TOWARDS A STANDARD METHODOLOGY FOR ECOLOGICAL FOOTPRINT ANALYSIS OF SUB-NATIONAL REGIONS

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ABSTRACT

Since Wackernagel and Rees' initial development of the ecological footprint (EF) as a concept in the 1990's there has been widespread interest in the methodology. The *National Footprint Accounts*, published in summary form as part of WWF's *Living Planet Report*, currently measure the EF per capita of more than 250 countries and provides the 'global EF standard', both methodologically and in terms of global environmental sustainability (supplying an average world resident's EF and the average biocapacity available per world resident).

This interest, plus an independent and detailed critique commissioned by the European Parliament's Scientific, Technical and Options Assessment, has led to the inclusion of the EF within the European Commission's Common Indicator set for assessing regional sustainability (ECIP). EF studies from Europe demonstrated broad differences in the application of the methodology and a wide variation in data sources used, which made comparisons between regions problematic. A panel of European practitioners recommended that a standard methodology be developed according to basic criteria:

1. Compatibility with *National Footprint Accounts* (*NFA*)
2. The EF should be disaggregated into policy-relevant components
3. The datasets used should be those readily available Europe-wide
4. The model should be interactive to facilitate scenario development

The ECIP project led to the development of the Stepwise methodology, a basic European EF standard. Stepwise was extended and revised for a Scottish study, representing the first time a detailed and informative analysis was applied to a major sub-national region, compatible with the *NFA*. This paper describes Stepwise applied to Scotland.

INTRODUCTION

The ecological footprint (EF) is a concept that addresses both the human use of natural resources and the available supply of natural resources. The EF is the bioproductive area required to provide the goods and services consumed by individuals, communities or organisations. It can also be derived for products or for particular activities. The available supply of resources, termed biocapacity, is the area of bioproductive land and sea on the planet. By comparing 'demand' (EF) with 'supply' (biocapacity) over a set period (e.g. a year) an indication of environmental sustainability can be made. If more of nature's resources are consumed than are available (i.e. can be supplied within the set period), then it is possible to assume that the rate of consumption is not sustainable [1].

Since Wackernagel and Rees' initial development of the EF concept in the 1990's [2] there has been widespread interest in the methodology. For example, a recent 'Google' search for "ecological footprint" produced 86,000 results. However, due to both the encompassing nature of the EF concept and the specific demands placed upon it by different audiences, there has been widespread use of the term ‘ecological footprint’, which has led to confusion over its exact definition and calculation.

As interest in the EF has grown and become more focussed, the need to standardise methodological applications has grown clearer. This need has been recognised and to date, resulted in a Europe-wide programme and most recently, the formation of the Global Footprint Network [3] to address these issues.

Within the UK, Best Foot Forward has led EF developments and made the first significant move towards a standard EF methodology by aligning sub-national EF studies with the *National Footprint Accounts* (*NFA*) [4], published in summary form as part of WWF’s Living Planet Report [5]. This move resulted in the development of the Stepwise [6] methodology, the first standard methodology for Europe. Under the Biffaward programme on sustainable resource use, the Stepwise methodology has been refined and extended for sub-national use. This paper describes the experience of using Stepwise to measure the EF of Scotland’s residents [7].

THE BIFFAWARD PROGRAMME

In 1998 Biffaward set up a programme on sustainable resource use to promote Mass Balance studies focusing on specific materials, sectors and geographical areas across the UK [8]. Best Foot Forward, Viridis and others have extended this approach to include resource flow and EF analyses. The aim of this approach has been to provide comprehensive baseline data, highlight current data gaps and provide the basis against which improvements in resource efficiency can be measured. The resource flow studies provide information on flows through the economy, including total material use, water, emissions and waste.

The EF is a natural follow on from a resource flow analysis, as it uses much of the same data. However, some additional data requirements are needed, as the EF shifts the focus away from the economy, to the consumption of resources by residents. The EF can also highlight resource efficiency as well as indicate environmental sustainability of the population. By manipulating data to represent achievement of future policy targets, scenarios can be created to show the impact of such policies. Equally, EF can also highlight the scale of the targets that would be needed for the population to become environmentally sustainable.

THE NATIONAL FOOTPRINT ACCOUNTS (NFA)

Since Wackernagel and Rees’ initial development, Wackernagel and various research teams have compiled the ‘Footprint of Nations’. This was first published in 1997 [9] and measured the EF of 52 nations. It has since evolved into the *NFA*, published in summary form as part of WWF’s Living Planet Report, and includes more than 250 nations.

