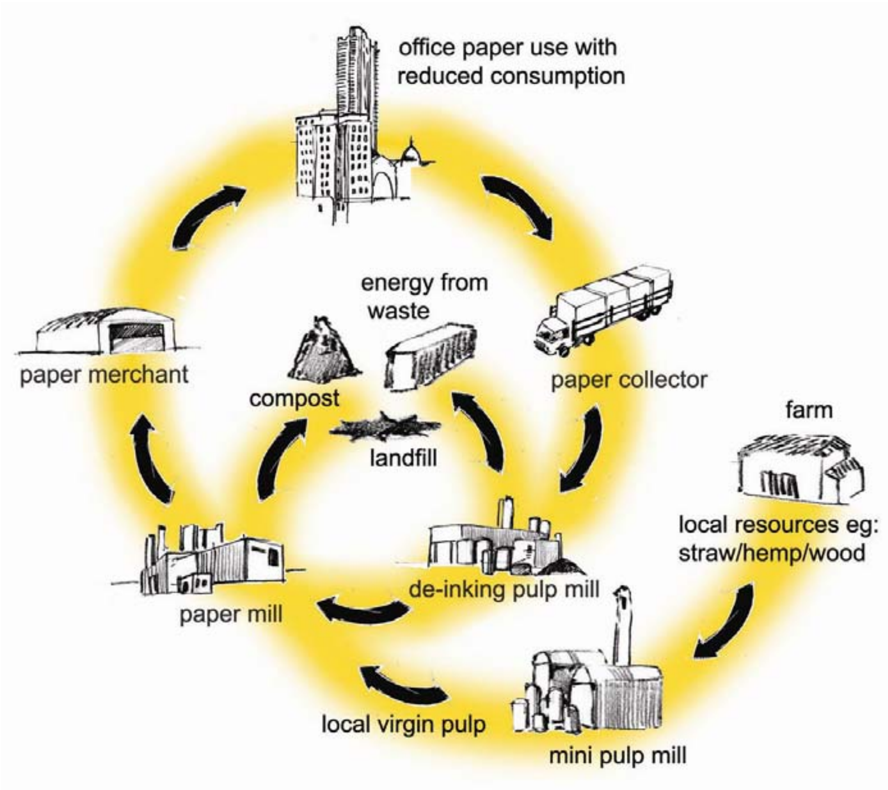
Get your own back – the local office paper recycle and buy back loop

Summary of a Life Cycle Assessment and Ecological Footprint Analysis and comparison of the local loop with imported virgin and recycled paper



BioRegional Development Group
BedZED Centre, 24, Helios Road,
Wallington, Surrey SM6 7BZ
www.bioregional.com

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Introduction and Summary

Paper purchasers have to consider many criteria when buying office and printing paper, sustainability being one of them. This report aims to give the paper purchaser more information to help them make the right choices and also aims to influence the debate about sustainable paper production.

This short report summarises the findings of a Life Cycle Assessment[1] and an Ecological Footprint [2] analysis of the local office paper recycle and buy back system promoted by BioRegional and compares it to the impact of imported virgin paper and imported recycled paper. The full reports are available from www.bioregional.com.

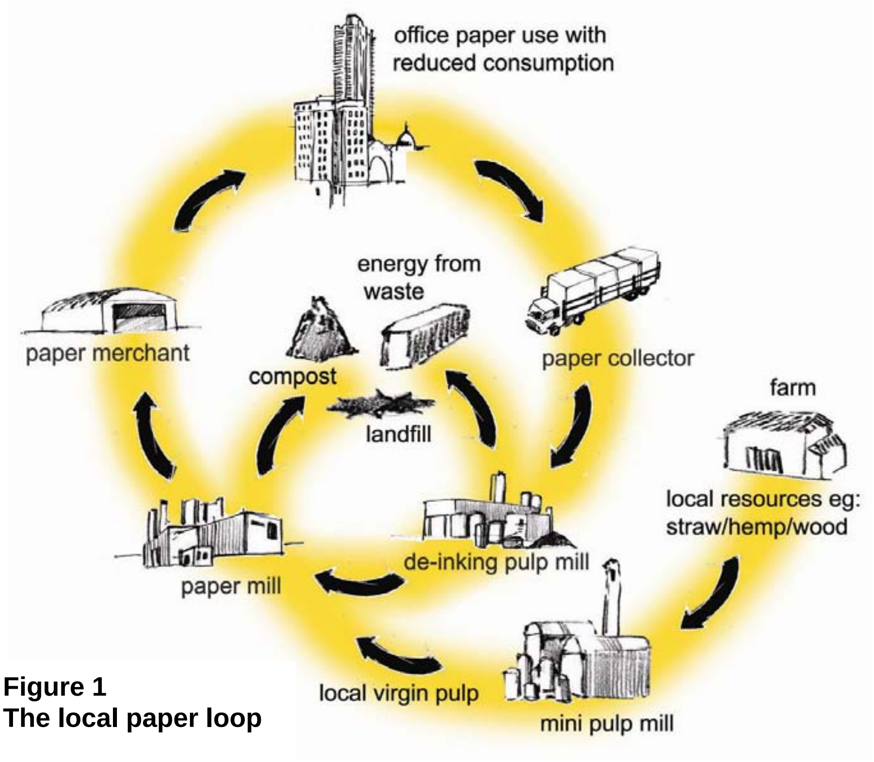

Figure 1
The local paper loop

Why a local recycle and buy-back loop?

BioRegional Development Group are an entrepreneurial environmental charity based in south London who work to establish solutions for sustainability in the areas of eco-housing and sustainable lifestyles, paper, textiles and forestry.

BioRegional's unique approach is to promote local or "bioregional" production to make more of things we need locally where possible, especially using waste or other locally available sustainable materials to reduce our overall ecological footprint, reduce transport and lorries on our roads and create sustainable, diverse local economies and jobs.

Since 1999 BioRegional have enrolled over 1,000 organisations in London and the south east into a local paper loop where organisations recycle their office paper to the local recycling mill in Kent, operated by m-real, and buy back the paper produced, branded as EVOLVE, closing the loop on their paper use (Figure 1). Participating organisations include large organisations such as Direct Line, small

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[1] LCA is defined as studying the environmental aspects and potential impacts of a product or process or service throughout its life, from raw material acquisition through production, use and disposal (ISO, 1997).

[2] The ecological footprint gives an indication of the biologically productive areas of land and sea required to meet our consumption of food, energy, materials and for absorbing our wastes.

offices and Governmental organisations including the GLA, the House of Commons and a number of local authorities, including Lambeth and Wandsworth. BioRegional have promoted the local loop through Local Paper for London, Local Paper for Surrey and since 2003, through The Laundry, the first kerbside recycling collection for small businesses in London (www.laundry.biz).

Printing and writing papers are the highest quality papers with more raw materials and energy needed to produce them than for example newsprint. Over 95% of printing and writing paper is imported as finished paper or pulp to make paper in the UK. We could collect and recycle more of this grade of paper as a locally arising resource to reduce pressure on the world's forests and on our overflowing landfill sites and create more jobs and value in the UK.

As paper can only be recycled up to five times – because the fibres shorten and degrade each time they are recycled - we will always need some virgin pulp and so BioRegional have also been working to develop small pulp mill technology, the MiniMill, which can cost effectively pulp local materials such as wheat straw or sustainably produced wood to produce the virgin pulp we need more locally. You can see more information about this on BioRegional's website.

Office based organisations can play a leading role in reducing the environmental impact of our paper use as they purchase over a million tonnes of high quality paper every year in the UK. A 2002 BioRegional study [3] showed that just 5% of business papers have any recycled content. Quite impressively, 36% of office paper is collected for recycling, but a further 32% could easily be collected.

So, whilst offices are doing quite well at recycling, they could do better and too few offices are purchasing recycled paper.

This study shows the huge environmental impact savings of combining recycling with purchase of locally produced recycled paper.

