GFN model would assume that one tonne

of cotton is produced with the same resource efficiency in every country in the world.

Another difference between the modelling approaches is how they take into account supply chains and the impacts of products not directly known; the indirect impacts of products. An input-output approach provides a full supply chain impact because it is a macro-economic model of the whole economy with all links between sectors included. The GFN approach takes the supply chains of products into account by allocating part of the ecological footprint of a primary product used for manufacturing of a secondary product (e.g. cereals for pork meat or roundwood for paper) to the secondary (or daughter) product. This procedure is not applicable to more highly manufactured products, such as electrical equipment or services. Consequently, such products do not carry any non-energy land embodiments in the GFN accounting method. This leads to an overestimate in the embodied energy footprints for most raw materials and manufactured products, with underestimates of the impact of services. This makes the aggregated footprint figure similar to the SEI model estimate, but gives very different results at a disaggregated level.



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These differences, although not so crucial on an aggregated national level, have a considerable effect when considering the impact of traded goods and services. The allocation of indirect impacts is necessary as we do not just consume food, fuels and materials directly, but we consume just as much indirectly through the use of manufactured foods and services.

Input-output based models like the SEI model are comprehensive, detailed and robust, including the indirect impacts of traded goods and services. Despite this, input-output models are not yet applied internationally therefore the NFA-PLUM model is useful for comparing footprint estimate across the world. Beyond this, input-output analysis provides the most suitable approach, overcoming the intensity inaccuracies, the inclusion of traded services and manufactured goods (indirect impacts), consistency with the United Nations Accounting Standards, high sector disaggregation, spatial disaggregation and suitability for scenario generation (Wiedmann, 2008⁶). A number of countries across the world have already or are currently developing their own input-output based model for calculating footprints and analysing the impact of consumption. Some have also compared their estimates to those produced by GFN.

3.3 CHANGES TO THE ECOLOGICAL FOOTPRINT RESULTS IN REAP 2006

This section addresses the two key questions.

- Why is there such a difference between the 2004 and 2006 datasets?
- How should this drop in ecological footprint be interpreted?

Between releases the SEI methodology has remained the same. The cause of the change in footprint is the updates made to the National Footprint Accounts (NFA, 2008). These data are used as inputs to the SEI model and consequently the final results differ, see Table 2. The changes to the NFA are described on pages 29 and 30 in GFN's *Ecological Footprint Atlas, 2008*⁷. The main changes to the NFA are the updated equivalence factors.

The 2003 UK ecological footprint results reported by GFN in two different time series releases (the 2008 edition and the previous 2006 edition) vary in total by only 6 per cent (see Total column in Table 3). However, as the comparison in Table 3 shows the individual land type variation between the two data

6 Wiedmann, T. (2008) A first empirical comparison of energy Footprints embodied in trade - MRIO versus PLUM. *Ecological Economics*, 68(7), 1975-1990. <http://dx.doi.org/10.1016/j.ecolecon.2008.06.023>.

7 Ewing B., S. Goldfinger, M. Wackernagel, M. Stechbart, S. M. Rizk, A. Reed and J. Kitzes. 2008. *The Ecological Footprint Atlas 2008*. Oakland: Global Footprint Network. http://www.footprintnetwork.org/en/index.php/GFN/page/ecological_footprint_atlas_2008

Table 2 Comparison between UK figures from SEI 2009 release and GFN 2008 edition

	Year	Cropland	Grazing land	Forest land	Fishing ground	Carbon sequestration land	Built-up land	Nuclear Power	Total
EF of UK from SEI (Aug. 09)	2005	1.18	0.26	0.2	0.1	2.78	0.2	-	4.72
EF of UK from GFN Living Planet Report 2008/2008 edition results	2005	0.87	0.21	0.46	0.08	3.51	0.2	-	5.33

releases were far greater than the total difference, with the land type changes balancing each other out to generate a relatively small change overall. SEI use the NFA figures to generate footprint results, taking the individual land types and allocating these to sectors, which are then used to build up the total ecological footprint. Consequently, these changes to land types between releases have a relatively large impact on the SEI total footprint figures.

The next table shows how the contribution of different land types varies considerably between GFN data releases, the impact of fishing ground for example, increased by 76 per cent, whilst grazing land and built-up land decreased by 33 per cent and 47 per cent respectively. These large changes across land types in the GFN figures by chance balance out to give only a 6

per cent difference in the total footprint figure between releases.

The methodology for calculating footprints varies between organisations and is constantly being updated and improved. The figures, like the majority of published datasets, are continually subject to revision. We have produced a consistent time series of the ecological and GHG footprint for the UK and regions, which provides a robust basis for the assessment of longer-term trends. While data updates may require the re-interpretation of year-on-year assessments and target reporting, it is important to note that the overall message of these results is that consumption, particularly in the developed world, is occurring in a way that is not compatible with long-term ecological sustainability.

Table 3 Comparison between UK figures for 2003 in the GFN 2008 edition Ecological Footprint results and GFN 2006 edition results

	Year	Cropland	Grazing land	Forest land	Fishing ground	Carbon sequestration land	Built-up land	Nuclear Power	Total
EF of UK from GFN Living Planet Report 2008/2008ed results	2003	0.87	0.2	0.47	0.06	3.43	0.2	-	5.23
EF of UK from GFN Living Planet Report 2006/2006ed results	2003	0.68	0.3	0.46	0.25	3.21	0.38	0.31	5.59
Total change		0.19	-0.1	0.01	-0.19	0.22	-0.18	-0.31	-0.36
% change		28%	-33%	2%	-76%	7%	-47%	-100%	-6%

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