The *NFA* use an EF methodology known as the 'compound' (or 'top-down') approach. It is called the compound approach as it captures all resource use (including trade) within a geographical boundary, and is measured at a national level. To calculate the per capita EF of a nation, using the compound methodology, the following national data is used:

- Production, import and export of materials, such as crops and timber,
- Energy consumption, including the net balance of embodied energy through

traded products, and
• National land use.

To enable comparisons between nations and sub-national areas, which have different bioproductive capabilities, the EF is presented in global hectares (gha).

1 gha = 1 ha of biologically productive space with world average productivity

To convert different areas with differing productivities into standardised global hectares, two conversion stages are required:

1. Local yields are converted into average global yields for each area type. Sea is an exception, as global average yields are used throughout. The *NFA* gives 'yield factors' for each nation to enable this conversion. The conversion results are presented in specific area types, for example global average arable area and global average forest area.
2. 'Global average' area types (arable, pasture, forest, built and sea) are converted into standard hectares of global average productivity by the application of 'equivalence factors'. The equivalence factors, from the *NFA*, are also subject to change due mainly to data availability and variability in the bioproductivity of the planet over time.

The results of the *NFA* are presented as the EF per capita and split between the different area types assessed. Table 1 shows the latest results for the UK from the Living Planet Report 2002 [5], which uses data from 1999.

Area type	**Per capita ecological footprint (gha)**	**Per capita biocapacity (gha)**
Crop area	0.68	0.52
Forest AWS*	0.32	0.13
Wood fuel	0.0003	-
Forest NAWS**	-	0.001
Permanent pasture	0.33	0.41
Fishing grounds	0.47	0.36
Built land	0.21	0.21
Hydro area	0.001	0.001
Energy	3.33	0
Total ecological footprint	**5.35**	**1.64**

* Available wood supply.
** No available wood supply.
Source: [4]

Table 1: The 1999 *NFA* for the UK [4]

While the *NFA* represent the global EF standard, the results are not particularly relevant to policy-makers or individuals, as they do not relate to policy areas or activities, such as waste or transport. It is possible, using a 'component' methodology to provide a policy relevant disaggregation of the *NFA*. Components, such as the production and consumption of food, domestic energy, personal transport and the materials, products and services traded and consumed, are analysed.

THE GEOGRAPHICAL AND RESPONSIBILITY PRINCIPLES

Before a regional EF can be calculated, a fundamental boundary decision needs to be made: should it calculate the EF of the region (geographical principle) or consumption associated with the region’s residents (responsibility principle)?

These two approaches can give very different answers. As an example, how are airports accounted for? Is the full impact of all the airports' activities included as part of the region's EF (geographical principle) or only that part attributable to the region's residents using the airports (responsibility principle)?

The Stepwise EF methodology uses the responsibility principle, which is compatible with other global, regional and city studies, including the European Commission's Common Indicator set (ECIP) for assessing regional sustainability. For more information regarding the independent and detailed critique commissioned by the European Parliament's Scientific, Technical and Options Assessment and the European use of the EF see Lewan & Simmons [10], Ecotec [11] and Tarzia (ed.) [12].

THE BASIC STEPWISE METHODOLOGY

The basic Stepwise uses a component (bottom-up) approach to re-analyse the *NFA*. Stepwise involves applying the EF conversion factors (gha per unit of consumption) used in the *NFA*, supplemented by life cycle data when required, to national average consumption data to derive EF results for each component.

For example, to derive a component EF for a car passenger travelling one kilometre, data on fuel use, materials and energy for manufacture and maintenance of the vehicle, and the share of UK roadspace appropriated by the car is analysed (Table 2). The associated conversion factors are then applied to the number of passenger-kilometres (pass-km) travelled and used to breakdown the energy and built land categories of the *NFA*.

Average car travel (1 pass-km)	**Energy land**	**Built land**
Carbon per pass-km (kg)	0.031	
Uplift factor*	145%	
Carbon responsibility	69%	
World carbon absorption (tonnes C/ha/yr)	0.95	
Direct land (total ha)		258,175
Land use (ha/car km)		0.0000006
Equivalence factor	1.35	2.18
Yield factor		2.44
Average occupancy (persons/car)		1.6
Total ecological footprint (gha/pass-km)	**0.000043**	**0.000002**

Table 2: An example EF analysis of average UK car travel, per pass-km [7]

Additional analyses are required whenever a new component or sub-component is assessed, for example crop land and pasture for animal-based food products or the sea for fish and other sea-based products.

