open
one planet
economy network

OPEN: EU Scenario Quantification Report:

Scenarios for a One Planet Economy

OPEN:EU

OPEN:EU Scenario Quantification Report:Scenarios for a One Planet Economy

PROJECT REPORT

AUGUST 2011

Katy Roelich (Stockholm Environment Institute)

Anne Owen (Stockholm Environment Institute)

Chris West (Stockholm Environment Institute)

David Moore (Global Footprint Network)

7th Framework Programme for Research and Technological Development
The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement N° 227065. The contents of this report are the sole responsibility of the One Planet Economy Network and can in no way be taken to reflect the views of the European Union.

Acknowledgements

We are grateful to the participants from the September 2010 Scenarios workshop that helped us to develop the scenario frameworks and narratives describing four different pathways to reaching a One Planet Economy in Europe by 2050. We are also grateful to the Ecologic Institute and the Sustainable Europe Research Institute for their work on the development of qualitative scenario narratives that form the foundation of this report.

Contents

Abbreviations

CF	Carbon Footprint
EE-MRIO	Environmentlly Extended Multi-regional input-output model
EC	European Commission
EF	Ecological Footprint
EU	European Union
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GFN	Global Footprint Network
GHG	Greenhouse Gases
GMO	Genetically Modified Organism
IPCC	Intergovernmental Panel on Climate Change
NFA	National Footprint Accounts
OECD	Organisation for Economic Cooperation and Development
OPEN:EU	One Planet Economy Network: Europe
UNEP	United Nations Environment Programme
WF	Water Footprint
WFN	Water Footprint Network
WWF	World Wide Fund For Nature

Executive Summary

This report presents the methodology and results of scenario quantification undertaken in parallel to the development of One Planet Economy Network scenario narratives (the OPEN:EU scenarios). The OPEN:EU scenarios were developed to demonstrate how we might move towards a One Planet Economy over the next four decades. The ultimate aim of the scenarios is to provide better policy support and to stimulate engagement in the process of change.

The scenario narratives on which this quantification are based were co-developed with expert stakeholders during a workshop and through subsequent iteration of storylines. The narratives examine a range of futures and the policy interventions that would be relevant to move towards a One Planet Economy in each of these futures. The scenarios intended to achieve a One Planet Economy. The four scenarios created were:

- Scenario 1 – Clever and caring – a future with a quality driven mindset towards development with dynamic technological innovation.
- Scenario 2 – Fast forward - a future with a quantity driven mindset towards development with dynamic technological innovation.
- Scenario 3 – Breaking point - a future with a quantity driven mindset towards development with technological stagnation.
- Scenario 4 – Slow motion - a future with a quality driven mindset towards development with technological stagnation.

Quantification of the impacts of consumption and production on the Footprint Family of Indicators in the future scenarios was carried out using the Environmentally Extended Multi Region Input-Output model (EE-MRIO) and EUREAPA tool developed during the OPEN:EU project. It is recognised that the economy-environment model that forms the foundation of EUREAPA has limitations when applied to scenarios, such as static production structure. However, it is considered that it presents an excellent opportunity to consider both supply side (resource efficiency) and demand side (resource sufficiency) intervention within the same modelling framework.

The changes in EUREAPA variables as a result of the narrative and policy interventions were derived by assessing the strength of cumulative policy impact on each variable for each indicator and determining a viable range of changes to each variable. The two assessments were combined to quantify a change to each variable, indicator and scenario.

Changes were applied to each of the EU-27 countries in EUREAPA to quantify the footprint per capita in 2020 and 2050, which are the years considered most frequently in policy and scenario literature. There is insufficient data to estimate year-on-year changes over the scenario time period and interpolation between the time point selected would represent an over-interpretation of uncertain results. Therefore, results have been quanitfied as a snapshot of the footprint in these years, rather than as a time series. It is recognised that this approach has a number of limitations, and potential improvements.

Scenarios results show significant reductions of up to 79.8, 69.4, and 51.5 per cent reductions (by 2050), for carbon, Ecological and water per capita footprints respectively. Illustrative environmental limits[1] were determined for carbon and Ecological Footprints to

---

[1] Illustrative environmetnal limits refers to the relevant environmental limits or 'benchmarks' against which the scenario results were compared in order to determine their effectiveness at achieving a One Planet Economy.

assess the effectiveness of scenarios at achieving a One Planet Economy. It is not currently possible to define an environmental limit for the water footprint, since this is highly dependent on the local availability and quality of water

No scenario was able to achieve sufficient reduction to achieve footprints within the illustrative environmental limits. This was particularly significant in quantity driven scenarios (scenarios 2 and 3) where only a minimal reduction in expenditure was allowed by the assumptions governing the scenarios. The impact embedded in goods that are consumed and the intermediate trade that support housing, transport and services cannot be reduced sufficiently by 2050. This challenges the fundamental assumption that we can continue to grow our economies and individual expenditure while reducing environmental impacts to within the limits of a One Planet Economy.

Decarbonisation of the electricity supply is an essential part of the policy mix but alone is not enough to achieve the impact reductions required for a One Planet Economy. Some sectors of industry require energy in a form that cannot be supplied by electricity (i.e. direct use of fuels) limiting complete decarbonisation by 2050. Decarbonisation of the electricity supply must be supported by complementary measures to improve production efficiency and promote resource sufficiency (consumption).

Overall, policy that targets production has a more significant effect when indicators are linked to the energy system (and carbon). However, policy to encourage resource sufficiency will be an essential part of any future policy mix that aims to achieve reductions of the scale required and to address impacts that are not related to energy supply and carbon.

It is important to consider the impact embedded in goods and services that are imported to the EU. An early iteration of the quantification exercise, where no changes were made to efficiency outside the EU, resulted in footprints that were twice as large as the final results. Only when the efficiency of industry and energy outside the EU was improved did the footprint approach the environmental limits in any of the scenarios.

The scenarios show a much less dramatic reduction in the water footprint than in the carbon and Ecological Footprints. This is partly attributable to the limited scope of policy in this area and the limitations in reducing water consumption in the agricultural sectors, where the majority of the water footprint occurs.

Several limitations of the modeling approach used in this study could be improved through further research.

- Within the constraints of the current modeling framework and policy mix no scenario achieved a one planet economy by 2050. Further investigation into the causes of the residual footprint and measures that might reduce this to below the one planet limit.
- Further work is needed to explore water footprint reduction and to compare results to a measure of water scarcity. This may require more geographically disaggregated results and detailed data on future water scarcity.
- The static nature of the EE-MRIO model and the exclusion of capital expenditure from calculations of the footprint could be addressed through amending the production structure and modeling the effect of the additional capital expenditure required to deliver the policy interventions considered in this study. This might allow modeling of a time series to show the cumulative footprint over time.

- Consideration of the differential responses to policy across the EU27 would provide a more accurate reflection of the potential reductions in idivudual countries.
- The response of individual actors (particularly citizens) could be more accurately modeled.
- The effect of the scenarios on non-quantitative indicators could be quantified.

However, the scenario quatification exercise has provided some useful insight into the relative effect of policy interventions on the Footprint Family of indicators and provided a basis for meaningful discussion on progress towards a One Planet Economy.

1. Introduction

The OPEN: EU project[2] centres on the goal of transitioning Europe to a One Planet Economy[3] by 2050 and understanding what it would take to make this transformation. The first aim is to support policy makers in their thinking about what kind of effort is necessary and how effective different policy settings are likely to be in transforming Europe into a One Planet Economy. The second aim is to assist policy makers by providing them with a practical tool for illustrating the magnitude of the impact of different policy decisions on delivering on this goal.

To this end, the project team has brought together a set of 3 environmental footprint indicators (Ecological, Carbon, and Water) to measure the EU's progress toward the goal of a One Planet Economy. The Footprint Family of indicators - when integrated and combined with the EUREAPA tool - allows policy makers to measure the impact of consumption and production on key environmental pressures and to compare this to relevant thresholds or benchmarks.

The problem to be addressed is quite clear: if everybody in the world had a lifestyle similar to that of an EU citizen 2.5 planets would be required to sustain the environmental impact associated with the consumption and production of goods and services (Moore et al., 2011). Understanding how to tackle this problem is less clear, however. The policy interventions needed over the next 40 years to arrive at a One Planet Economy depend on multiple interrelated factors influencing consumption and production patterns in Europe. For example, where consumption is concerned, there is considerable uncertainty and complexity due to the nexus between economic development, human behaviour, technology and governance – all of these factors influence consumption patterns, which are also strongly linked to cultural and social identity.

The OPEN:EU project addressed these uncertainties through the development and analysis of different hypothetical but plausible future scenarios, characterising the future and its shifting variables through structured, but imaginative thinking. The OPEN:EU scenarios were created based on a participatory process involving stakeholders of the OPEN:EU project in September 2010. The scenario development process and the resulting scenarios and policy measures required to achieve a One Planet Economy are described in Gardner et al., 2011.

This report explains the process of quantifying the impact of the lifestyles described in these scenarios on the Footprint Family and presents the results of this quantification. Section 2 of this report describes the approach to scenario quantification. Section 3 describes the quantification methodology in more detail, including the principal assumptions that were made during quantification. Section 4 presents the results of quantification and section 5 compares these results to relevant environmental limits. Section 6 summarises insights drawn from the wuantification results and section 7 identifies limitations of the exercise and touches on issues that could be addressed in further research.

---

[2] http://www.oneplaneteconomynetwork.org/

[3] A One Planet Economy is an economy that respects all environmental limits and is socially and financially sustainable, enabling people and nature to thrive.

2. Scenario Quantification Approach

2.1 What are scenarios?

Scenarios can be defined as ‘plausible and often simplified descriptions of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces and relationships’ (Millennium Ecosystem Assessment, 2005). Thus, a scenario consists of the end-state (an image of the future or a vision) and of the path by which this is reached.