Another way in which organisations can reduce the environmental impact of their paper use is to simply reduce paper consumption. Offices can reduce paper bills by minimising paper use through simple actions like setting up computers to print on both sides of the paper, checking the first copy for errors before making 100 copies! Or using scrap paper for notes. AT&T set the default on their office copiers and printers to double sided mode and cut paper costs by 15 per cent.

[3] Feasibility Study - Increasing graphics paper recycling & buy back in the UK (Nov 2002) www.bioregional.com

What did the study compare?
The LCA and ecological footprint study compared three types of office paper. It was based on the production and supply of one tonne of office paper in each case.

1. Local recycled paper – including the collection of waste paper, operating data for the production of EVOLVE from the m-real paper mill in Kent, UK and distribution of finished paper for sale within a 101 kilometre radius (London to mill site in Kent).

2. Imported recycled paper – including waste paper collection, industry average operating data for recycled paper mills in the USA (Paper Task Force study, 2002[4]) and distribution.

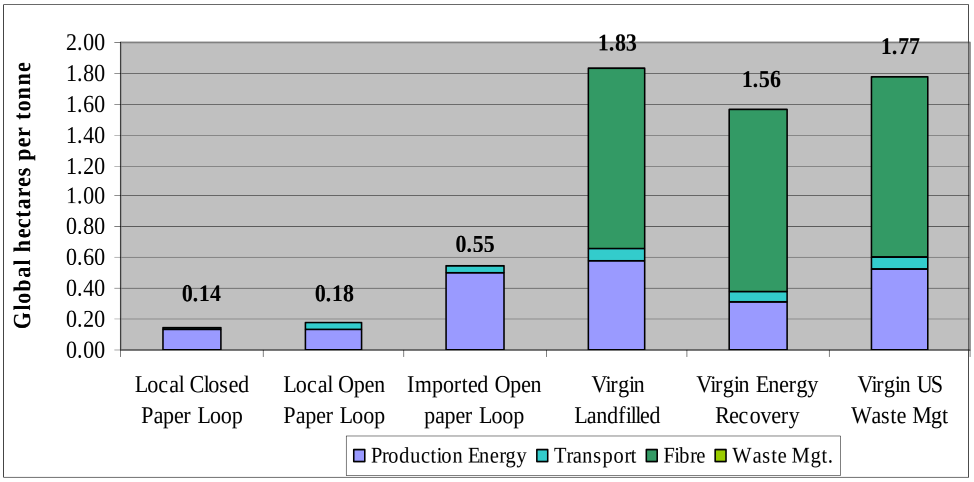
3. Imported virgin paper – including collection of wood, industry average operating data for a typical virgin wood pulp and paper mill in the USA including recovery of renewable energy from wood waste for pulp mill operation (Paper Task Force study) and distribution.

What the studies found
Intuitively it seemed to us that the local loop should be a better choice for our environment (and our economy), but to actually quantify it BioRegional commissioned Novensys Consulting and Surrey University to carry out a Life Cycle Assessment of the local paper recycle and buy back system compared to the impact of imported virgin paper and imported recycled paper. BioRegional asked Best Foot Forward to use the data to produce an Ecological Footprint Analysis and comparison.

The key findings are that

1. The local paper loop system is environmentally preferable to imported virgin paper production, incineration for energy recovery and imported recycled paper. The local loop system has lower impacts in terms of climate change, acidification and use of finite fossil fuel and mineral resources
2. Ecological Footprint analysis of the data shows that the local paper loop system reduces the ecological footprint of office paper use by a staggering 92% compared to imported virgin paper (figure 2)

Figure 2 The ecological footprint per tonne of paper, by production system



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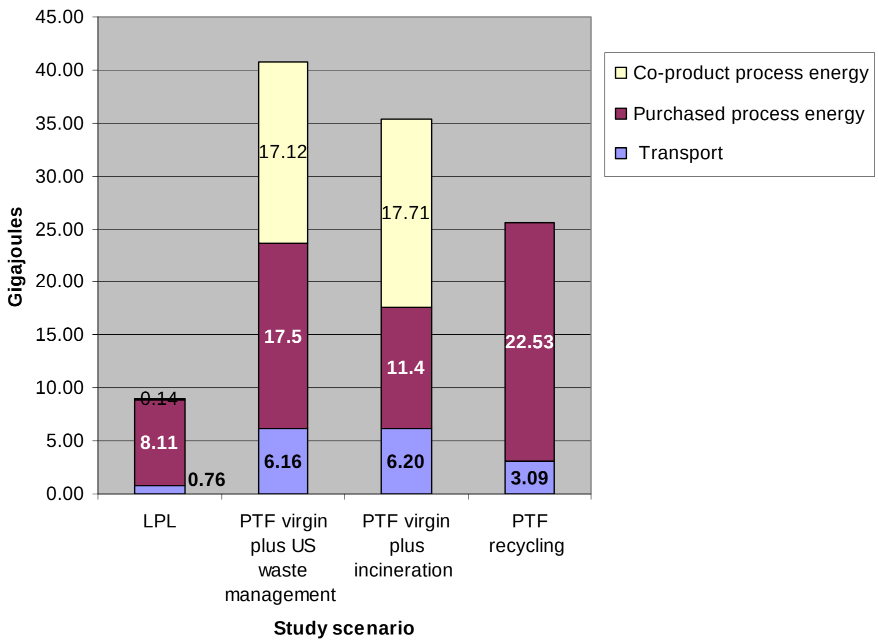
4 Paper Task Force Study. Duke University, Environmental Defense Fund, Johnson & Johnson, McDonald's, The Prudential Assurance Company of America, Time Inc. (2002) *White Paper no 3 Lifecycle environmental comparison: virgin paper and recyclec paper-based systems.* Originally published on December 19, 1995 data in Sections II and IV and Appendices C and D updated in February 2002

Energy

The paper industry is very energy intensive using 10% of the world's industrial energy and 4% of total world energy[5] . Energy use in the pulp and papermaking process was found to be by far the biggest impact in this study. The energy used in production and transport to collect the raw materials and deliver the finished product are shown in figure 3 below.

Figure 3 **Comparison of delivered energy used in the LPL and PTF systems**



The m-real mill where the EVOLVE recycled paper is made was built in 1996 and is a modern and very efficient plant.

We compared the EVOLVE paper made at the m-real plant to paper made in US paper mills[4] because although in the UK we buy more of our paper from within Europe, full life cycle data for European pulp and paper mills was not available. Every paper mill is different but paper made in Europe is known to be produced slightly more efficiently on average than paper made in the USA. The most energy efficient European virgin paper mills using Best Available Techniques (not an average European mill) will use between 18-27 GJ per tonne of paper compared to the US actual industry average figures of 35 GJ per tonne. A best practice European recycled paper mill will use 7.5-12 GJ per tonne. The figures are set out in Table 1 for comparison.