The Stepwise components represent the main categories of impact, and each key component can be further sub-divided into smaller categories, for example 'direct energy' into fuel types such as electricity, gas and domestic heating oil. Each of these sub-categories can be broken down further, for example into domestic and commercial service sectors. The availability and reliability of data is the key limiting factor in determining the number and coverage of components. Stepwise components have been chosen to reflect data availability at the European level to maintain consistency and compatibility.

When all EF calculations are complete, the key component EFs are added together to obtain a total EF. A complete UK EF enables various regions within the UK to calculate their EFs by altering UK average consumption data.

THE EXTENDED STEPWISE METHODOLOGY

To calculate the EF of Scotland's residents for *Scotland's Footprint* [7], the basic Stepwise methodology was extended and revised. Maintaining the Stepwise boundaries, several components were broken down into a greater level of detail. This primarily related to the Food and Materials & Waste components, but also addressed tourism. However, the most significant changes were in the Materials & Waste component.

In the basic Stepwise methodology, Materials & Waste is a general category and includes the resources not captured in other components, i.e. direct energy, food, personal transport, water and built land. This is mainly due to the complexity of trade flows and lack of suitable and reliable consumption data. These issues were addressed for *Scotland's Footprint* by using the Europe-wide trade data source, ProdCom (Products of the European Community) [13]. This data relates to the value and volume of UK manufacturers' product sales, imports, exports, net balance (imports – exports) and net supply (apparent consumption) and covers approximately 4,800 products. However, products are not the only materials consumed, and to derive final consumption data, ProdCom data is combined with raw material data from a range of UK data sources [see 7 for further information].

Once consumption data is finalised, ecological footprint calculations are carried out for each consumption item. To derive an EF conversion factor for a material is more complex than other components, particularly where imports, exports and differing national production efficiencies are taken into account. Below is an example of how the EF of 'railway or tramway sleepers (cross-ties) of wood, not impregnated' is calculated. The equations below are used to calculate separate EFs for energy use and forest use, as well as considering where the wood was produced, imports and exports. When completed, the energy (1-3) and forest (4-6) equations are adjusted for apparent consumption separately (production + imports – exports). Finally the resulting energy and forest aspects are summed to produce a total EF for 'railway or tramway sleepers (cross-ties) of wood, not impregnated' (SIC 20101010).

PRODUCTION ENERGY EQUATION:

$$((C*E*Nc)+(C*E*Wni*Wc))/WCA*CR*EQ \qquad (1)$$

IMPORT ENERGY EQUATION:

$$((C*E*Wc)+(C*E*Wni*Wc))/WCA*CR*EQ \qquad (2)$$

EXPORT ENERGY EQUATION:

$$((C*E*Nc)+(C*E*Wni*Wc))/WCA*CR*EQ \qquad (3)$$

Where:
C = Consumption (tonnes)
E = Embodied energy (GJ/tonne)
Nc = National carbon content of energy (tC/GJ)
Wni = World nuclear intensity (nuclear GJ/GJ)
Wc = World carbon content of energy (tC/GJ)
WCA = World average carbon absorption (tC/ha/yr)
CR = Carbon responsibility (69%)
EQ = Equivalence factor (1.35 for energy land)

FOREST PRODUCTION EQUATION:

$$(C/Cv*EQ)/(NY*(NHLF/NNLF)/YF)/Rr \qquad (4)$$

FOREST IMPORT EQUATION:

$$(C/Cv*EQ)/(WY*(WHLF/WNLF)) \qquad (5)$$

FOREST EXPORT EQUATION:

$$C*((EFi+EFp)/(I+P)) \qquad (6)$$

Where:
C = Consumption (tonnes)
Cv = Conversion (tonnes to WRME tonnes underbark)
Efi = EF of imports
EFp = EF of production
EQ = Equivalence factor (1.35 for forest)
I = Import (tonnes)
NY = National yield (m3 underbark/ha/yr)
NHLF = National harvest loss factor (%)
NNLF = National natural loss factor (%)
P = Production (tonnes)
Rr = Roundwood ratio (converts tonnes underbark to m3 underbark)
WY = World yield (m3 underbark/ha/yr)
WHLF = World harvest loss factor (%)
WNLF = World natural loss factor (%)
YF = Yield factor (2.63 for UK forest)

Once EF calculations are completed for all products and materials, it is then possible to provide the Materials & Waste component with sub-component data. Improving the resolution of the analysis in this manner enables a more informative analysis. For example, the material or product type with the largest and smallest EFs can be identified.