Storylines are the qualitative and descriptive component of such scenarios. They reflect the assumptions about drivers of change and describe the consequences or outcomes of a scenario. Scenario storylines aim to open our eyes to different ways of perceiving the world. It is important to note that scenarios are not meant to be predictions and that ‘they do not seek truth’ (Rounsevell and Metzger, 2010). They ‘explore the possible, not just the probable, and challenge their users to think beyond conventional wisdom’ (UNEP, IISD, 2007).

2.2 The OPEN:EU Scenarios

The aim of the One Planet Economy Network is to help transform Europe to a One Planet Economy by 2050. Given the long timeframe, the wide range of factors and the complex interrelationships between these factors, often involving feedback loops, the degree of uncertainty in any attempt to predict future outcomes would be very high.

To try to address this uncertainty and complexity scenarios have been developed that describe different ways in which the European Union might move towards One Planet Economy in 2050. The ultimate aim of the scenarios is to provide better policy support and to stimulate engagement in the process of change.

The OPEN:EU scenario framework was co-developed with expert stakeholders at a two-day workshop in Brussels in September 2010 using a well-established methodology produced by UNEP (UNEP, IISD, 2007). Following the workshop, stakeholders were consulted on a number of occasions as the framework was used to create qualitative scenarios and feedback was integrated as narratives developed.

The storylines developed as a result of this exercise serve to test the robustness of currently discussed policy approaches in meeting the One Planet Economy goal. By examining a range of plausible futures involving different assumptions, it is possible to begin to identify which kinds of policy interventions are most likely help achieve a One Planet Economy in the EU (Gardner et al., 2011). A brief summary of the scenarios is provided in Table 1 below.

This report describes how these storylines and associated policy analysis was used to quantify the impact of consumption and production of EU citizens in each of the four scenarios.

Table 1: **Summary of scenario characteristics (Gardner et al. 2011)**

	Clever and Caring (Scenario 1)	Fast Forward (Scenario 2)	Breaking Point (Scenario 3)	Slow Motion (Scenario 4)
Key assumptions	• Quality-driven mindset towards development • Dynamic technological innovation	• Quantity-driven mindset towards development • Dynamic technological innovation	• Quantity-driven mindset towards development • Technological stagnation	• Quality-driven mindset towards development • Technological stagnation
Key features	• People have voluntarily become more socially responsible and environmentally aware in their lifestyles and act less selfishly • Planned obsolescence of technology has been replaced by planned durability and reuse • Energy infrastructure is largely decentralised and flexible. • Competition has largely been replaced by cooperation	• Aggressive policies to stay within the boundaries of a OPE despite ongoing growth focus and to deal with global distributional issues • Global production zoning • Mix of regulation, taxation and innovation delivered massive efficiency gains, decarbonisation of power sector and shift to renewable electricity use for transport and heating	• European society is strongly divided, a large gap exists between rich and poor • The costs of new technologies did not fall rapidly enough and new technologies were not deployed quickly enough to avoid energy shortages • Scarcity of resources leads to global resource conflicts • Shareholder profits dominate over stakeholder values • Nearly every aspect of life is eventually regulated by the state to address spiralling consumption	• Prices are strong drivers towards resource efficiency and sufficiency • Collaboration and knowledge sharing are more important forces than competition in business • Dynamic social innovation increases human capabilities, welfare and environmental sustainability • Culture of repair and reuse, reinforcing a strong circular economy • Holistic approach to education: self-awareness, environmental awareness, spiritual and community values play a key part

	Clever and Caring (Scenario 1)	Fast Forward (Scenario 2)	Breaking Point (Scenario 3)	Slow Motion (Scenario 4)
Main policy interventions	• **Economy**: Environmental pricing reform • **Labour**: guaranteed minimum "living" wage; mandated phased-in limits on maximum paid weekly working hours • **Resources**: footprint tax, advanced labelling, household waste measures • **Energy**: advanced fossil-fuel power plants are successfully deployed along with a large-scale roll-out of renewables; strong carbon pricing and energy efficiency schemes • **Trade**: Extra-EU investment in low carbon development; global benefit-maximising trade policies aimed at high impact trade sectors; GMO food import ban	• **Economy**: focus on spurring strong competition for eco-innovation • **Labour**: guaranteed minimum "living" wage across the EU • **Resources**: Personal resource and emissions allowances , footprint tax • **Energy**: Carbon pricing, smart metering, ban on conventional vehicles • **Trade**: preferential trade with countries with the lowest footprint intensity	• **Economy**: shift in the tax burden from labour to resources • **Welfare**: strong measures to control population growth • **Labour**: Progressive income taxation to curtail excessive demand and provide funds for R&D investment. • **Resources**: Personal resource and emissions allowances , footprint tax, meat tax; strong measures to foster "reduce, reuse, recycle" • **Energy**: highest carbon prices of all scenarios and aggressive "at the pump" petrol taxes • **Trade**: strong restrictions	• **Economy**: transition to a beyond-GDP model, helped by OPE indicators • **Labour**: guaranteed minimum "living" wage; limits on weekly working hours; 2 years of community service • **Resources**: footprint tax, advanced labelling, household waste measures • **Energy**: carbon tax replaces cap and trade; phase out of inefficient appliances • **Agriculture**: Measures to achieve 95% organic farming / permaculture production • **Trade**: fuel import policy, GMO food import ban

2.3 Approaches to Scenario Quantification

There are two broad approaches to scenario quantification: optimisation and simulation. (Dawkins and Wood, 2011). Simulation models are used to explore alternative pathways through changing the model input variables. Optimisation models instead compute a pathway based on a specified solution e.g. least cost subject to a variety of (emissions) constraints (Scott, 2010) (see Nakata, Silva, and Rodionov, 2010; Loulou et al., 2004). The approach used in this report is economic simulation using the EUREAPA tool. The EUREAPA tool is an open system; it is not a predictive or dynamic model. Each variable change must be made explicitly (i.e. by the user, not computationally). The method is based on the assumptions made, rather than a pre-determined set of economic rules.

The assumptions can be determined by either historical trend analysis, expert opinion or a combination of both. Historical trend analysis is useful for understanding how and to what extent relationships between variables have evolved in the past, which may provide an indication of boundaries to changes in the future. However, historical trends will not cover any fundamental shifts in lifestyle or production efficiency. Consequently, the approach used in this report is based on expert opinion to determine the scale of change to consumption and production that might be brought about in each scenario. The strength of this approach is a more insightful and realistic projection, but it is more data and labour intensive than a trend projection.

2.4 EUREAPA and Scenario Quantification

Quantification of the impacts of consumption and production on the Footprint Family of indicators in the future scenarios was carried out using the Environmentally Extended Multi Region Input-Output model (EE-MRIO) and EUREAPA tool developed during the OPEN:EU project.

The EE-MRIO brings together the three footprint indicators under an input-output ecological-economic modelling system (Weinzettel et al., 2011) to allow direct comparison of the indicators. Environmentally Extended Input-output (EEIO) models have been used for decades for the analysis of environmental impacts caused by human activities in complex economic systems (Minx et al., 2009). The strength of this approach is that it addresses both production and consumption processes. The method allocates environmental pressures associated with production and the supply chain processes to groups of final products by means of inter-industry economic transactions. Utilizing a multi-regional framework significantly adds to the depth of the analysis, tracking international trade and the environmental repercussions (Wiedmann, Lenzen et al., 2007; Peters and Hertwich, 2009).

At its greatest level of detail, the EE-MRIO model can take the emissions associated with 57 consumption sectors for 113 regions, and show the contribution that each sector in every other country makes towards this impact. For example, the quantity of emissions from 'bovine cattle production' in Brazil that contributes to the UK's consumption of 'leather products' can be determined[4]. The EUREAPA tool is a usable, task orientated interface that presents this vast amount of data in an understandable way for a policy

---

[4] Because some of the leather consumed in the UK is made from the skins of cows farmed in Brazil.

audience, helping them to draw out interesting findings to allow users to make informed policy decisions.

EUREAPA also allows users to create scenarios to explore how potential changes in consumption and production might affect the Footprint Family in the future. The scenario variables within EUREAPA describe future environmental change based on the understanding that environmental impact is driven by population, affluence and technology (Ehrlich and Holdren, 1971). As a result, the variables in EUREAPA affect both the direct intensity of production and the household demand for products and are described in more detail in Table 2 below.

Table 2: **EUREAPA Scenario Variables**

Variable	**Description**
Population	Users can change the number of residents in their country of interest.
Spending (affluence – total output)	Users can increase or decrease overall spending.
Basket of spend (affluence composition of household consumption)	Users can move expenditure between consumption baskets and alter the proportion of spend on products within baskets to model the effect of changing expenditure patterns.
Production efficiency (technology)	Users can change the efficiency of each of the 57 production sectors in a particular country. This can be done separately for each footprint indicator.
Energy mix (technology)	Users can change the source of energy used by each sector, including the electricity sector to model changes in the national energy mix.

Scenarios can be created for any year or series of years that the user specifies to provide maximum flexibility. Users can make changes to consumption and production in their own country or in any of the 45 regions[5] presented in the tool. The tool does not allow users to make changes to the Input-Output model at the heart of EUREAPA, which restricts their ability to make changes to the structure of the economy or to intermediate transactions between industrial structures. This is a significant limitation of the GTAP database upon which the EE-MRIO is based. Changes to the production strucutre of any country would require a complete re-balancing of the entire matrix, which is extremely time consuming and inaccurate. This is a particular limitation for long-term scenarios, where fundamental changes to the economy are required.

The tool's scenario function has been designed to allow users to change variables directly and independently. Users must identify evidence to support any changes they make; the model does not contain any assumptions or forecasts of potential future changes. When using tools to create scenarios and support decision making it is important that the connection between model variables and impact indicators is transparent (Boulanger and

---

[5] Part of the process of simplifying the model for a policy audience involved aggregating to 45 regions from 113. Th EUREAPA tool is designed for assessing issues concerning the EU; a selection of other countries has been included for comparison. The 45 regions include the EU-27 countries, 16 countries (including major trading partners of the EU-27), a regain containing the remaining annex B countries and a region containing non-annex B countries.