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[5] Towards a Sustainable Paper Cycle, 1996, International Institute for Environment and Development www.iied.org

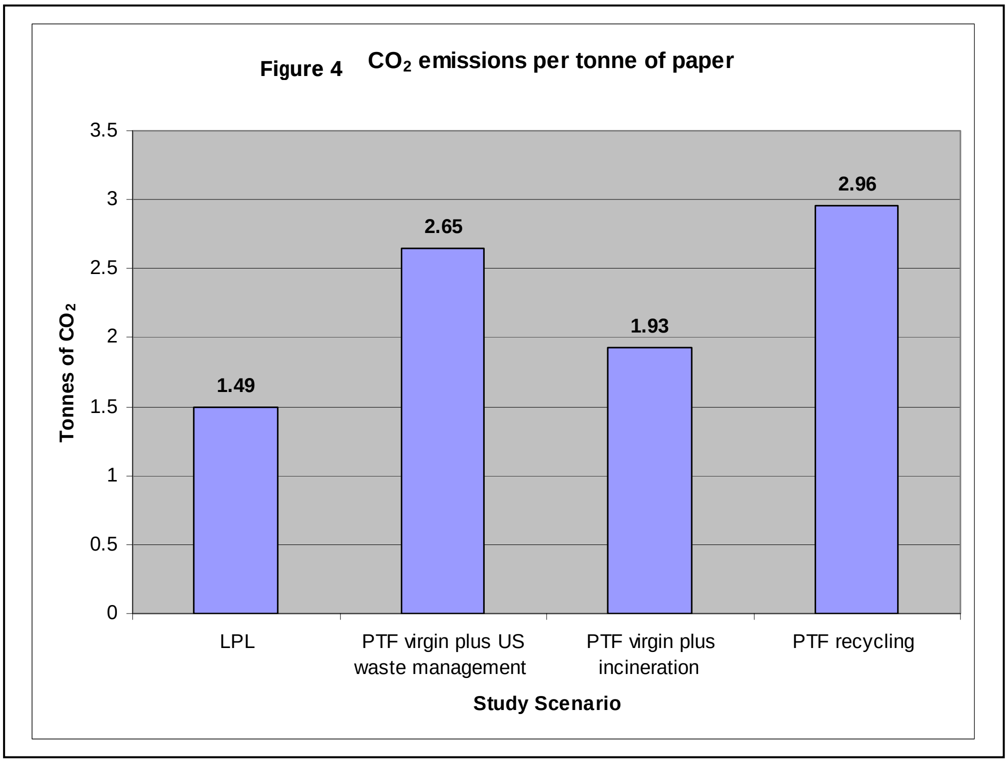
Table 1 Energy Use (GJ) in printing & writing paper mills per tonne of paper produced & distributed

	Energy used in production	Of which, co-product energy	Of which, Purchased energy	Transport energy
Virgin paper US average (actual figs PTF)	35	17.12	17.5	6.16
Virgin Paper European Best Available Technologies	18-27			
Recycled Paper US average (actual Figs PTF)	22.5	0	22.5	3.09
Recycled paper European Best Available Technologies	7.5-12			
Recycled paper m-real mill, Kent,UK Local Paper Loop	8.25	8.11	0.14	0.76

Transport

Transport energy is a lower proportion of energy used for each tonne of paper. But it is still a significant figure being 8% of energy used. The local loop was defined as 101 kilometres between the customer and the mill and transport impacts were reduced by 88% in this case. The study also showed that purchase of recycled paper made in Kent by customers as far away as Glasgow still has a lower impact than imported virgin or recycled paper.

Carbon dioxide emissions and climate change impacts



The carbon savings of the local recycled paper and buy back system compared to the virgin imported paper and imported recycled paper are shown in Table 4 below. As energy is recovered from wood waste in the virgin paper scenarios this reduces carbon dioxide emissions but recycled paper made locally in an efficient mill has the lowest carbon impact. As noted previously the LCA data shows a less inefficient mill

The climate change impacts of sending paper to landfill were not considered in the study but are significant. Methane, which is produced when paper decomposes in a landfill site, has 21 times the global warming potential of CO_2. This methane can be converted to CO_2 emissions for comparison. Each tonne of recycled paper produced saves the equivalent of 600kg of CO_2 emissions if that paper is not sent to landfill when considered over a 100 year time horizon.

Reduced transport in the local loop accounts for savings of 420kgs per tonne of paper compared to imported virgin paper.

Local employment

Increased use of recycled paper utilises waste as a domestic raw material, so reducing imports of pulp. According to Paperback, research suggests that 12 jobs can be created in the economy for every 1,000 tonnes of paper recycled.

Conclusions

The LCA and ecological footprint study show that for UK organisations combining recycling with buying back the paper produced, locally or anywhere within the UK reduces the ecological footprint of an offices paper consumption by up to 92% compared to using imported virgin paper.

Sue Riddlestone
BioRegional
May 2006

Return to Sender

An evaluation of the environmental impacts of the BioRegional Local Paper Loop for production and buy back of 100 percent recycled paper

Summary report of the results of a research project completed by the University of Surrey for BioRegional

August 2005

Contents

Page No

Life Cycle Assessment of BioRegional's Local Paper Loop

The study

BioRegional commissioned the University of Surrey and Novensys Consulting to prepare a study of the specific environmental impacts of recycling paper through the Local Paper Loop system using the tool of Life Cycle Assessment (LCA). The Local Paper Loop system involves a 100 per cent recycled paper product, called EVOLVE.

Objectives

The objectives of the study were:

- To establish the environmental impacts of the Local Paper Loop system for the production of recycled paper.
- To compare the environmental impacts of producing EVOLVE to those generated by other ways of providing graphics-quality office paper.
- To see if the Local Paper Loop system represents an environmental improvement to common alternatives.

Data collection

In the evaluation primary data was collected from M-Real UK Ltd which operates the mill manufacturing EVOLVE (2004). This information was combined with aggregated data provided from Simapro LCA software background databases and research of a Research Engineer from the University of Surrey between 1997 and 2003 (Hart, 2005).

Main conclusions

Recycling and buy back of office paper through the Local Paper Loop is environmentally preferable to typical paper production and waste management of paper, incineration for energy recovery and open loop recycling[6] of paper.

The Local Paper Loop system produces fewer environmental impacts which contribute to human-induced global warming, acidification and the use of finite fossil fuel and mineral resources than production of virgin office paper and typical waste management methods.

Report structure

This report is divided into three parts. In the first the results of the LCA on the Local Paper Loop system are reported. In the second the major environmental impacts of this system are compared with other ways of delivering graphics quality paper for office use. The final section provides greater detail on the methodology of the LCA study.

All results presented relate to the production of a tonne of office paper. Unless otherwise stated energy figures relate to delivered rather than primary energy use. To make it easier to understand the results of the LCA normalised figures have been used whenever appropriate.

[6] Open loop recycling is conventional recycling of recovered paper from diverse sources, in a system that does not directly re-supply the local consumer, but sells recycled office paper to customers in the standard manner via the open market.

Part I
BioRegional's Local Paper Loop

This section summarises the environmental evaluation of the Local Paper Loop (LPL) scheme which provides 100 per cent recycled graphics-quality paper for use in offices in and around London. The system has been operating since November 1999. The main activities of the LPL system are shown in Figure 1.

In the LPL system discarded paper is collected as segregated waste from users, and recycled in a modern mill located in the South East of England. An important feature of the LPL system is that the recycled paper product called EVOLVE is sold directly to the businesses from which recovered paper is originally collected. Returning the recycled paper to users can act as an incentive to promote recycling. This approach is often referred to as closed loop recycling[7].