Waste is not specifically identified within the Materials & Waste component, as all products and materials, which eventually become waste, are accounted when they are first consumed. However, due to the common focus on waste at the local level, it is usually the focus for scenarios when addressing the materials & waste component [7].

THE ECOLOGICAL FOOTPRINT: SCOTLAND'S FOOTPRINT

To illustrate the Stepwise methodology and the value of EF as a sustainability indicator, the results from *Scotland's Footprint* are summarised below. Table 3 shows the headline analysis.

Component	Ecological footprint (gha)	Per capita ecological footprint (gha)	% of total ecological footprint
Total ecological footprint	**27,082,915**	**5.35**	**100%**
Of which…			
Direct Energy*	4,902,562	0.97	18%
Materials & Waste	10,164,881	2.01	38%
Food	7,834,524	1.55	29%
Personal Transport	3,038,280	0.60	11%
Water	98,767	0.02	0.4%
Built Land	1,043,902	0.21	4%

* Includes domestic and services energy.

Note: Totals may differ due to rounding.

Table 3: The EF of Scotland's residents, by component, in 2001

The EF can also be analysed at a component level. As well as the identification of big hitters, consumption of resources can be compared with the resource efficiency of supply. For example, Figure 1 shows the consumption of domestic electricity and gas against their EFs. This highlights the lower carbon content (per GWh) of gas.

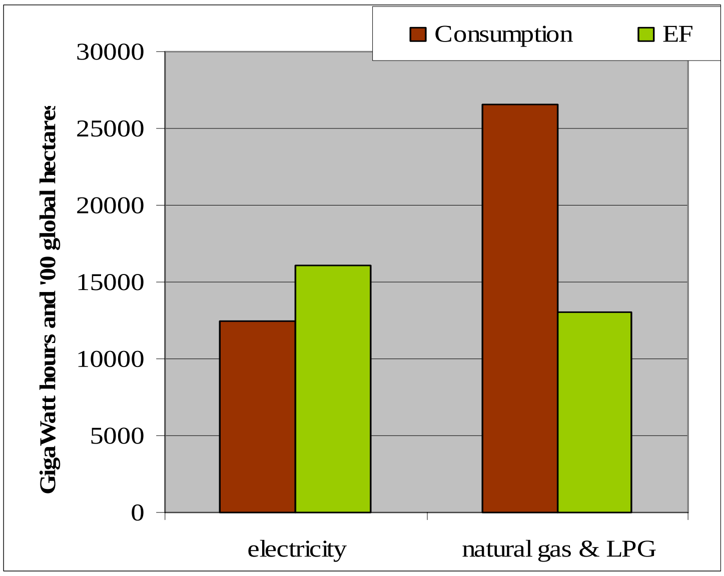

Figure 1: Consumption and EF of domestic electricity and gas by Scotland's residents, in 2001

Comparisons of regional consumption and EFs can also be shown for components. For example, Figure 2 shows a comparison of food consumption and EF between various UK regions, using the UK average as a baseline. This shows that the different EFs are more than a question of eating less.

Another strength of the EF is the ability for comparisons. One example is the comparison between the EF and biocapacity. For example, when comparing Scotland residents' EF with the global average biocapacity per capita (known as an earthshare) a measure of environmental sustainability can be made, for example:

"If everyone on the planet consumed as much as an average Scotland resident, an additional 1.8 Earths would be required to sustainably support global resource consumption"

Additionally, comparisons with other EFs can be made at various levels. For example, Figure 3 compares the EF of UK regions and cities with Africa and Figure 4 compares the EF of Scotland's residents with the world. These comparisons are possible due to the use of standard EF methodologies, i.e. the *NFA* and Stepwise.