Bréchet, 2005). This reduces uncertainty about a model's quantities, structure and its pertinence, improving confidence in the tool's outputs. It also encourages a more interdisciplinary approach to scenario development allowing a number of different stakeholders to contribute to changes made to model variables.

3. Determining Changes to Scenario Variables

Section 2 described the approach to scenario quantification using the EUREAPA tool. This provides a great deal of flexibility in describing changes to production and consumption in the future. However, this flexibility also presents a challenge; how to quantify the potential change to the efficiency and energy mix of 57 industrial sectors and the patterns of consumption in 45 world regions over the next 40 years in each of the scenarios?

It is not possible to predict the effect of the individual policy interventions, described in the Scenario narrative report (Garner et al. 2011), on all variables with any certainty. Nor is the combined effect of all policy additive – the interventions do not operate independently. Therefore, an approach to quantification is required that assesses the likely influence of the combination of all interventions on EUREAPA variables.

The approach developed for this project involved assessing the strength of cumulative policy impact on each variable for each indicator and determining a viable range of changes to each variable. The approach to estimating the cumulative policy effect is described in section 3.1 below. The approach to quantifying a viable range of changes to each variable (described as rules) is described in sections 3.2 to 3.4 below. The two assessments were combined to quantify a change to each variable, indicator and scenario.

Changes were applied to quantify the footprint of an EU-27 citizen in 2020 and 2050, which are the years considered most frequently in policy and scenario literature. There is insufficient data to estimate year-on-year changes over the scenario time period and interpolation between the time point selected would represent an over-interpretation of uncertain results. Therefore, results have been quantified as a snapshot of the footprint in these years, rather than as a time series. The limitations and potential improvements to this approach are discussed in section 7.

The proportional changes generated using this approach were applied to all countries in the EU-27. It is recognized that some countries have more potential for efficiency improvements and energy system transformation; however, it was beyond the scope of this report to apply differential changes based on this potential.

3.1 Policy Impact

The relative likelihood that each policy intervention described in the scenario narrative report (Gardner et al, 2011) would effect a change on a EUREAPA variable was assessed using a combination of literature review and qualitative assessment (see bibliography). The potential scale of change (the rank, r) was described using a scale from 0 (no impact) to 4 (the most significant impact possible). This was assessed for each industrial sector's efficiency and energy mix and for each consumption category, as well as for policies which decrease overall spend. The impact was assessed for the effect of policy on countries within the EU-27.

The cumulative impact was assessed using a system to weight and combine the effect of the interventions. Each policy impact, *P*, was given a weighted rank of:

$$P = \begin{cases} 0, & r = 0 \\ a^{r-1}/a^3, & r > 0 \end{cases}$$

where *a* = an arbitrarily chosen weight and *r* = rank.

The weighting is arbitrary and was selected to balance the desired differences in policy strength with an ability to produce full efficiency gains. For example, if a large weight was chosen then minor policies would have little impact on efficiency, and if a small weight chosen then just a few minor policies can lead to big efficiency gains. A weighting of 4 was selected to achieve this balance.

For each EUREAPA variable a maximum, C_{max}, and minimum, C_{min}, possible change was defined. The adjusted variable change (i.e. gain in efficiency/change in energy mix/reduction in consumption/reduction in spend), C_{adj}, was calculated to lie within these minimum and maximum values, by adjusting the policy impacts, *P*, summed across all policies:

$$C_{adj} = \begin{cases} C_{max} - ((1 - \Sigma P) \times (C_{max} - C_{min})), & \Sigma P \leq 1 \\ C_{max}, & \Sigma P > 1 \end{cases}$$

Worked Example:
Table 3 shows an example of a collection of policy interventions with a weight of 4, i.e. *a* = 4.

Table 3: **Example policy impact weighting**

Policy	**A**	**B**	**C**	**D**	**E**	**F**
Rank (r)	0	2	3	4	1	1
Policy Impact (*P*)	0	1/16	1/4	1	1/64	1/64

These weighted ranks are summed to establish the cumulative policy impact;

$$\Sigma P = 1.34375$$

In this case the combined policy impact is greater than 1 so the full variable change, C_{max}, is achieved. This will always be the case if a scenario contains a policy with a rank of 4.

An example without the policy ranking of 4, is presented in Table 4 below.

Table 4: **Example policy impact weighting without maximum impact**

Policy	**A**	**B**	**C**	**D**	**E**
Rank (r)	0	2	3	1	1
Policy Impact (*P*)	0	1/16	1/4	1/64	1/64

The cumulative policy impact in this example is calculated as:

$$\Sigma P = 0.375$$

In this case the combined policy impact is less than 1 and the full variable change is not achieved. In this case the adjusted policy impact will fall within the range of C_{min} and C_{max}.

The system described is biased by the presence of more policies. If there are lots of policies there is more chance of maximum efficiency gains. However, it is considered that this is a fair reflection of reality – the greater the policy focus, the greater potential for change.

3.2 Production Rules

The viable range of improvement in production efficiency in the EU-27 countries was identified through a process of literature review, drawing on information about current improvement trends and maxmimum efficiency gains for industrial and service sectors. Efficiency improvements by 2020 and 2050 were identified. The principal sources of information for each indicator are described below. Equivalent rates of efficiency and energy mix changes were applied to non-EU countries to reflect technology transfer.

3.2.1 CARBON FOOTPRINT

In the EUREAPA tool, improvements in process carbon intensities result from reducing energy consumption per unit of product or service delivered and from changing the mix of energy used in each sector. Changes to the mix of energy are dealt with in section 3.3. This section deals with reducing the energy required in production of goods and services – industry becoming more energy efficient.

Two principal sources of data were used to identify the range of energy saving that could occur:

Europe’s Share of the Climate Challenge (Heaps et al., 2009) examines how Europe can rapidly reduce emissions of greenhouse gases. It presents a sector-by-sector mitigation scenario for all EU-27 countries that can achieve emissions reductions of 40 per cent in 2020 and 90 per cent in 2050 relative to 1990 levels. These cuts are achieved by a combination of radical improvements in energy efficiency and accelerated changes in energy mix towards renewable energy. The report includes only efficiency measures that can be achieved with current technology or those that will be commercialised in 20-30 years.

Estimates for reduction in energy consumption in the mitigation scenario were used to generate the maximum effiicency gains for the Carbon Footprint. Where sectoral detail was less disaggregated than in EUREAPA, the efficiency gain for the aggregated group was applied to all EUREAPA sectors in that group.

2050 Pathway Analysis (DECC, 2010) was produced to support the 2050 Pathway Calculator. It includes evidence supporting the range of changes that tool users can apply to the UK energy system and production processes. It is recognised that this analysis was specific to the United Kingdom but the evidence upon which it was based was collected from sources outside the UK. Results corresponded quite closely to those found in Heaps et al. (2009) so it considered to be relevant to the whole of the EU.

For each sector of the economy, four trajectories have been developed, ranging from little or no effort to reduce emissions or save energy (level 1) to extremely ambitious changes that push towards the physical or technical limits of what can be achieved (level 4). The report was prepared with the input of industry and energy system experts and has been subject to public scrutiny, through calls for evidence.

Estimates for the maximum reduction in energy consumption in key economic sectors were compared to the figures provided by *Europe's Share of the Climate Challenge* and the more conservative estimate was selected. The *Pathways Analysis* report gave lower trajectory estimates of change, which were used as the lower range of efficiency improvements.

Efficiency improvements within the air and water transport sectors were taken from **Energy Technology Perspectives (IEA, 2010)** as no estimates were provided in either of the other two publications.

3.2.2 ECOLOGICAL FOOTPRINT

Three principal sources of data were used to estimate the mid-point value of potential changes in crop, livestock, forest, and fish yields. The low-end of the potential range was assumed to be half of the mid-point, and the high-end was assumed to be the larger of either 1.5 times the mid-point yield or 1 percent total increase.

Agricultural Outlook (OECD-FAO, 2010) is an annual report prepared by the Organization for Economic Cooperation and Development (OECD) and the Food and Agriculture Organization (FAO). It gives projections for the following decade (in this case, between 2010 and 2020) in terms of supply and demand of crop and livestock products, but does not list yields. In order to estimate yield changes, it is assumed that the physical area under production remains constant. Additionally, the annual change in production over the coming decades is assumed to continue in a linear fashion until 2050.

ProdSTAT (FAO, 2011) is a database of production statistics compiled by the FAO. In this case, statistics on forest product production between 1990 and 2008 were extracted. In conjunction with **ResourceSTAT** (FAO, 2011), which provides forest area information, yearly yield data was derived. Log yield was plotted over time, and the linear trend in this (equating to an exponential increase in yield) was found and extrapolated between 2010 and 2050.

FishSTAT (FAO, 2011) is a database of fish capture statistics compiled by the FAO. The area of water under production was assumed to remain constant, so the linear trend in log fish production between 1990 and 2007 was taken to be the change in yields. Since fishery yields are projected to decline, the upper and lower bounds for fishery yield projections was assumed to be 10% higher and 10% lower than the mid-point projection over the entire projection period.

3.2.3 WATER FOOTPRINT

Two principal sources of data were used to identify the range of water reduction that could occur:

EU Water Saving Potential (Ecologic, 2007) was produced to support the European Commission in the preparation of a Communication on water scarcity and droughts. The study addresses the savings that can be achieved from technical measures by 2030. It concentrates on the four main water users: public water supply, agriculture, industry and tourism. It is based largely on literature review and synthesis of data from existing studies. Estimates of potential efficiency improvements were used to generate maximum efficiency gains in the water footprint. It was assumed that half of the reductions estimated in this report could be achieved by 2020 and no further reduction was achieved beyond 2030.

