Carbon Conversations Star Ratings – explanation of the methodology

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1. Introduction

Halving an individual carbon footprint involves a huge number of actions. Some will have a big impact, some small. Some will only have an impact combined with other actions, others will have an impact if done alone but a greater impact if done with others. Some will apply to one person but not to another. All will suffer from the law of diminishing returns. Predicting the carbon savings from any action is rather a dark art. Predictions are affected not only by the data available and the method of analysis (where there is not always consensus from the scientists and engineers doing the sums) but on a host of other variables such as the size of your footprint today, variations in the weather, how easy you find the action and its interaction with other steps you are taking.

As we say repeatedly in the *In Time for Tomorrow?* there is no substitute for monitoring each area of your footprint, recording actual figures for home energy and travel and using the methods suggested for monitoring food and purchases. Comparing current energy use and consumption with previous measurements is the only accurate way of seeing the effect of the carbon reduction actions you take.

In order to make carbon reduction plans however some guidelines are necessary. The tables of actions and star ratings found throughout *In Time for Tomorrow?* indicate the relative importance of different steps you can take. It shows what are the likely easy wins and which actions have a small impact but contribute to the larger sum. In this article we explain how carbon emissions for any action are arrived at, the thinking behind the star ratings and how we arrived at the designation for each action.

2. Approaches to working out carbon emissions

Estimating the impact of any action requires us to know the current footprint of that activity and then the effect of the change. The first may be more or less easy to calculate and the second may depend on a host of interrelated influences. For example it is fairly easy to calculate last winter's carbon emissions for your house – you simply have to read the meters. Predicting the effect of turning down your thermostat is harder however. The savings made will depend on the exact amount you turn it down, the programming of your timer, the construction of your house and the weather. With more complicated activities – for example the carbon emissions of a summer holiday in Crete – trickier questions emerge. What part of the travel company's and hotel's carbon emissions belong to your holiday? How do you divide the emissions of heating the swimming pool between all the guests? How do you compare this with a camping trip to Wales?

Over the last couple of decades our understanding of these problems has developed rapidly and the quality of the data has been refined. There are three approaches to calculating the carbon footprint of any activity or product – 'bottom up' case-study methods, 'top down' statistical methods and modelling. Using a combination of all three provides some checks and makes results more reliable.

2:1 From the bottom up

This approach takes a particular product, service or activity and examines all the inputs of energy that have occurred in its creation in order to arrive at its carbon footprint. This is often referred to as 'whole life costing' or a 'cradle to grave' approach.

Take the example of a cake. We could start with the direct emissions caused by lighting the oven and cooking the cake. To that we must add the emissions embodied in each ingredient, for example the fertiliser used to grow the crops, the processes used to refine and preserve them and the fuel used in their transport. On top of this come a share of the materials used in manufacturing agricultural machinery, the oven and the cake tin, the energy costs of taking away wastes and so on.

To be useful, we must be clear about which aspects of manufacture, distribution and use have been included and which left out. Only when common standards and 'boundaries' have been agreed can we compare products and use the data in the calculation of other products.

The limitation of this 'case study' approach is that each product or service needs its own audit and analysis. If we want to know whether it is better to make a cake at home from raw ingredients or buy one from the supermarket we must complete the analysis for both products and then compare them. The picture is complicated because figures may vary for the same product manufactured by different processes, in different countries or by different companies. Commercial interests may cause figures to remain unreported or be massaged to be more complimentary for the manufacturer.

A common standard (BSI PAS2050) for this method of analysis is being adopted and used by a small number of suppliers, and you may see carbon footprints on an increasing number of products.

2:2 From the top down

This is a statistical approach and uses the huge amount of information collected by government and industry about the national economy. For example there are figures for the amount of gas imported and the amount sold to the food processing industry. There is also published data for the tonnes of different baked products produced and imported. Dividing one by the other can give us the direct emissions for factory-baked cakes. This method also provides data for the indirect and embodied emissions in goods and services. For example, we can measure the actual fuel consumed by a steel works and the weight of steel manufactured. This tells us the embodied energy for a tonne of steel, a figure that will be needed in a case study calculation for a motor car. This statistical approach is the method behind the popular book *How Bad Are Bananas* (Berners-Lee 2010).

This approach is limited by a number of factors: the way the data is collected, the effect of the boundaries set by the collection and analysis of the data and the level of disaggregation in the statistics. The level of aggregation or disaggregation means that the data may only be available for industries or regions as a whole. We may not be able to distinguish between the amount of fertiliser used by arable or horticultural production and more significantly whether imported steel has been produced more or less efficiently than the home made product.

2:3 Modelling

Both the statistical and case study methods only report on existing emissions and/or specific products. By creating models of processes involved in the production and use of goods and services and using the data we already have to calibrate them, we can study a greater variety of products and predict the savings that might result from different actions. For example we can model the effects of a switch from car use to public transport, from a high meat to a low meat diet or from poorly insulated to well insulated houses.