Figure 1 Local Paper Loop simplified process flow chart

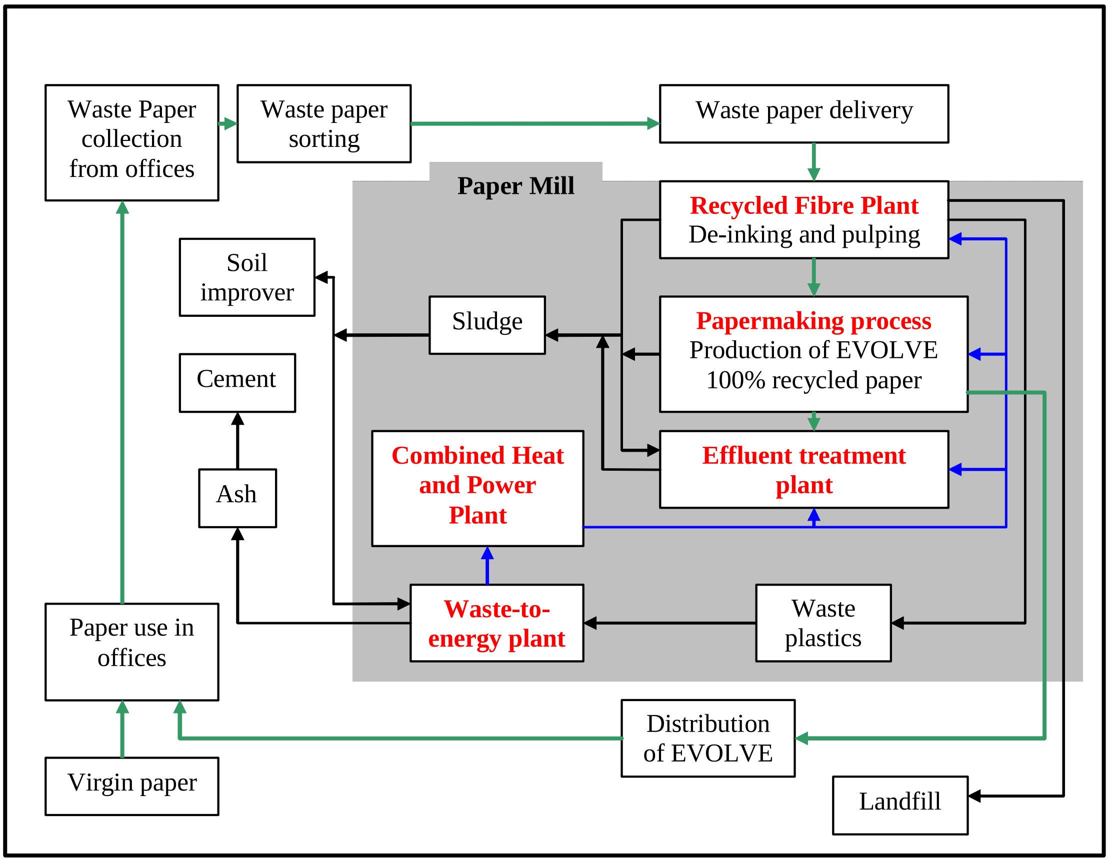


Figure 1 is a simplified[8] diagram of the processes that make up the LPL system. Green arrows show the paper fibre flows in the system. Blue arrows show electricity and

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[7] The closed loop recycling model has been used as the basis for modelling the system. However, in practice the loop cannot be entirely closed in a market economy as some of the paper will always go elsewhere and, in fact, virgin fibre is needed to enter the system at some point to maintain supply and quality in the LPL product (Hart *et al.*, 2005).

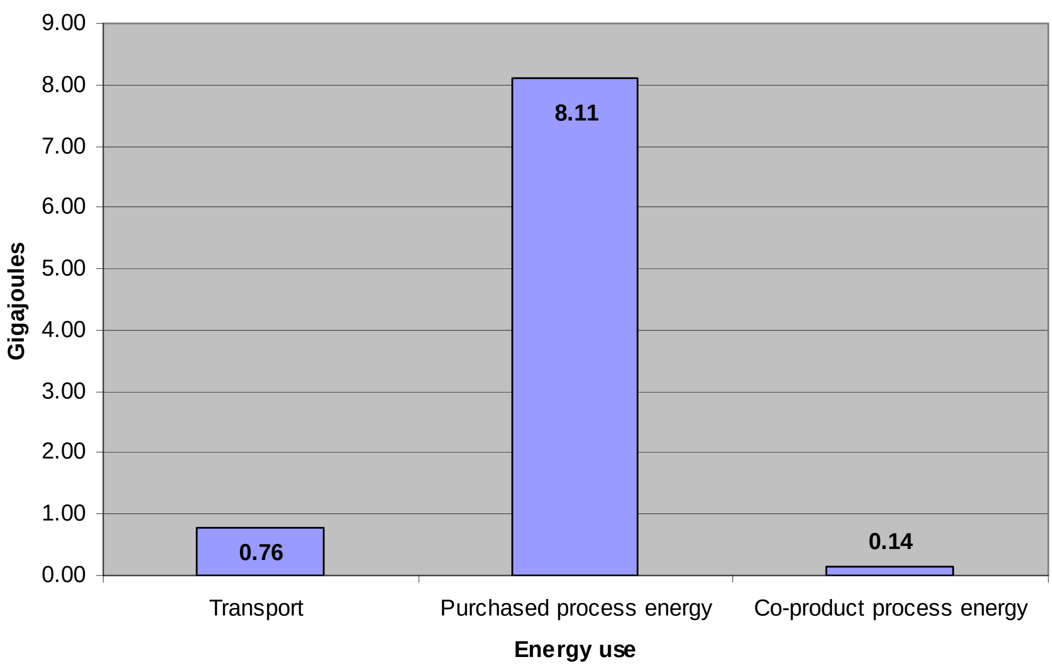
[8] Some background inputs, such as chemical additives and packaging materials, are not shown in the diagram.

thermal energy (steam) flows within the paper milling process. The shaded area highlights activities that occur in the paper mill. The combined heat and power (CHP) plant is natural gas fired and provides both thermal and electrical process energy. The waste to energy (WTE) plant is fired by both recovered paper sludge from the papermaking process and recovered plastics from the recovered paper stream. The WTE plant provides thermal energy to the process. Both plants also provide energy to other industrial processes on the same site.

LPL energy

It is common to find that the most important environmental impacts from recycling paper are associated with energy use. The delivered energy used in the production of a tonne of EVOLVE is shown in Figure 2. An explanation of delivered energy and the other terms used to describe energy in this report is provided in part III.

Figure 2 Delivered energy used in LPL production of recycled paper



In Figure 2 transport energy includes the collection of recovered paper and distribution of EVOLVE. It also includes transport of materials from the LPL process so that they can be included in other production processes or sent for final disposal. Purchased process energy refers to energy supplied to the process within the paper mill from the CHP plant and used in background processes within the supply chain. Co-product process energy[9] refers to energy supplied from the WTE plant from combustion of waste materials, including plastics, extracted from the waste paper stream (see part III for a definition of purchased and co-product process energy). Purchased process energy accounts for 98 percent of the process energy used to manufacture EVOLVE. Co-product process energy accounts for the remaining 2 percent. The utilisation of co-

[9] Co-product process energy is generated from process wastes, such as recovered paper sludge or waste wood residues. It is usually utilised on site within the same process from which the waste is generated.

product process energy releases value from process waste, reduces the amount of process waste created and reduces the requirement for energy from fossil fuel resources.