Charting our Water Future (2030 Water Resources Group, 2009) was produced to investigate how competing demands for scarce water resources could be met by 2030. The project was supported by an expert advisory group including industry, academia and civil society organisations. The report outlines measure to achieve demand-side reductions and the likely scale of reduction in water consumption. It was assumed that half of the reductions estimated in this report could be achieved by 2020 and no further reduction was achieved beyond 2030.

3.3 Energy Mix Rules

The current mix of energy sources used by industry, energy and service sectors varies dramatically across Europe, based on available resources (for exampe hydropower dominates electricity generation in Scandinavia) and political positions (for example nuclear power dominates electricity generation in France). The ultimate aspiration is to decarbonise the electricity system and move towards total electrification of industry. This would dramatically reduce the carbon emissions occuring in the EU and those embedded in goods and services imported from the EU. However, some sectors require the direct use of fuels for generating the heat required to carry out chemical transformations, therefore complete electrification may not be possible.

The viable range of future energy use mixes of each of the 57 production sectors was estimated by increasing renewable energy and electricity to the maximum feasible proportions in 2020 and 2050. The remaining energy requirement was then allocated across the remaining fuels according to current proportion (as a proportion of non-electricity energy in the current mix). This allowed us to model a sector and country specific mix, within the contraints of this project. It is recognised that there are more sophisticated and accurate approaches to modelling future energy systems. This time consuming work is beyond the scope of the curent project but could be explored in future scenario exercises.

The maximum feasible proportions of renewable energy and electricty were estimated based on evidence presented in **Europe's Share of the Climate Challenge** (described above) and **Energy Technology Perspectives** (IEA 2010).

Energy Technology Perspectives presents scenarios of the technology required to acheive emissions reductions sufficient to avoid exceeding atmospheric concentraitons of CO2 in excess of 450ppm. The scenario development process used assessment of costs and benefits to identify the least cost pathways for meeting the goals of emisions mitigation and energy security. Specifically, *"ETP 2010 examines the future fuel and technology options available for electricity generation and for the key end-use sectors of industry, buildings and transport"* (IEA, 2010).

Where sectoral detail was less disaggregated than in EUREAPA, the renewable energy and electricity proportions for the aggregated group was applied to all EUREAPA sectors in that group.

3.4 Consumption Rules

The EUREAPA tool allows users to make changes to both the total amount spent by an average citizen and the proportion of that expenditure spent on each of the 62 consumption categories[6].

3.4.1 TOTAL SPENDING

In scenarios 1 and 4, where there was a focus on quality of life over GDP growth, it was assumed that some reduction in expenditure could be allowed, since economic growth was not a central driver in the scenarios[7]. It was also assumed that the income inequality in these scenarios was dramatically reduced, further affecting the average expenditure.

The potential expenditure reduction per capita was estimated to be 43 percent based on calculations in Victor (2011) which presents a scenario for stable degrowth of the Canadian economy to a steady state 43 percent lower than the baseline value. It is recognised that more research is required to understand the implication of this assumption on the European economy. However, earlier iterations of the quantification, where lower rates of expenditure reduction were applied failed to achieve One Planet Economy benchmarks by over 35 per cent.

It was assumed that there would be no increase in expenditure in scenarios 2 and 3, despite the pressure to grow GDP. It was assumed that GDP growth was achieved through government expenditure and that citizens didn't buy more goods and services, but spent more money on them. Therefore, only very minor reductions to expenditure were allowed in scenario 2 with a slightly higher reduction in scenario 3, where there was a greater focus on consumption because of a poorer contribution from technology.

---

[6] Note additional consumption categories have been produced by the disaggregation of production sectors where consumption from these sectors is for substantially different purposes. For example, coal and petroleum have been split into household coal and petroleum and transport petroleum.

[7] It was assumed that this could be achieved without negatively affecting employment or welfare, based on scenarios developed by Peter Victor (Victor, 2011)

3.4.2 EXPENDITURE PROPORTIONS

The viable range of reductions in expenditure on the 62 categories of goods and services in the EU-27 countries was identified through a process of literature review, drawing on information about the effect of current policy and the potential reductions that could be achieved in the future. Reductions by 2020 and 2050 were identified. The expenditure total was balanced to ensure that the total proportions summed to 100 by increasing the proportion of spend on the recreational service sectors. The principal sources of information that support these assumptions are described below.

Meeting the UK Climate Challenge: the contribution of Resource Efficiency (WRAP, 2009) explores the contribution that resource efficiency (production) and sufficiency (consumption) can make to acheiving greenhouse gas emissions reductions. It developed the following scenarios of how consumption from industrial and service sectors might change up to 2050):

- Quick win – the changes that might occur relatively easily at no additional cost and with current technology.
- Best practice – the changes that might occur if best available technology and consumption behaviour was adopted by 2050.
- Beyond best practice – the maximum potential change assuming that all major barriers could be overcome.

The ’quick win’ and ’beyond best practice’ scenarios were used to identify the lower and higher ranges of consumption changes possible by 2020 and 2050. It is recognised that these scenarios were developed for expenditure in the UK, and as a result may not be relevant for all EU-27 countries.

Where scenarios did not cover sectors of interest, further detail was obtained from Heaps et al. (2009), which includes data on housing and transport.

3.5 Population

Population of the EU-27 was amended to take into account Eurostat’s population projections (Eurostat, 2011). Population projections are what-if scenarios that aim to provide information about the likely future size of the population. Eurostat's population projections is one of several possible population change scenarios based on assumptions for fertility, mortality and migration (UN 2011). The method used for population projections is the "cohort-component" method (Eurostat 2011).

4. Quantification Results

The results of scenario quantification on the magnitude of each footprint in the EU-27 are presented below. Results are presented as the mean per capita footprint for the EU-27 to allow more effective comparison. Interim results for 2020 are presented to show the progression in footprint reductions.

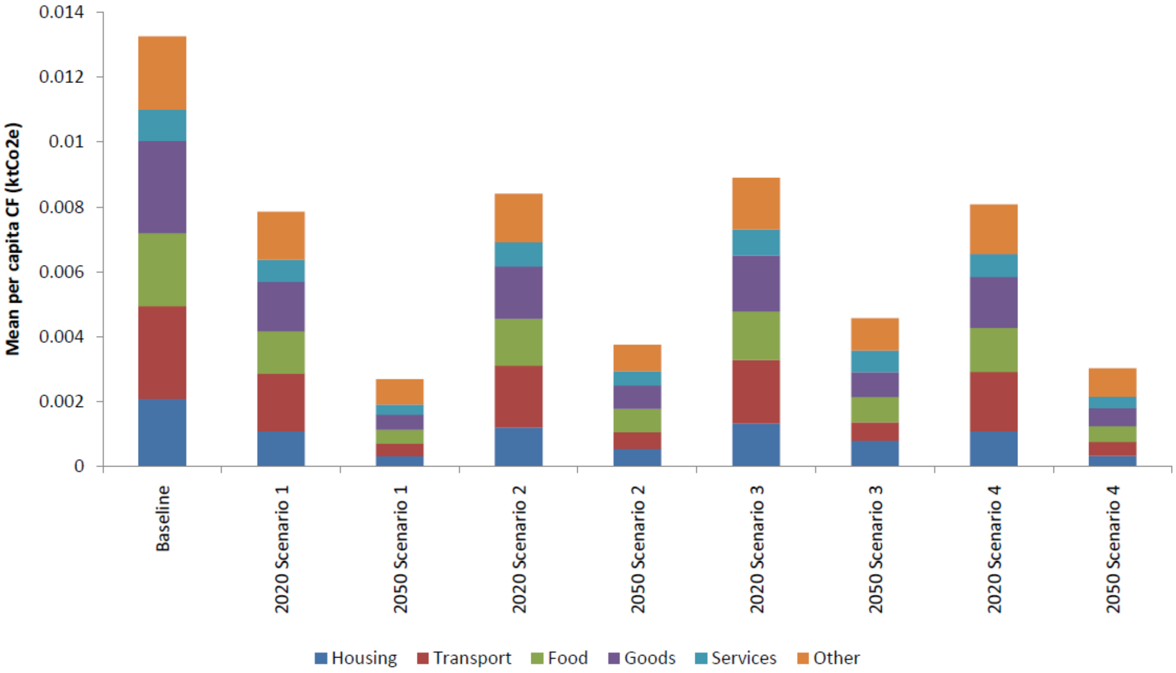
4.1 Carbon Footprint

Scenario results have been presented for the carbon footprint of an average EU citizen in 2020 and 2050 and are compared to the Baseline (2004) in Figure 1 below.

Figure 1 shows that there has been a significant reduction in the carbon footprint by 2050 across all scenarios with a maximum reduction from the baseline of 79.8 per cent by 2050 in scenario 1. This is as a result of its combination of dramatic efficiency improvements and reductions in consumption in this scenario. A less significant reduction of 65.5 per cent by 2050 was shown in scenario 3, where a slower rate of production efficiency improvements have been compounded by pressure for economic growth, reducing the effectiveness of consumption policy.