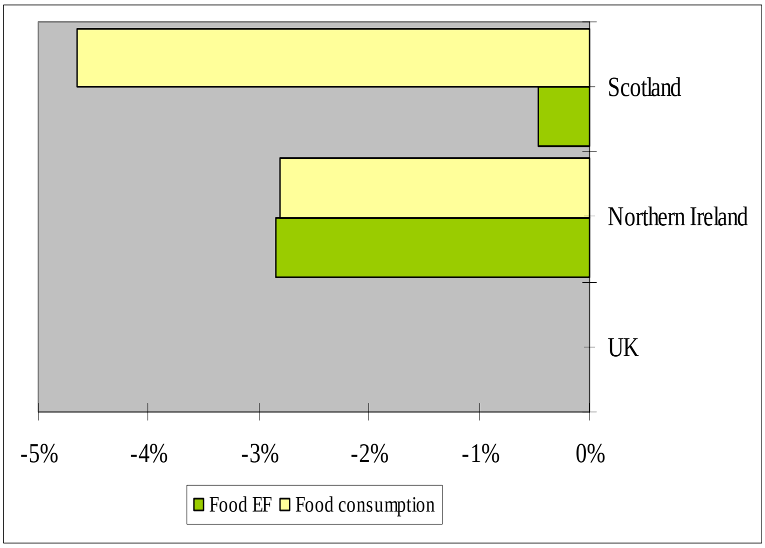

Figure 2: Comparing food consumption and EF per capita using the UK average as a baseline, in 2001

When a baseline EF has been measured, attention can turn towards the past and/or the future. For example, when a standard method is used, trends can be constructed by comparing the EFs of previous years. This was done for the Living Planet Report 2002 [5], when the world population's total EF was plotted from 1961-1999.

Looking to the future, scenarios can be constructed which show snap-shots of what the future EF might be if certain actions or policies were carried out. As an example, Figure 5 shows the EF of various waste management targets adopted in Scotland, along with actions required to achieve environmental sustainability for household

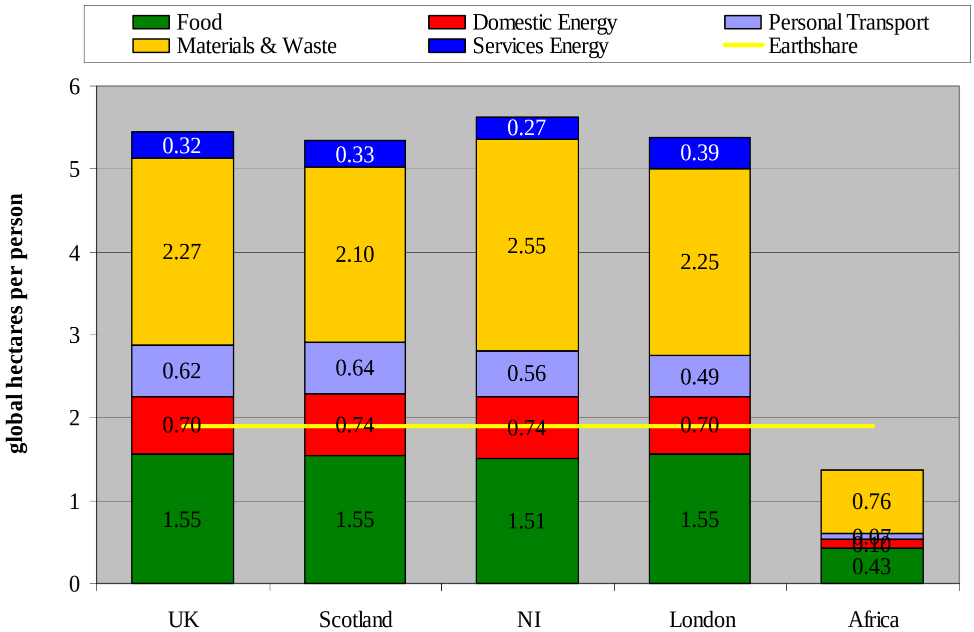

Figure 3: A comparison between the resident EF of Scotland, the UK, Northern Ireland, London and Africa

waste. The '*one planet lifestyle*' line indicates the across-the-board reduction of 64% needed to achieve the earthshare. In practice, much as with any 'expenditure budget', it may be feasible, or indeed desirable and necessary to achieve varying reductions for each of the components.