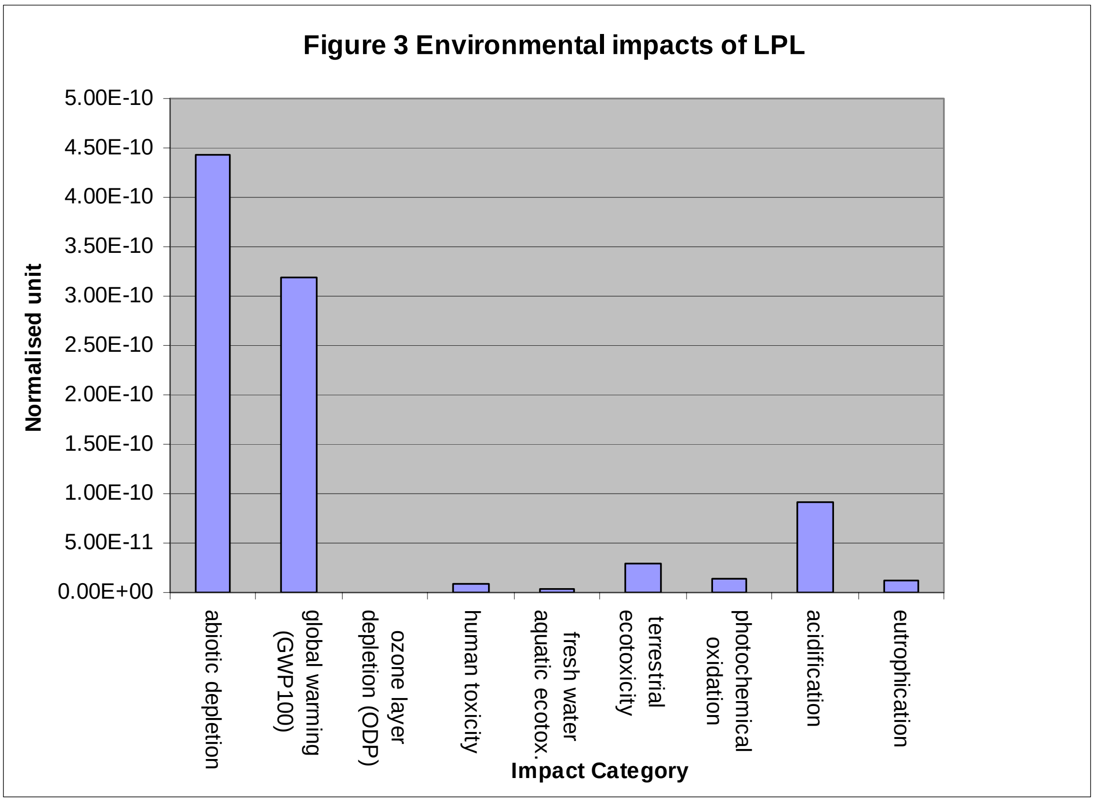
The total amount of delivered energy used in the production of 1 tonne of EVOLVE is 9 gigajoules. This is associated with the emission of 1.49 tonnes of CO_2, contributing to human-induced global warming, based on the transport and process energy requirements outlined above. Driving a 1.4-2 litre petrol engine car 4680 miles (equivalent to 90 miles a week over a year) releases a similar amount of CO2 to the atmosphere (Future Forests, 2004). The majority of energy is used in the production of de-inked pulp and other paper making activities.

In terms of transport energy, the majority is used in collection and distribution of paper. Also 71 kg of ash is transported to a cement works and 231 kg of paper sludge is sent for use as a soil improver. The energy used in the collection and redistribution (transport) of paper is relatively modest when compared to the total energy used in production. However it is of importance as this figure would be much higher if the local supply loop were not in place (see Part II for a comparison of the different transport impacts)[10].

LPL wider environmental impacts

To give a wider picture of the environmental impacts it is necessary to look at a broad set of environmental impacts as well as direct energy use. The full set of impacts associated with LPL is provided in Figure 3. The normalised scale shows the relative levels of the impacts in each category. By looking at the wider set of impacts it is possible to identify whether there are other significant environmental implications associated with activities within the LPL system. A key for all the different impact categories and a definition of normalisation is provided in part III.

[10] The LPL study omits energy used in the sorting of paper into different grades prior to delivery to the paper mill. Although the energy used in the sorting of different materials is accounted for in the PTF report, this is a small energy requirement. The absence of this element from the LPL figures will not change the overall balance of the results.



As might be expected the most significant environmental impacts are ones that are linked closely to the use of energy resources. Abiotic resources relate to the depletion of non-renewable fuels such as gas, oil and coal, and mineral resources. Global warming potential is a measure of the contribution to human-induced climate change, and acidification describes emissions which can acidify land and water, for example by forming acid rain.

Figure 4 highlights the different activities that contribute to generating environmental impacts. Process energy (incorporating both purchased and co-product process energy) used in pulping and papermaking, and energy used in the manufacture of chemical raw materials and the production of packaging materials for EVOLVE generate the majority of impacts in the LPL system. Using unwanted paper sludge as a soil conditioner avoids environmental burdens associated with landfill in several categories, most notably eutrophication and acidification.

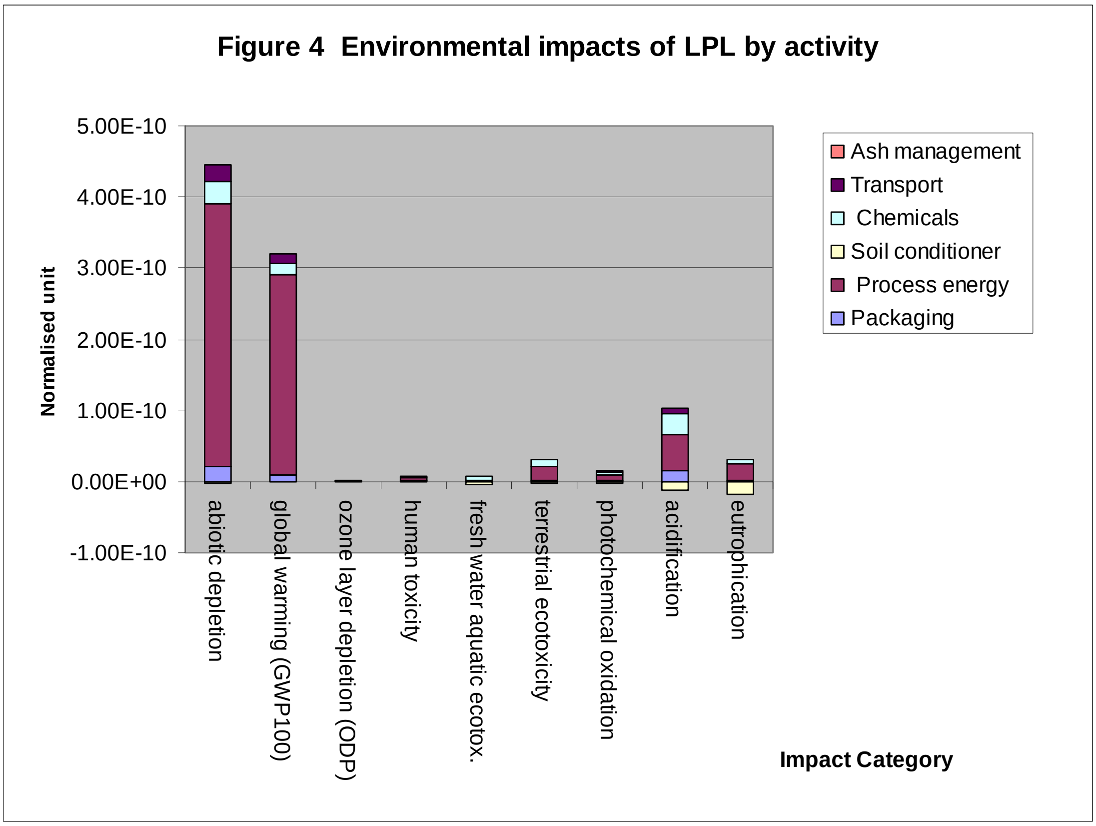


Figure 4 Environmental impacts of LPL by activity
Normalised unit
5.00E-10
4.00E-10
3.00E-10
2.00E-10
1.00E-10
0.00E+00
-1.00E-10
abiotic depletion
global warming (GWP100)
ozone layer depletion (ODP)
human toxicity
fresh water aquatic ecotox.
terrestrial ecotoxicity
photochemical oxidation
acidification
eutrophication
Impact Category
Ash management
Transport
Chemicals
Soil conditioner
Process energy
Packaging

Part II
Comparing LPL with common systems for paper production and waste management

An important part of the environmental assessment is to clarify whether recycling and buy-back of recovered paper using the LPL approach does represent an environmental improvement. Or, put simply, that LPL uses fewer resources and generates fewer emissions than the use of virgin and recycled paper from conventional approaches.

The US Paper Task Force (PTF) report (Duke University *et al* 2002) has been used to provide information on the manufacture of virgin paper and the landfill, incineration and recycling of recovered paper. This describes the impacts of typical waste management activities for paper. The report, originally completed in the mid 1990s, was updated to include revised data in 2002. The PTF report is based on industry average data intended to be representative of the facilities and activities involved in the production and waste management of printing and writing paper, whereas the LPL system is based on a state-of-the-art approach. The comparisons and conclusions presented in this report remain valid, although this limitation should be borne in mind when interpreting them.