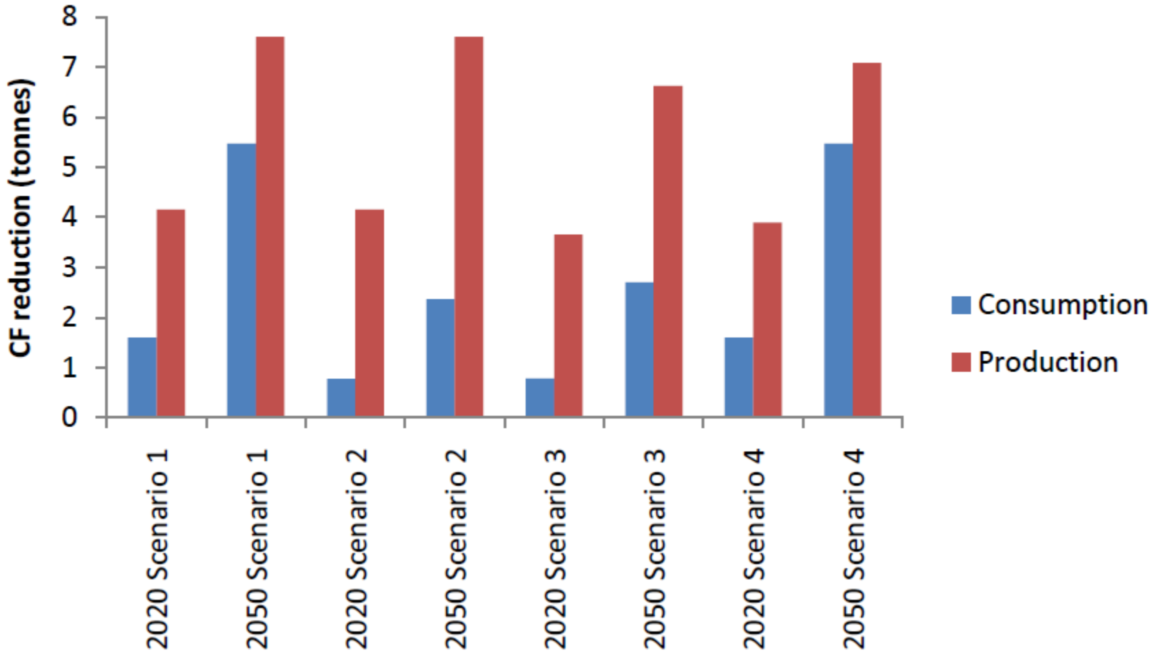
There is a significant reduction in the footprint from housing and transport in all scenarios as a result of decarbonisation of the electricity sector and rapid conversion to electric vehicles (between 3.58 and 4.24 tonnes). Reduction in the impact of goods and services are much greater in scenarios 1 and 4, where reductions in overall expenditure have been implemented. There has been a limited reduction from ‘other’ expenditure categories (predominantly construction and government’s expenditure) because of the limited opportunity for efficiency improvement and reduction in spend in these categories.

Figure 1: **Scenario results - Mean Carbon Footprint per capita of EU 27**



In order to demonstrate the relative effect of production-side (resource efficiency) and consumption-side (resource sufficiency) policy, the relative reductions as a result of the measures outlined in the scenarios is shown in Figure 2.

Figure 2: **Relative contribution of resource efficiency and resource sufficiency policy to per capita carbon footprint reductions.**



The results indicate that, for the carbon footprint, the improvements in energy efficiency and reduction in carbon intensity of energy contribute most significantly to reductions. However, in those scenarios where consumption is addressed in detail, this policy makes a significant contribution to carbon footprint reductions. If applied in isolation, consumption policy would result in a 41.3 per cent reduction in carbon footprint in scenario 1 compared to a 57.3 per cent reduction for production policy[8]. It is interesting to note that the proportional contribution of consumption policy becomes more significant in 2050, which reflects the time lag associated with responses to consumption policy.

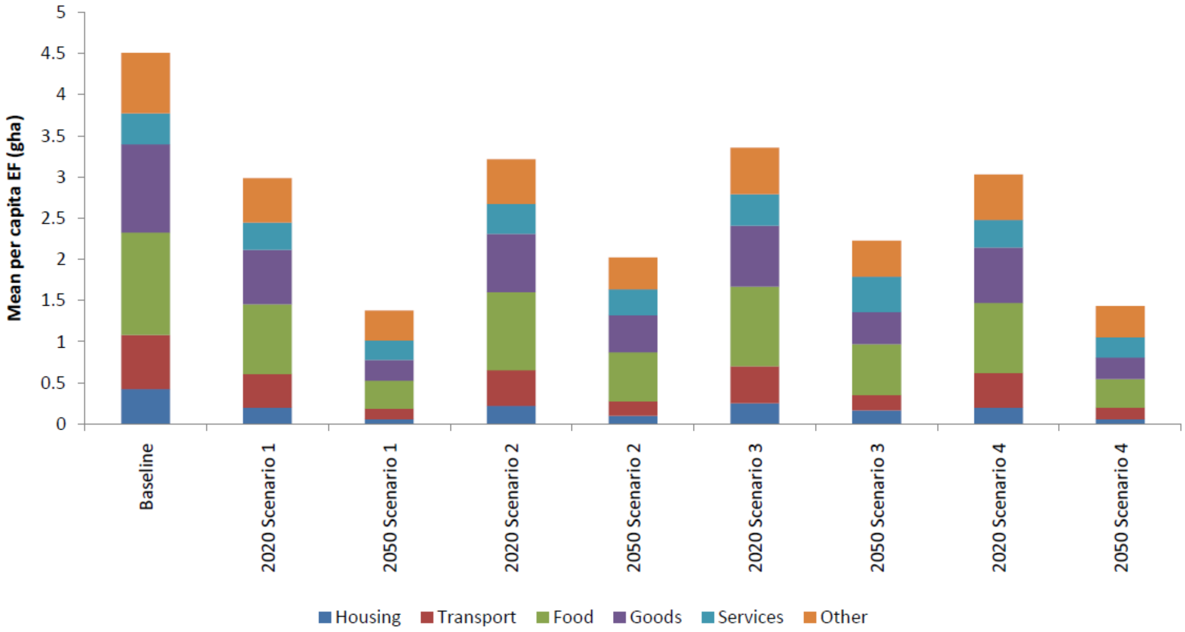
4.2 Ecological Footprint

Scenario results have been presented for the Ecological Footprint of an average EU citizen in 2020 and 2050 and are compared to the Baseline (2004) in Figure 3 below. Figure 3 shows a similar trend to carbon footprint results, with the exception of the service sector, where the reduction is less dramatic. This shows a reduction of 69.4 per cent in scenario 1 compared to 79.8 percent for the carbon footprint. This is because the service sector has a relatively high built-land footprint, which increases as money spent on goods is transferred to services. This is off-set to some extent by efficiency improvements (particularly energy efficiency and the associated carbon sequestration footprint) in these sectors.

---

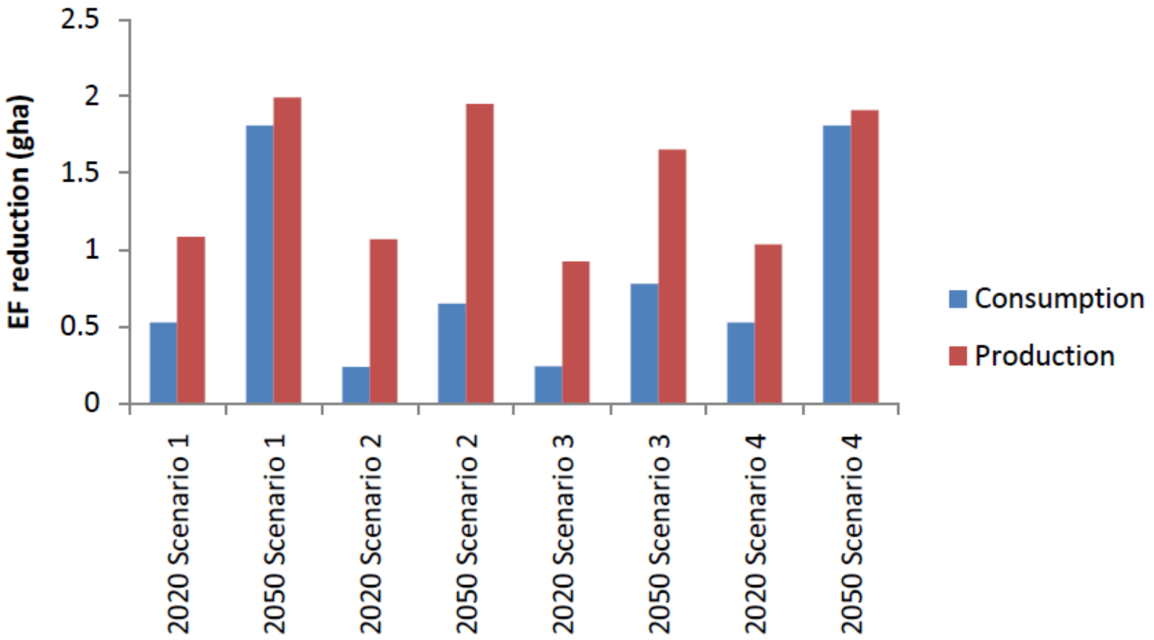
[8] Note that these reductions do not add up to the total reduction shown in Figure 1. They have been applied separately and are not additive. When applied in combination the total reduction is less because consumption reductions are applied to products that are produced more efficiently.

Figure 3: **Scenario results - Mean Ecological Footprint per capita of EU 27**



The relative reduction in Ecological Footprint as a result of production-side (resource efficiency) and consumption-side (resource sufficiency) policy in the scenarios is shown in Figure 4 below.

Figure 4: **Relative contribution of resource efficiency and resource sufficiency policy to per capita Ecological Footprint reductions.**



The results for Ecological Footprint show that resource efficiency and resource sufficiency policy has a similar effect in scenarios where changes to consumption are strongly promoted (scenarios 1 and 4). There is a more significant reduction from consumption policy in scenario 3 to off-set the limitations on production efficiency gains imposed by less rapid technological development.