Modelling usually consists of computer based calculations of particular systems which simulate their operation. This approach is used in the building regulations to set standards for energy conservation and is also the basis of the House Game in session two of Carbon Conversations which models a worse-than-average home and enables us to demonstrate the impact of changes suggested.

These three approaches are complementary. The statistical, top down approach provides a reality check on the mass of data that comes from the bottom up case studies. Modelling allows us to make predictions and is also used by analysts to disaggregate statistical data. Although theory and methods are still developing many of the techniques have been well tried and tested and are used in different fields by engineers, economists and business managers.

3. Why is it so difficult?

In our lists of actions in *In Time for Tomorrow?* we have taken data from sources that use all these approaches and done a little modelling of our own. Where possible we have compared different figures and looked for the consensus. But while we are confident that we have reliable figures, there are a number of reasons why it is not possible to do more than provide a 5 point rating system for this list. The exact savings for a particular person are influenced by too many variables to give an exact figure in kilograms of carbon dioxide for each action.

3:1 Everyone is different

To produce a table of emissions and savings, we have to assume average or typical patterns of consumption or use. The starting point for our calculations is an average sized house, with an average sized family, using a typical amount of heating, eating a typical British diet, travelling an average distance to work and spending an average salary on a typical range of products.

Very few people are actually average. We are distributed all along the scale and the difference between one end of the scale and the other can be great. There are also a number of scales involved. A person may have an average housing footprint but an extreme travel one for example.

Each person's starting point or baseline will be different. One person will already have taken many of the actions on our list. Another will be a complete beginner. One person's house is large, another's is small. For example, insulating the loft of a large house where no other energy-efficiency measures have been taken could save twice the amount of carbon dioxide that insulating the loft of a small house where the draft-stripping and cavity wall insulation have already been completed.

3:2 The law of diminishing returns

One of the simplest limitations on the outcome of an action is the law of diminishing returns. Many of the actions that we take do not have a fixed outcome, but make a percentage change to an existing component of our footprint.

This is reflected in the House Game by a logarithmic scale: as the game progresses it becomes increasingly difficult to achieve each additional tonne of savings. Another example can be found in actions taken to reduce a travel footprint. The amount of petrol we use is dependent on the distance we drive, the speed we drive at and the size of the car. In order to halve the petrol we use we could halve our mileage, drive 40% slower or buy a car that is twice as efficient. Any one of these actions might save a tonne from a two tonne footprint. Doing all three cannot save three tonnes however, but will cause three halvings, from two tonnes to one tonne, from one tonne to half a tonne and from half a tonne to a quarter of a tonne.

Where actions affect separate areas of the footprint they can be added together but in general the law of diminishing returns applies to each area.

3:3 Interactions between different actions

One of the reasons for the proportional nature of the outcomes of our actions is that combinations of things work together to cause our emissions. Some of these interactions are straightforward and we can compound the percentage savings as we make the changes. Other interactions may be more complex. For example, changing your diet may change the amount of energy you use cooking. Similarly, there is a complex relationship between the level of insulation in your house, the temperature you set the thermostat and the amount of gas you use. Some of these interactions may increase the proportional savings, others may diminish the effect.

3:4 Uncertainty

Even when you examine one action for a particular person with a known baseline footprint, there are still limitations to the precision possible.

1. The accuracy of the predicted saving can only be as accurate as the definition of the action. For example: 'Install loft insulation' gives a wide choice of materials and thicknesses, 'Driving to the speed limit' has a different effect on the motorway and in a built-up area, 'Reducing intake of dairy produce by 50%' doesn't define the proportions of milk, cheese and butter in the action. Most of the items on the list allow for a reasonable margin of interpretation.

2. The vigour with which someone pursues an action may change. People sometimes become more effective over time, sometimes less.

3. The implementation may depend upon external factors, such as the weather which of course varies from year to year.

3:5 Rebound

All the considerations above assume that the savings are retained as the modelling predicts. However, there is another layer of complexity to undermine our actions and intentions. As savings are made, the released resources can be directed into activities that create further emissions. This rebound effect can happen at three levels.

Direct rebound

As people make lifestyle changes they may also make little compensations for the actions they are taking. Once their house is insulated people often allow the temperature to increase a little. This may be because they were cold before, because they feel they can now afford to be a little more comfortable or because the control system is not very good. Thus some of the predicted saving will be offset by the temperature rise. On a larger scale, direct rebound is apparent in the fact that as car engines become more efficient, car sizes tend to increase and people tend to drive further.

Indirect rebound

Some actions result in day-to-day cost savings, although the capital outlay may have been considerable. For example, a more efficient car or a well insulated house both cost less to run. Since there are direct or embodied emissions in everything that we spend money on, any saved money which is spent on something else will push our carbon emissions back up again. So unless we carefully bank the savings or reduce our income to match the reduced spending, we cannot avoid some indirect rebound.