The PTF report looks at the impacts of the following scenarios:

- Virgin office paper production plus incineration of used office paper to produce electricity for the national grid and / or recovered heat;
- Virgin office paper production plus typical US waste management, which involves 80 percent landfill and 20 percent incineration of recovered paper[11]; and
- Recycling of pooled recovered paper from diverse sources in a system that does not directly re-supply the local consumer, but sells recycled office paper to customers in the standard manner via the open market. This type of approach is frequently referred to as open loop recycling. It is termed 'PTF recycling' in this section.

Numerous studies have indicated that recycling or incineration of paper with energy recovery is preferable to 100 percent landfill (European Topic Centre on Waste and Material Flows, 2004). Therefore, the landfill of paper on its own has not been investigated.

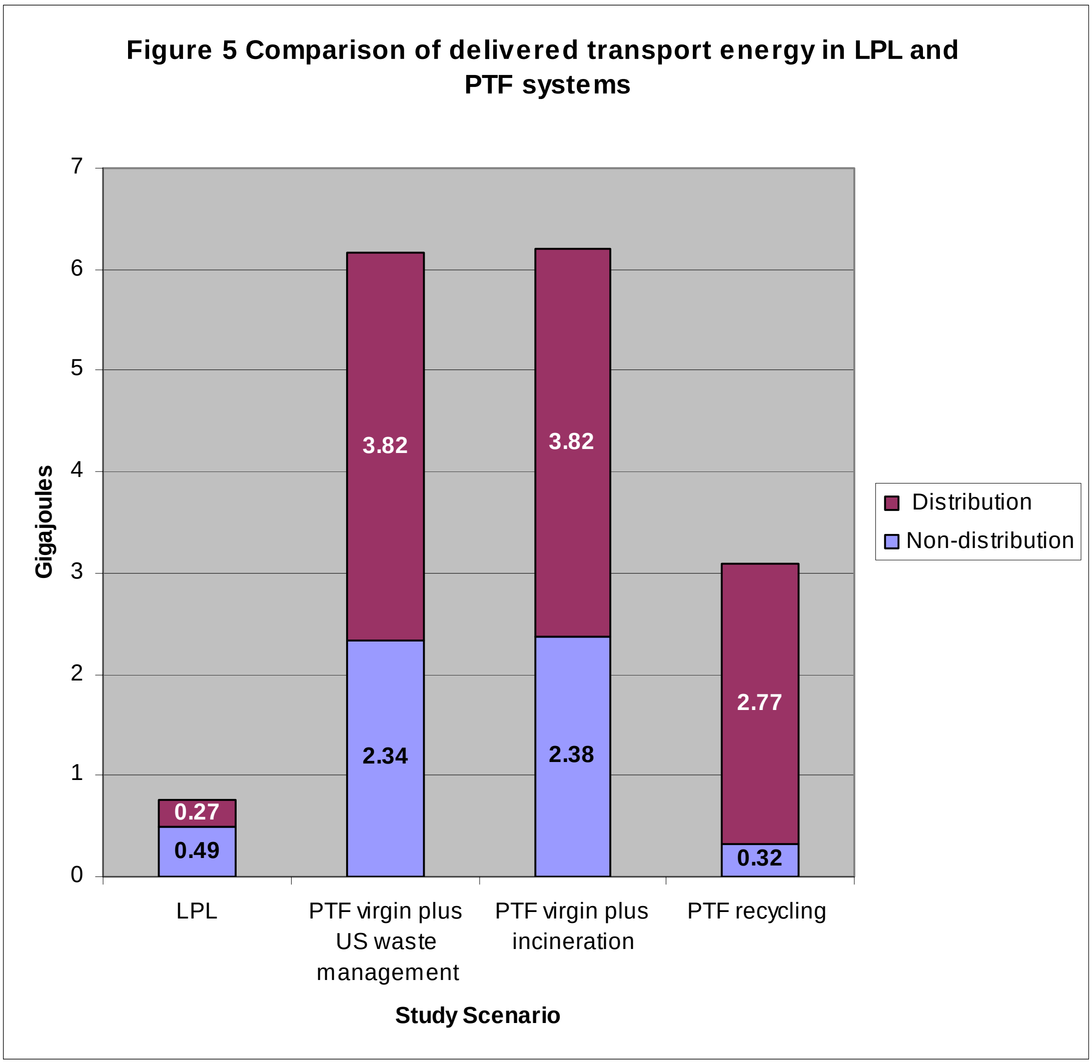
As the most significant environmental impacts of both the LPL and PTF studies are related to energy use, this has been used as an indicator for comparison. Comparisons are made on the basis of:

- Delivered energy requirements (figures 5 and 6).
- Results from the LCA of the LPL system (as presented in part I) with those of a LCA of the purchased process energy and transport requirements for the different PTF scenarios (figure 7 and figure 8). For comparative purposes the PTF figures have been dealt with as though the energy had been consumed in the UK, using the UK grid electricity generation fuel mix (DTI, 2004). The comparison is limited to purchased process energy for the PTF scenarios because only very limited

[11] In the UK 51 percent of industrial and commercial waste is landfilled and 37 percent is reused or recycled, whilst the remainder is recovered, incinerated and otherwise disposed of. For municipal waste the figures are 75 percent landfill, 16 percent recycled or composted, 9 percent incinerated with energy recovery and 1 percent otherwise disposed of (Defra, 2005).

information is available in the PTF report on the composition of co-product process energy. Consequently it was not possible to accurately model this element of the PTF energy requirements within the LCA[12].

Transport energy



In Figure 5 non-distribution transport energy includes the harvesting of trees in the production of virgin paper, collection of paper for disposal or recycling, and the movement of ash and paper sludge during waste handling. Distribution refers to the delivery of the paper product to the UK customer. The distribution transport energy requirements for the PTF scenarios are sourced directly from doctoral research by Hart (2005).

The energy used in the collection and redistribution of the discarded paper within the LPL scheme is significantly lower than that associated with the transport requirements of any of the PTF options. This is because the LPL system, being based on the premise of local production and consumption, is designed to minimise transport requirements. The

[12] The majority of the co-product energy element is likely to derive from renewable resources (i.e. wood waste and pulping liquors) and thus would not add significantly to the environmental impact of the PTF scenarios.

standard model, illustrated in this study with the PTF scenarios, is not designed to achieve this.

The energy used in harvesting trees for virgin paper production accounts for much of the higher non-distribution demand in the PTF virgin plus US waste management and PTF virgin plus incineration scenarios.

The slightly higher non-distribution transport energy requirement in the LPL system compared to PTF recycling suggests that the transport requirements for recovered paper collection and process waste management are marginally higher for the LPL system than the PTF recycling scenario. It should be noted, however, that this small difference is likely to fall within the level of uncertainty that can be expected to be associated with this data.

When looking at the transport energy impacts for the LPL cycle it was assumed that the distances travelled to distribute EVOLVE are the same as those for collection of the discarded paper (101 km). However, it is worth considering the changes to the energy used caused by supplying EVOLVE to customers who live elsewhere in the UK.

- If the customer lived in Manchester (410 km from the paper mill) the distribution transport energy requirement would increase to 1.11 GJ. Thus the total transport energy requirement would be 1.6 GJ
- If the customer lived in Glasgow (742 km) the distribution transport energy requirement would increase to 2.01 GJ. Thus the total transport energy requirement would be 2.5 GJ.

When compared with the PTF options, the transport energy used in the LPL cycle is significantly lower for customers in many areas of the UK, even when the distance travelled to supply EVOLVE is significantly greater than those modelled in the LPL LCA.