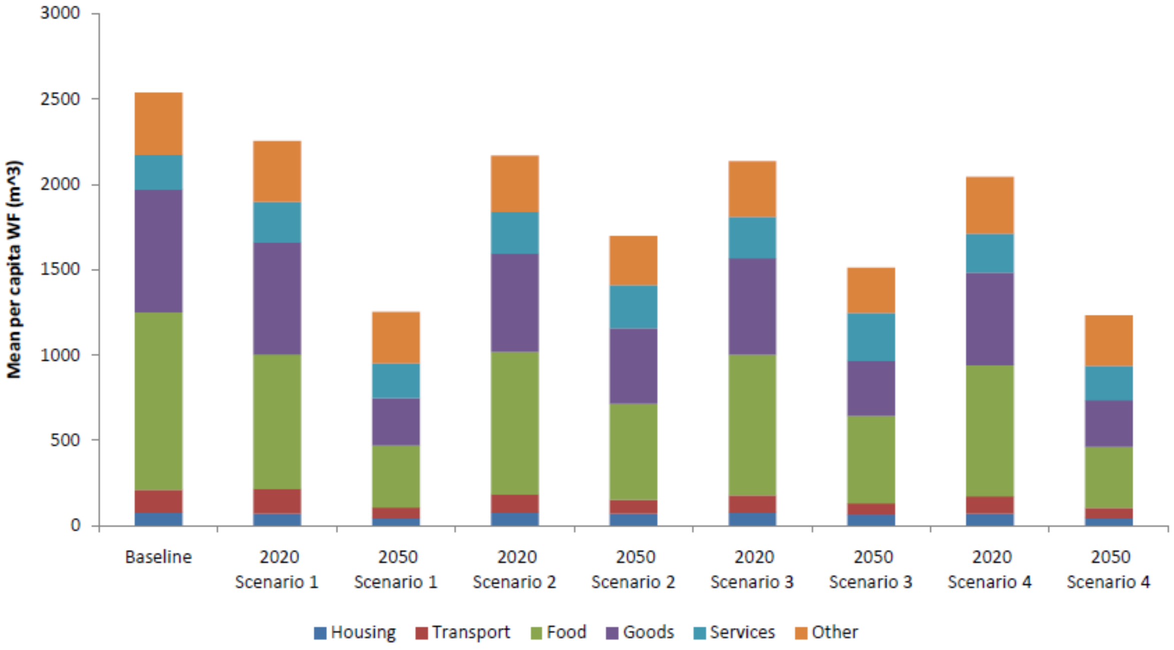
4.3 Water Footprint

Scenario results have been presented for the water footprint of an average EU citizen in 2020 and 2050 and are compared to the Baseline (2004) in Figure 5 below.

There is a much less dramatic reduction in the water footprint than in the other two footprint indicators (50.7 percent in Scenario 1 compared to 79.8 per cent for carbon and 69.4 per cent for Ecological Footprint). This can be attributed to the limited scope of policy in this area and the limitations in reducing water consumption in the agricultural sectors, where the majority of the water footprint occurs. The most significant reduction occurs in the food sector (678 m^3 in scenario 1), since this is where the majority of the water footprint occurs.

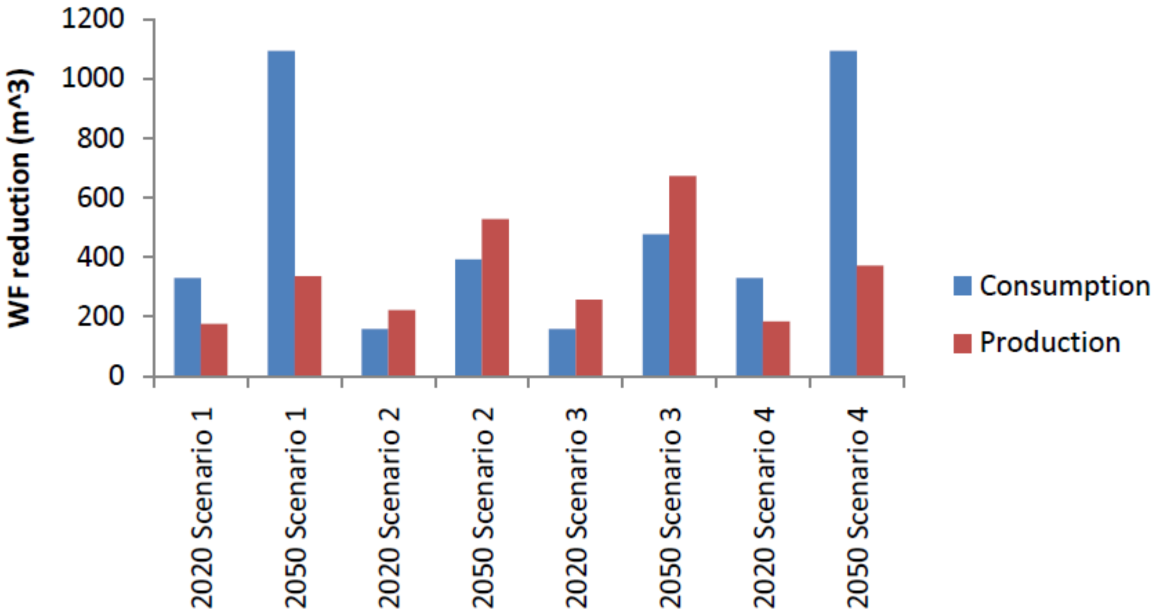
Water consumption in the service sector increases in all scenarios, as a result of transferring money spent on goods to services, without significant improvements in the water efficiency of these sectors. It is important to remember that the service sector consumes products from other sectors and will include water embedded in these products.

Figure 5: **Scenario results - Mean water footprint per capita of EU 27**



The relative reduction in water footprint as a result of production-side (resource efficiency) and consumption-side (resource sufficiency) policy in the scenarios is shown in Figure 6.

Figure 6: **Relative contribution of resource efficiency and resource sufficiency policy to water footprint reductions.**



The contribution of resource sufficiency is far greater than resource efficiency in relation to the water footprint. It is not possible to reduce water use completely during the production of goods (as you can if you decarbonise the energy used to produce goods). Therefore, avoiding consumption of goods with a high water impact (for example meat) reduces the embedded water to a far greater extent than producing the goods more efficiently.

5. Comparison to benchmarks

In order to assess the effectiveness of the scenarios at achieving a One Planet Economy, it is necessary to compare them to relevant environmental limits which, in part, define the One Planet Economy Concept. These ‘benchmarks’ and the reductions achieve in the scenarios in relation to these benchmarks are discussed below.

5.1 Carbon Footprint

A number of scientific assessments agree that a global temperature increase of less than two degrees Celsius over pre-industrial levels by the end of the century is essential in avoiding dangerous climate change (IPCC 2007). In becoming signatories to the ‘Copenhagen Accord’ many countries have accepted the significance of the two degrees Celsius limit and have ratified their commitment through placing it at the centre of their national climate change mitigation policies (UNEP 2010).Therefore, the environmental limit for the carbon footprint is greenhouse gas emissions equal to or below a level that would cause global emissions to result in an increase in global temperature of over two degrees Celsius.

5.1.1 ESTIMATING A CARBON FOOTPRINT BENCHMARK

There is a great deal of debate surrounding both the concentration of emissions in the atmosphere that would result in a rise in global temperature of more than two degress Celsius and the quantity of emissions that would result in this atmospheric concentration. This is particularly the case with non-CO_2 greenhouse gases as a result of uncertainty over their warming effect.

For the purposes of this scenario exercise the assumptions set out in the German Advisory Council on Global Change (WBGU, 2009) have been adopted. This report focuses on carbon dioxide alone and uses the simple link between carbon emissions and temperature rise to suggest a total cumulative emissions cap of 750GtCO_2 between 2010 and 2050 with a 67% probability of keeping within two degrees Celsius of warming.

It is not possible to simply divide this figure by the number of years over which the budget is allocated, since there will need to be a gradual reduction from current levels to future requirements. A high level of emissions in the near-term will mean that the average annual emissions will need to be reduced in the long-term. An alternative allocation methodology (Contraction and Convergence) would be to assume that emissions gradually contract to an appropriate point, without exceeding the cumulative emissions budget (GCI, 2005; Ecofys, 2009). When this approach is applied to a global cumulative budget of 750GtCO_2 this produces an annual budget in 2050 of 9.6GtCO_2. Assuming a population of 9.1 billion (UN, 2011) this equates to a limit of 1.05 tonnes CO_2 per capita. This will be used as the benchmark for the CO_2 portion of the carbon footprint in 2050. However, it is recognised that alternative budgets could be proposed and this figure is used for illustrative purposes only.

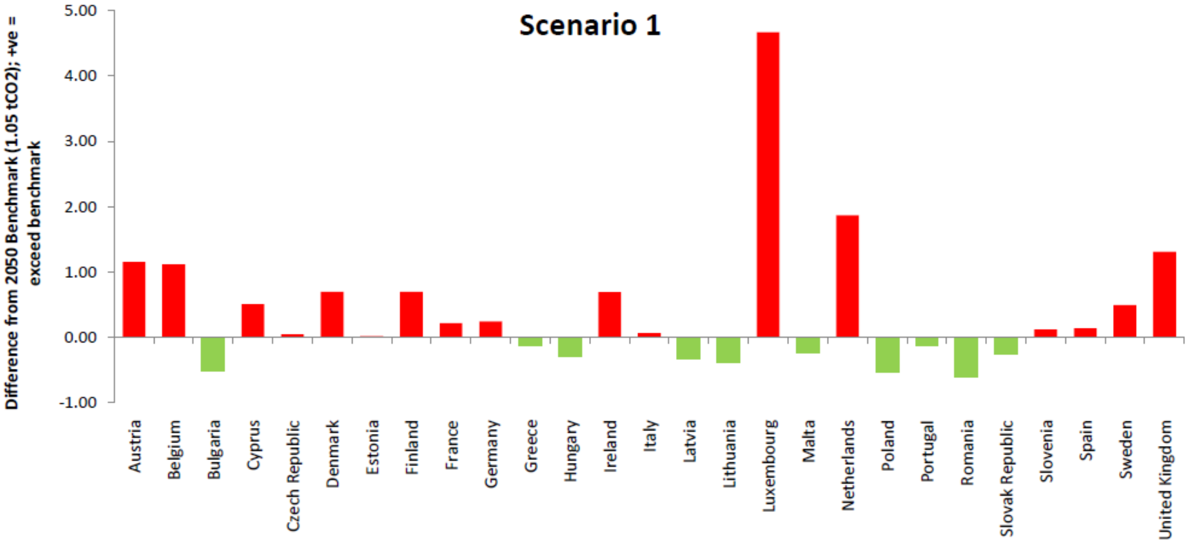
5.1.2 COMPARING THE RESULTS TO THE BENCHMARK

The carbon footprint of the EU-27 countries in scenario 1[9] is compared to the carbon footprint benchmark in Figure 7.