Backfire

There is a danger that the cash savings will be spent on products or services with emissions comparable to the carbon savings achieved in the first place. At the worst, we may splash out in a way that backfires completely. A small number of goods and services have greater emissions, per pound spent, than the fuel we purchase. Chief among these are budget air travel, exotic foods and building products. If you spend the savings from your solar panel on a flight to Barcelona, you will have increased your emissions overall.

4. What we've done

The Carbon Conversations project grew out of the work on Carbon Footprinting by Peter Harper and colleagues at the Centre for Alternative Technology. In particular, we have used his statistical analysis of UK footprints as the base line for our calculations.

There are a number of published sources that provide data and examples for the items that we list, primarily DEFRA, DTI and EST, listed in the references.

We have also made some of our own calculations, mostly to adjust existing data to the baselines we are using.

We have compared our figures and assumptions with similar work by others (Berners-Lee 2010, Desai 2002, Goodall 2007, Marshall 200, Vale 2009,) and with work done for the

Scottish Climate Challenge Fund by Caledonian University which also draws on similar sources.

Almost all of the figures assume single actions for average UK citizens and range from 50kg to several tonnes of CO2 savings. Given the range of values and the fact that you can't just add them up, we needed a simple scheme that would band actions so that participants can recognise the relative importance of each one.

We have grouped the actions in bands of approximately doubling magnitude and labelled them with stars.

*	Up to 100kg
**	Between 100kg and 250kg
***	Between 250kg and 500kg
****	Between 500kg and 1000kg
*****	Over 1000kg

Actions that have little or no impact on carbon emissions have been given a ✪ symbol. They are included as they may be an important step in preparation for more important actions or have an impact on other aspects of an ecological footprint.

You cannot convert stars to kg and add them up for all the reasons given above but particularly because of the diminishing returns and interactions. There is no substitute for monitoring and recording!

Housing

In this section, the star ratings give savings per household, not per individual footprint.

We have assumed average emissions of 6 tonnes per dwelling. The modelling is based on a 80m2 semi detached house, with varying types of construction and features. We have also assumed gas heating, which applies to over 80% of UK mainland houses. Savings will be greater for electric and oil heated homes.

Most of the figures have come from calculations for typical houses. The model is based on the SAP calculation for domestic energy emissions (Building Research Establishment 2009) with improvements introduced by Cambridge Architectural Research for the Scottish Government (Scottish Government Social Research 2009). The same calculations underlie the Home Energy Game in session two of Carbon Conversations. In particular, the model allows for user differences and upgrades to the building. Some of the figures relied on our own expert knowledge and are supported by other footprint calculators, most importantly the CCF/CAT calculator and Peter Harper's statistical analysis. We have also compared the figures with both the Caledonian and Energy Saving Trust data.

Travel

The star ratings in this section are for an individual footprint.

The work underlying the Travel Dilemmas game in session three of Carbon Conversations was used for this section with figures taken from additional sources and a few of our own calculations. The star ratings are for an individual footprint. We have tried to make our figures match the transport footprint calculated from Peter Harper's data.

Where we have calculated figures from first principles we have assumed annual mileage per car of 8,420 miles (National travel survey 2009) and per person mileage of 5,706 (National Statistics - www.statistics.gov). Average occupancy is 1.56 but can fall to 1.2 for commuting trips; Typical fuel efficiencies, conversion factors and occupancy figures come from DEFRA data.

We have also taken figures from EST tables, although these rarely declare their supporting assumptions and we have used data from Peter Harper's work. Additionally we have relied on modelling of basic principles to adjust some of the figures to our common baseline.

Food and Water

The star ratings in this section are for an individual footprint.

The data on food is less reliable than that on housing or travel, as the carbon emissions from food are almost entirely embedded or indirect and there are also the effects of other greenhouse gases to take account of. We have also used data from Tara Garnett (2008) to assign proportions of CO_2 equivalents to different parts of your diet. Additional figures and checks come from the Sustainable Development Commission, EST and Caledonian.

Consumption and Waste

The star ratings in this section are for an individual footprint.

This data is also less reliable as again the emissions are by definition indirect or embedded in the products, however as we discuss in *In Time for Tomorrow*? the best indicator for consumption is household income. There is a table for this in In Time for Tomorrow based on work by Minx et al (2009) and Gough et al (2012).

The star ratings are for an individual footprint but are based on the work above, on some of Peter Harper's work and also on Tim Jackson's analysis for the Carbon Trust (Carbon Trust 2006) of business sectors and from Berners-Lee (2010), both of which are based on "input - output analysis". There is also some data taken from the Caledonian study.

5. Conclusion

It is important to remember that the point of the star ratings is to give an indication of the relative importance of different actions.

As we say in *In Time for Tomorrow?,* the initial footprint calculation gives you a rough idea of your carbon footprint and one of the major points of the Carbon Conversations process is to help people make more accurate calculations of their own to find their personal baseline and begin to make reductions. The star ratings are no substitute for this.

6. References

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