Total energy

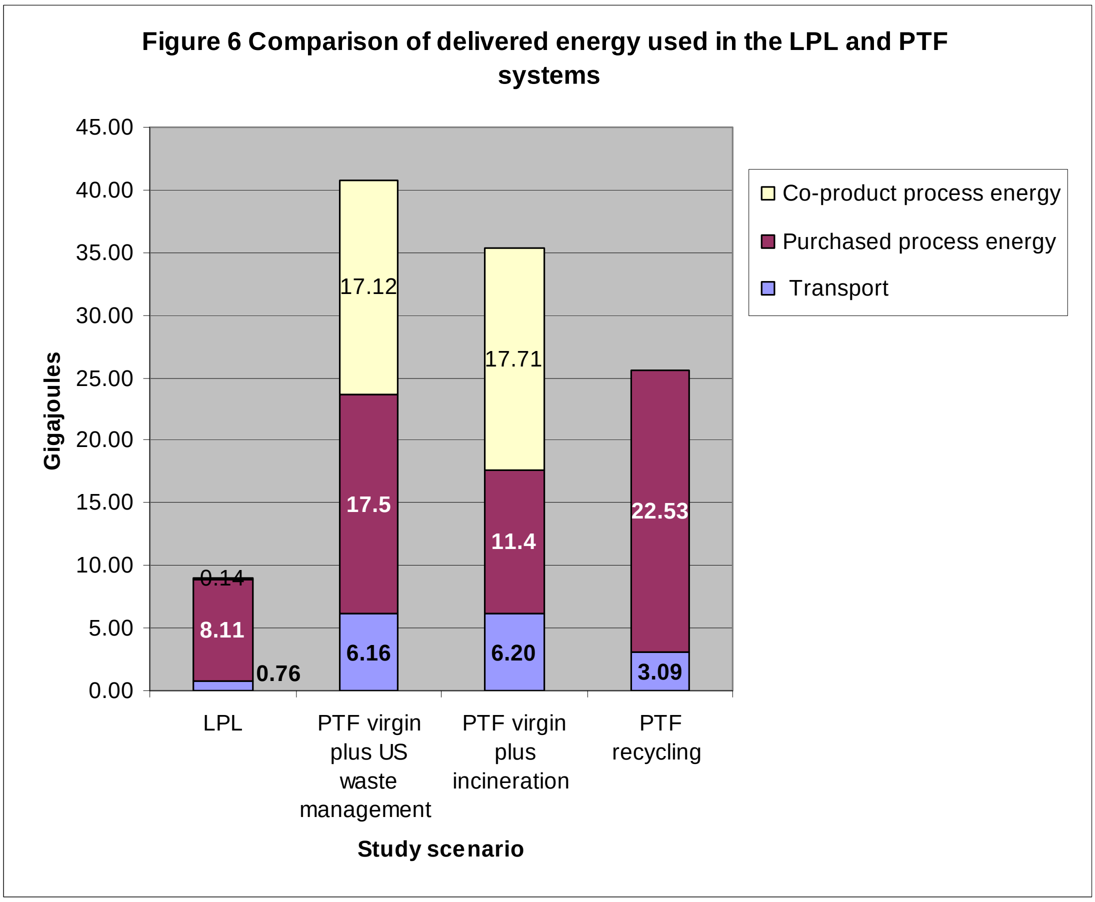


Figure 6 presents delivered energy requirements across the scenarios. The concepts of purchased process energy and co-product process energy were explained earlier with regard to the LPL system. Here they are applied in the same way to the PTF scenarios. For the PTF scenarios purchased process energy is drawn from the electricity national grid or from other purchased energy sources. Co-product process energy is, for example, generated in plants fired by wood residues (e.g. bark) and pulping liquors, both significant (and largely renewable) waste materials produced during the manufacture of virgin paper. It is common for virgin paper mills to reduce their use of purchased energy in this way.

The opportunity to utilise co-product process energy is much more limited in paper recycling systems, since they do not involve the production of significant amounts of energy-rich waste materials. Consequently PTF recycling does not utilise any co-product process energy. Similarly the contribution of co-product process energy to the LPL scenario is very small.

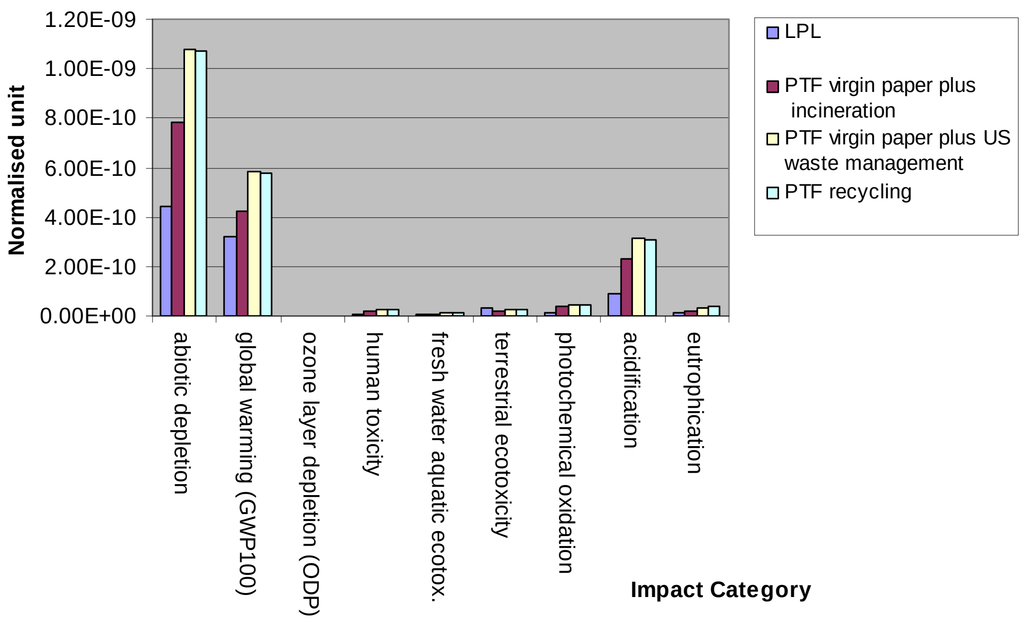
Figure 6 clearly shows that LPL production of EVOLVE uses less delivered energy than any of the PTF scenarios. In percentage terms the delivered energy consumption figure for LPL is 78 percent lower than that for PTF virgin plus US waste management option, 74 percent lower than the PTF virgin plus incineration option and 65 percent lower than the PTF recycling option.

The most energy efficient European virgin paper mills using the Best Available Techniques typically use in the region of 18-27 gigajoules per tonne of paper. For energy efficient European recovered paper mills (producing recycled printing and writing paper) this figure is typically in the region of 7.5-12 gigajoules per tonne. These figures include on site process heat and power requirements but not transport energy (European Commission, 2001) (the LPL and PTF figures include energy used in upstream and downstream activities in addition to that used in the paper mill).

Comparison of wider environmental impacts

The impact profile of the energy used in the different PFT waste management options and LPL system are compared in Figure 7. The comparison is based on purchased process energy drawn from the UK electricity generation fuel mix for the PTF scenarios (see page 10 for an explanation). Transport energy requirements for the PTF scenarios are divided evenly between road and rail (see part III for further detail).