---

[9] This has been selected to show the most optimistic assessment of the potential footprint in 2050.

Figure 7: **Comparison of carbon footprint per capita (2050) to carbon footprint benchmark**



The figure above shows that in scenario 1, the majority of countries in the EU-27 still exceed the illustrative benchmark for carbon dioxide emissions and rely on a number of (principally eastern European) countries to reduce the average per capita footprint. The mean CO_2[10] footprint per capita for the EU-27 was 1.3 tonnes CO_2, which also exceeds this benchmark. The very high result presented by Luxembourg has little effect on this mean as a result of its low population. It is beyond the scope of this report to consider the distributional effect of the policy interventions but this should be considered in future development.

5.2 Ecological Footprint

5.2.1 ESTIMATING AN ECOLOGICAL FOOTPRINT BENCHMARK

The environmental limit for Ecological Footprint is the total amount of bioavailable land (biocapcacity) available for human appropriation. This is estimated annually by the Global Footprint Network in their National Footprint Accounts (NFA). Forecasts of biocapacity have been developed by the Global Footprint Network (Moore et al., 2011). This paper forecasts that total biocapacity would continue to rise up to 2030, peaking at 12.5 billion gha (1.5 gha per capita) largely due to the effects of increased availability of land suitable for agriculture due to the initial effects of climate change. It was considered that total biocapacity would then decrease as the climate warms further, reaching 11.7 billion gha in 2050 (1.3 gha per capita). This is used as the benchmark for the Ecological Footprint in 2050.

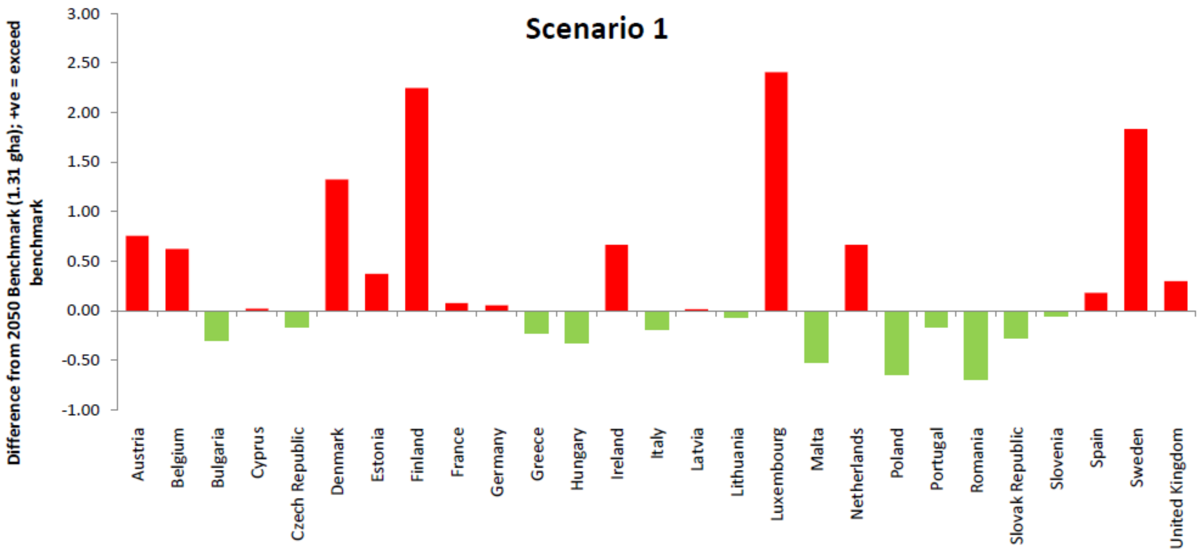
5.2.2 COMPARING THE RESULTS TO THE BENCHMARK

The Ecological Footprint of the EU-27 countries is compared to the Ecological Footprint benchmark in Figure 8.

---

[10] Note – benchmark is calculated for CO_2 only so only this portion of the carbon footprint is presented.

Figure 8: **Comparison of Ecological Footprint per capita (2050) to Ecological Footprint benchmark**



Over half of the EU-27 exceed the benchmark of 1.3gha per capita for the Ecological Footprint, although four countries only just exceeded this limit. The mean Ecological Footprint per capita for the EU-27 is 1.38 gha, which exceeds the benchmark, indicating that further reduction in these countries would be required. The highest exceedance was shown in Scandinavian countries and Luxembourg (3.72gha). Scandinavian countries had a very high forestry footprint relative to other countries, which contributed a significnat portion of the footprint in 2050. The forestry of government and capital expenditure is high in these countries, which was not addressed in the scenario changes. The lowest Ecological Footprint was in Romania, with a footprint of just 0.61 gha.

5.3 Water Footprint

It is not currently possible to define environmental limits for the water footprint, since this is highly dependent on the local availability and quality of water. No benchmark is proposed at this stage for the water footprint.

6. Discussion

The purpose of the scenario quantification exercise was not to forecast a detailed time-series of the footprint of EU citizens in the period up to 2050. Rather it was to explore the influence of different policy approaches on the EU's carbon, Ecological and water footprints and identify policy approaches that have the greatest influence. The results discussed in sections 4 and 5 have identified some significant outcomes.

It was not possible to achieve reductions to within illustrative environmental limits in scenarios 2 and 3 where only a minor reduction in expenditure was allowed as a result of the quantity driven development in these scenarios. The impact embedded in goods that are consumed and the intermediate trade that support housing, transport and services cannot be eliminated entirely by 2050. Further work may be required to investigate how the impact of government and capital expenditure could be reduced.

In contrast, in those scenarios where development was quality driven, and a more significant resuction in expenditure was allowed, the mean carbon and Ecological Footprint per capita in 2050 was much closer to achieving One Planet Economy limits. This challenges the fundamental assumption that it is possible to continue to grow our economies and individual expenditure while reducing environmental impacts to within limits used in this report.

Decarbonising of the electricity supply is an essential part of the policy mix but alone is not enough to achieve the impact reductions required. Some sectors of industry require energy in a form that cannot be supplied by electricity, limiting complete decarbonisation by 2050. Decarbonisation of the electricity supply must be supported by complementary measures to improve production efficiency and promote resource sufficiency (sustainable consumption). Aggressive resource sufficiency policies were required in scenario 3, where technological stagnation prevented the full efficiency gains and energy decarbonisation from being achieved.

Overall, policy that targets production has a more significant effect when indicators are linked to the energy system (and carbon). However, policy to encourage resource sufficiency will be an essential part of any future policy mix that aims to achieve reductions of the scale required and to address impacts that are not related to energy supply and carbon. Resource sufficiency policy was particularly important in reducing the water footprint.

It is important to consider the impact embedded in goods and services that are imported to the EU. An early iteration of the quantification exercise, where no changes were made to efficiency outside EU, resulted in footprints that were twice as big as the final results. Only when the efficiency of industry and energy outside the EU was improved did the footprint approach environmental limits in any of the scenarios.

The scenarios show a much less dramatic reduction in the water footprint than in the carbon and Ecological Footprints. This is partly attributable to the limited scope of policy in this area and the limitations in reducing water consumption in the agricultural sectors, where the majority of the water footprint occurs.

Further work is needed to explore water footprint reduction and to compare results to a measure of water scarcity. This may require more geographically disaggregated results and detailed data on future water scarcity.

7. Limitations and Further Research

The scenario quantification has attempted to quantify the footprint of citizens of the EU-27 in 2050 to determine the extent to which the scenarios developed in the project could move us towards a One Planet Economy. However, it is recognized that the approach used has many limitations and that further research would significantly improve the results.

The environment-economic model which forms the basis of the EUREAPA tool contains a static model of the economy. Its application in this project does not reflect changes in the production structure that might occur as a result of the scenarios and the resulting changes in supply chain impacts of goods and services. It is possible to make changes to the production structure of the model; however, this is a very time consuming process that would require detailed work to justify changes and re-balance the MRIO.

The scenario quantification did not consider the differential potential for improvement across the EU-27. As a result, there is a significant range of results across Member States (for example over 5 tonnes of difference between the highest and lowest carbon footprint). The impact of this distributional effect has not been considered in this report but the equality of this position should be considered in future work.

Scenarios 1 and 4 assume that there is a dramatic reduction in expenditure to enable reduction in footprints to approach environmental limits. There have been exploratory scenarios that demonstrate that this reduction is possible without destabilizing the economy (Victor, 2011) but this has not been widely tested. Contraction of economic growth in this way contradicts European economic policy and would need more detailed consideration.

The scenario quantification does not take into account the capital expenditure required to implement the policy described in the scenarios. As a result, the scenarios do not show the impact associated with the construction of this infrastructure renewal, which could reduce the effect of the policy outlined (particularly the production policy). The scenarios would benefit from more detailed consideration of the capital expenditure required to deliver a One Planet Economy.

The scenario results are presented as ‘snapshots’ of consumption at the scenario end-point (2050) and an interim point in time (2020). The results have not been presented as a time series, since it is beyond the scope of this report to calculate annual changes in footprints. It is not appropriate to interpolate between these snapshots, since this might misrepresent the confidence in the results. This means that it is not possible to calculate the cumulative footprint over the period of the scenarios and compare this to cumulative budgets, which are more appropriate for carbon footprints (Anderson and Bows, 2011, Bows and Barrett, 2010).