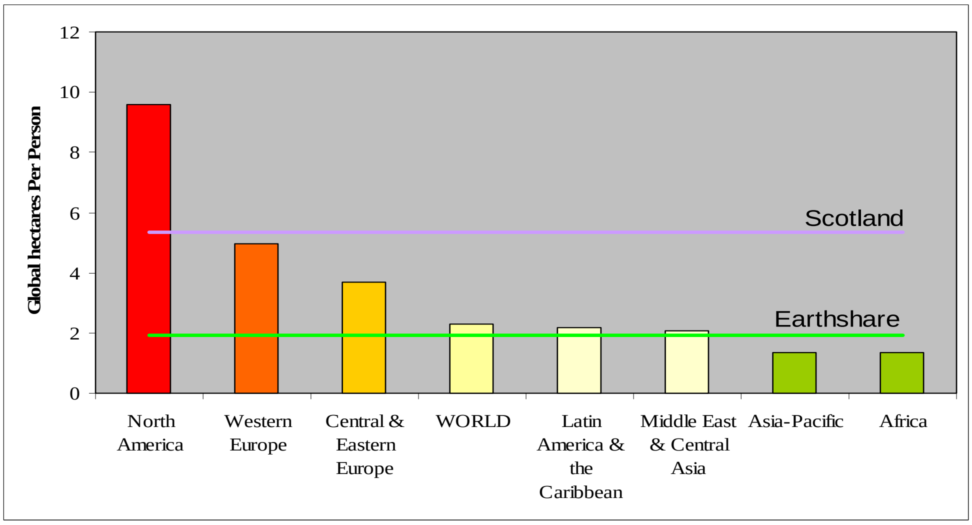

Figure 4: A comparison between the EF of Scotland's residents and the rest of the World, including the world average resident

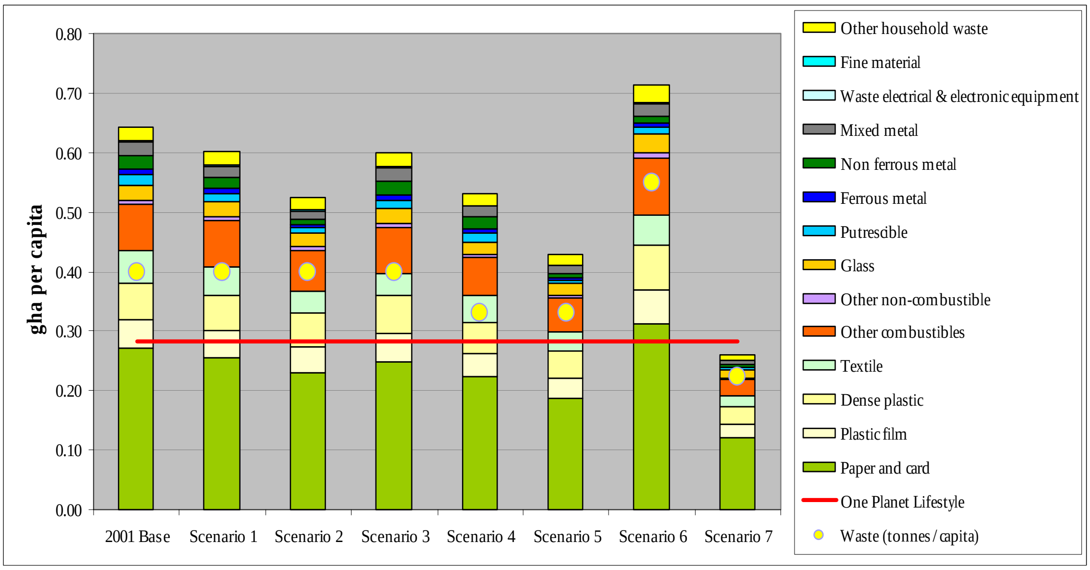

Figure 5: The EF of the Scotland household waste base case and 7 scenarios [7]

Such scenarios as those shown in Figure 5 can reveal various findings. For example, in Figure 5, scenario 2 represents all waste management targets being met, but with no waste minimisation, whereas scenario 4 only assumes waste minimisation and no change in waste management. This clearly highlights the benefits of waste reduction. Full details of Figure 5 and all the other results can be found in the *Scotland's Footprint* report, which is free to download from http://www.scotlands-footprint.com/.

CONCLUSION

The EF enables communities and governments across the world to indicate their environmental sustainability by comparing the supply and demand of natural resources. Standardising the methodology used to calculate national and sub-national EFs will also allow valid comparisons of performance and monitoring of progress towards environmental sustainability (a one planet lifestyle for everyone). Stepwise is the first 'component' EF methodology to achieve such a standard in a robust and transparent manner, and is aligned with the European Common Indicators Programme and the *National Footprint Accounts*. *Scotland's Footprint* results have been summarised to show the value of Stepwise and the EF and give examples of how generated results can be used. With the creation of the Global Footprint Network [3], the standardisation of applying EF, at various levels, is set to become universal.

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