It was an aspiration of the project to explicitly recognize the actors within the scenario and their potential responses to the policy interventions in the scenario (Roelich et al., 2010). However, it became obvious that this was beyond the scope of this, already ambitious, project. The scenarios would benefit greatly from a more detailed consideration of the role of the actors within the scenario.

Another aspiration of the project was to consider non-quantitative indicators in the scenarios, such as material living standards, education and economy. These are described in the scenario narratives (Gardner et al., 2011) but have not been qualified in detail. A more detailed investigation of these indicators would be of great benefit to the scenarios.

8. References

2030 Water Resources Group (2009) Charting our water future.

Anderson K, Bows A. (2011) Beyond 'dangerous' climate change: emission scenarios for a new world*, Philos. Trans. R. Soc. Lond. A* **369**(1934):20-44

Boulanger, P-M. and Bréchet, T. (2005) Models for policy-making in sustainable development: the state of the art and perspectives for research *Ecological Economics,* **55**(3), 337-350

Bows, A and Barrett, J. (2010) Cumulative emissions scenarios using a consumption-based approach: a glimmer of hope? *Carbon Management* **1**(1) 161-175

Dawkins, E. and Wood, R. (2011) Integration of an energy and consumption scenario tools into a multi-regional environmentally extended input-output model to examine the greenhouse gas consequences of domestic climate change strategies. *Paper prepared for the 9th conference of the European Society for Ecological Economics*

Department of Energy and Climate Change (2010) 2050 Pathways Analysis

Ecologic (2007) EU Water Saving Potential

Ecofys (2009). Sharing the effort under a global carbon budget. A report for WWF International.

Ehrlich, P. and J. Holdren (1971). Impact of Population Growth. *Science* **171**: 1212.

Food and Agriculture Organisation of the United Nations (FAO) FAO Stat Website http://faostat.fao.org/site/377/DesktopDefault.aspx?PageID=377#ancor accessed June 2011

Eurostat (2011) Population projections. Accessed 22nd July 2011.

http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tps00002

Gardner, L., Omann, I., Polzin, C., Stoessel, S., Wentrup, K. (2011) OPEN:EU Scneario storyline report: Scenarios for a One Planet Economy in Europe.

GCI. (2005). GCI Briefing: Contraction & Convergence. Global Commons Institute.

GLA (2009)

Heaps et al (2010) Europe's Share of the Climate Challenge

IEA (2010) Energy Technology Perspectives

IPCC 2007 climate change: Synthesis report, Cambridge, UK and New York

Loulou, R., Goldstein, G. and Noble, K. (2004) Documentation for the MARKAL family of models, Report for the Energy Technology Systems Analysis Programme

Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being. Island Press, Washington D.C.

Minx, J. C., T. Wiedmann, R. Wood, G. P. Peters, M. Lenzen, A. Owen, K. Scott, J. Barrett, K. Hubacek, G. Baiocchi, A. Paul, E. Dawkins, J. Briggs, D. Guan, S. Suh and F. Ackerman (2009). Input-output analysis and carbon footprinting: An overview of applications. *Economic Systems Research* **21**(3): 187-216.

Moore, D., Galli, A., Cranston, G.R., Reed, A., (2011) in press. Projecting future human demand on the Earth's regenerative capacity. *Ecological Indicators*.

Nakata, T., Silva, D., and Rodionov, M. (2011). Application of energy system models

for designing a low-carbon society. *Progress in Energy and Combustion Science* **37**(4):462-502.

OECD-FAO (2010) Agricultural Outlook 2010. DOI: 10.1787/agr_outlook-2010-en

Peters, G. P. and E. G. Hertwich (2008). CO2 Embodied in International Trade with Implications for Global Climate Policy *Environmental Science & Technology* **42**(5): 1401-1407.

Roelich, K., et al (2010) Scenario Scoping Report

http://www.oneplaneteconomynetwork.org/resources/programme-documents/Scenario_Scoping_Report.pdf

Scott, K. (2010 unpublished). A critical analysis of methods for modelling the UK's low carbon transition. Internal Working Paper, University of Manchester.

UNEP, IISD, 2007 Internationals Institute for Sustainable Development, GEO Resource Book. A training manual on integrated environmental assessment and reporting. Training Module 6 - scenario development and analysis.

United Nations, Department of Economic and Social Affairs, Population Division (2011). World Population Prospects: The 2010 Revision, CD-ROM Edition.

UNEP (2010) The Emissions Gap Report: Are the Copenhagen Accord Pledges Sufficienct to Limit GLoabl Warming to 2oC or 1.5oC A preliminary Assessment, UNEP, Nairobi.

Victor, P.A., (2011). Growth, degrowth and climate change: A scenario analysis, *Ecological Economic In press*

WBGU German Advisory Council on Climate Change (2009). Solving the climate dilemma: The budget approach. Special report.

Weinzettel, J., Steen-Olsen, K., et al. (2011), Footprint Family Technical Report: Integration into MRIO model: http://www.oneplaneteconomynetwork.org/resources/programmedocuments/OPEN_EU_WP2_EC_Deliverable_Technical_Document.pdf

Wiedmann, T., M. Lenzen, K. Turner and J. Barrett (2007). Examining the Global Environmental Impact of Regional Consumption Activities - Part 2: Review of input-output models for the assessment of environmental impacts embodied in trade. *Ecological Economics* **61**(1): 15-26.

WRAP, 2009, Meeting the UK climate change challenge: The contribution of resource efficiency. WRAP Project EVA128. Report prepared by Stockholm Environment Institute and University of Durham Business School, WRAP.

9. Bibliography

Audsley, E., Brander, M., Chatterton, J., Murphy-Bokern, D., Webster, C., and Williams, A.

(2009). *How low can we go? An assessment of greenhouse gas emissions from the UK food*

system and the scope to reduce them by 2050. FCRN-WWF-UK

Bakkes J. A. et al. Background report to the OECD Environmental Outlook to 2030 Overviews, details, and methodology of model-based analysis

Ekins, P., Skea, J. and Winskel, M. (2010). Energy 2050: the transition to a secure low-carbon energy system for the UK. Earthscan.

European Environment Agency (2010) The European Environment - State of the Environment Report - Consumption and Environment

- Material resources and waste

- Water resources - quantity and flows

Feng, K.S. et al. (2010) Distributional effects of climate change taxation: the case of the UK. Environmental Science and Technology **44**(10) 3670-3676

International Energy Agency (2010) World Energy Outlook 2010.

International Energy Agency (2010) Energy Technology Perspectives 2010

International Energy Agency (2009) Energy Technology Transitions for Industry

IPCC (2000) Emissions Scenarios - Summary for Policymakers. Cambridge University Press, UK

Jackson, T., Prosperity without growth - economics for a finite planet. London Earthscan.

Mont, O., Tukker, A. Product-Service Systems: reviewing achievements and refining the research agenda (2006) *Journal of Cleaner Production* 14(17) 1451-1454

Mont, O., Dalhammar, C. Sustainable consumption: at the cross-road of environmental and consumer policies. *International Journal of Sustainable Development* **8**(4) 258-279

Oakdene Hollins (2011) Further Benefits of Business Resource Efficiency Final Report to the Department for Environment, Food and Rural Affairs SPMT09-070 (ev0441)

OECD (2010) Environmental and Eco-Innovation: Concepts, Evidence and Policies

Joint Meetings of Tax and Environment Experts.

Rauschmayer, F., Omann, I., Fruhmann, J., Bohunovsky, L. (2008) What about needs? Re-conceptualising Sustainable Development. SERI Working Paper No 8

Ravetz, J. (2010) Pathways towards a One Planet Economy. Main report to WWF.

Scott, K. A literature review on sustainable lifestyles and recommendations for further research. An SEI project report for the Swedish Environment Ministry as a contribution to the Task Force on Sustainable Lifestyles.

Shove, E. and Walker, G. (2010) Governing transitions in the sustainability of everyday life. *Research Policy* **39** 471-476

Skinner I, van Essen H, Smokers R and Hill N (2010) *Towards the decarbonisation of EU's transport sector by 2050* Final report produced under the contract ENV.C.3/SER/2008/0053 between European Commission Directorate-General Environment and AEA Technology plc; see www.eutransportghg2050.eu

Sorrell, S. (2007) The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency A report produced by the Sussex Energy Group for the Technology and Policy Assessment function of the UK Energy Research Centre.

Tukker, A., Cohen, M. J., Hubacek, K., Mont, O. (2010) The Impacts of Household Consumption and Options for Change. *Journal of Industrial Ecology* **14**(1) 13-30

Tukker, A et al (2008) Sustainable Consumption Policies Effectiveness Evaluation Final Report Draft. A Scope Project Report.

Tukker, A. et al (2008) Fostering change to sustainable consumption and production: an evidence based view. *Journal of Cleaner Priduction* **16**(11) 1218-1225

Tukker, A., Butter, M. (2007) Governance of sustainable transitions: about the 4(0) ways to change the world. *Journal of Cleaner Production* **15**(1) 94-103

UNEP (2011) Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication

UNEP (2011) Vision for change - Recommendations for effective policies on sustainable lifestyles.

UNEP (2011) Decoupling: natural resource use and environmental impact from economic growth.

UK Energy Research Centre (2009) ROADMAP

COOPERATION

7th Framework Programme for Research and Technological Development.
The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement N° 227065.

Project Partners

eco logic

Global Footprint Network
Advancing the Science of Sustainability

Institute for European Environmental Policy

SEI STOCKHOLM ENVIRONMENT INSTITUTE

SERI

NTNU
Norwegian University of Science and Technology

UNIVERSITY OF TWENTE.

WWF

open
one planet
economy network

One Planet Economy Network
C/o WWF-UK, Panda House
Weyside Park, Catteshall Lane
Godalming, Surrey GU7 1XR, UK

Tel: +44 (0)14 83 41 24 98
Email: info@oneplaneteconomynetwork.org
Web: oneplaneteconomynetwork.org