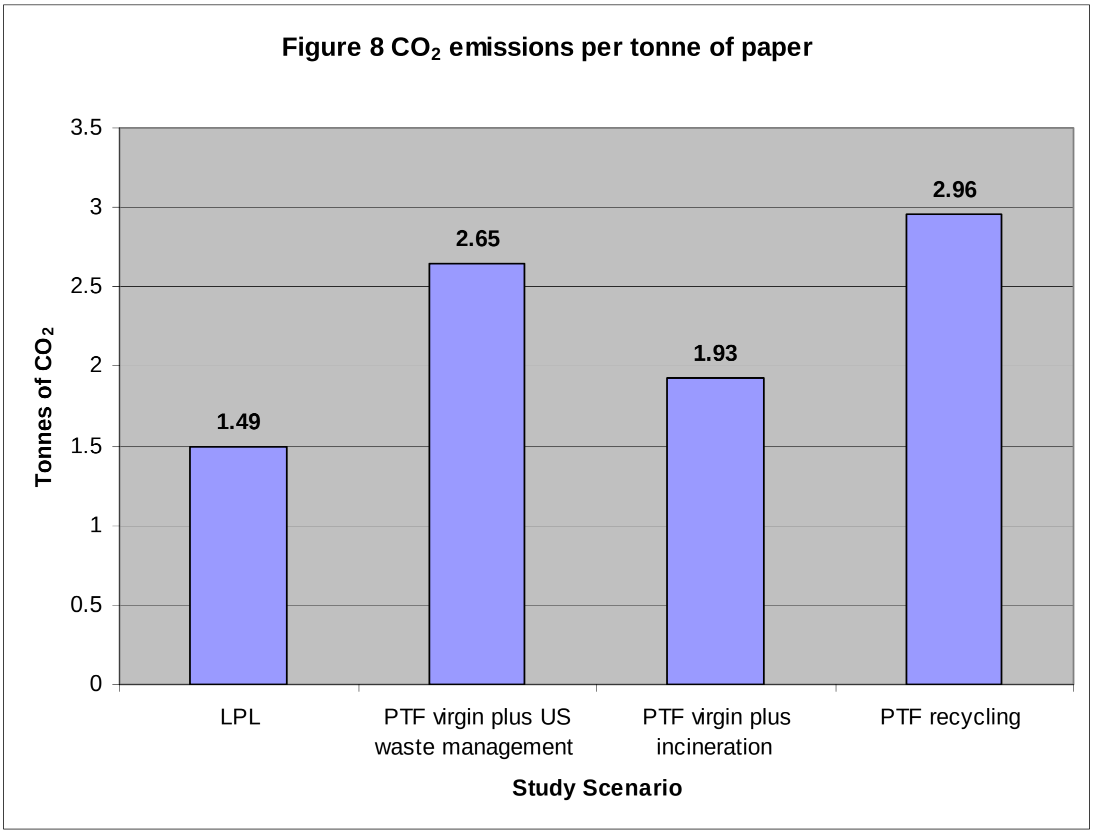
Figure 7 Comparison of environmental impacts related to energy use for LPL and PTF systems



In the majority of cases the impacts of LPL are significantly lower than the PTF scenarios. An important point is that LPL lowers impacts associated with the use of fossil fuel and mineral resources, human-induced global warming and acidification.

The LPL system does have slightly higher impacts on terrestrial (land-based) eco-systems than the PTF scenarios. The main reason for this is the emission of small quantities of heavy metals to the atmosphere from the WTE plant. Set against this, the LPL system greatly reduces the land area needed for trees to provide paper fibre; this is particularly significant for the hardwood fibres which come mainly from eucalyptus plantations in Iberia and South America (Hart, 2005). Overall it is reasonable to conclude that the benefits of using the WTE plant outweigh any additional impacts caused. The plant uses paper sludge that would otherwise be land-spread and waste plastics that would otherwise be landfilled and, in doing so, lowers the need for energy to be supplied from fossil fuel resources.

For every tonne of paper produced the LPL system emits less CO_2, the principal greenhouse gas, than any of the PTF options. The difference in the life cycle emissions of CO_2 gas in the LPL and PTF scenarios is shown in Figure 8.



Conclusions

The conclusions which can be drawn from the study are:

1. The major impact of the Local Paper Loop system is the use of energy in pulping and paper making processes. The impact of energy use in the transport of materials is modest.

2. Recycling of office paper through The Local Paper Loop is environmentally preferable to the Paper Task Force typical waste management of virgin paper, incineration for energy recovery and open loop recycling of paper scenarios. The majority of this environmental benefit is derived from the significantly lower energy consumption achieved in the paper pulping, paper making and transport in the Local Paper Loop system.

3. The Local Paper Loop system has lower impacts on global warming, acidification, and the use of finite fossil fuel and mineral resources than either incineration, open loop recycling or US waste management practices (80 percent landfill, 20 percent incineration).

Part III
LCA methodology

LCA is defined as studying "the environmental aspects and potential impacts of a product or process or service throughout its life, from raw material acquisition through production, use and disposal" (ISO, 1997). It involves analysing the environmental performance of product / service systems across the life cycle of the product system by evaluating the environmental burdens (i.e. energy and materials used and wastes released to the environment), assessing their impact and identifying and evaluating improvements.

LCA is commonly used in making comparisons across products, validating claims made about new products and services and identifying opportunities for improvements in environmental performance. It has also been used to guide environmental policy.

The basic methodology for LCA is well established. The Society for Environmental Toxicology and Chemistry (SETAC) has played a key role in developing LCA (e.g. Consoli *et al*, 1993). The technique is covered by international standards (ISO, 1997-2000).

Functional unit and system boundary

In this study the functional (reference) unit is the production of 1 tonne of uncoated wood free printing and writing paper, cut, packaged in A4 reams and delivered to London consumers.

The system boundary (items included within the study) for this study starts with the collection of recovered paper from offices within London and extends through to the manufacture and distribution of 100 percent recycled wood free printing and writing paper.

Comparing different systems

To ensure fair comparison it is necessary to ensure that the systems are always equivalent in respect of the functional unit (i.e. each system examines the production and disposal or recycling of 1 tonne of paper) and system boundary.

In order to compare the alternative systems it was necessary to consider not only the final product of recycling, but also the final product of incineration with energy recovery where the output is electricity and / or heat.

Exclusions

For every tonne of EVOLVE paper produced approximately 50 kg of assorted metals (staples etc.) is separated during pulping and de-inking. The assorted metals are then landfilled. This has been excluded from the LCA as the environmental impact is insignificant to the overall results presented.

The LPL study does not include the energy used for sorting recovered paper into different grades prior to delivery to the paper mill. This is a very small requirement relative to other energy requirements and its exclusion does not affect the overall balance of the results.

Energy definitions

Primary energy: the energy contained in raw unprocessed fuels and other resources, such as solar radiation, prior to conversion to useful forms of energy, such as electricity.

Delivered energy: energy utilised within the product system. It includes all energy (electrical, thermal etc.) that is directly used for processes and activities, for example by equipment and vehicles in the manufacture and transport of materials and products. Delivered energy is derived from primary energy resources via conversion, distribution and supply. Unless stated otherwise all energy figures quoted in this report refer to delivered energy.

Transport energy: delivered energy requirements for transport activities. *Distribution transport energy* refers to delivered energy requirements for the transport of the finished paper product to the UK consumer. *Non-distribution transport energy* refers to delivered energy requirements for all other transport activities.

Purchased process energy: process energy purchased from a third party, such as electricity purchased from an electricity supply company.

Co-product process energy: process energy generated from process wastes, such as recovered paper sludge in the case of recycled paper, or waste wood residues in the case of virgin paper. Usually utilised on site within the same process from which the waste is generated.

Assumptions and allocation issues

It was necessary to make a number of important assumptions and allocation decisions in this study. These were agreed with BioRegional and M-Real, and follow the procedure recommended by the International Organisation for Standardisation (ISO). They are listed below:

1. The Local Paper Loop operates as a closed loop system. Hart (2005) has shown that this is the case because paper enters the LPL system from other sources in sufficient quantities to make up the losses.
2. The distances travelled to distribute EVOLVE are the same as those for collection of the discarded paper used to make EVOLVE within the London area (101 km).
3. In weight terms the majority of chemical raw materials used in the pulping and production of paper were entered directly into the LCA model. However, a number of the chemical raw materials could not be directly entered into the LCA model because the formulations for these substances were unavailable due to commercial confidentiality. For these substances 15 kg were allocated as generic organic chemicals and 24 kg were allocated as generic inorganic chemicals per functional unit.
4. The paper mill is operating at full capacity.
5. All the ash from the waste-to-energy plant is used in the production of cement. This is used as a substitute for lime in the production of cement.
6. The distance travelled to supply ash to the cement works is 50km.
7. For every tonne of Evolve produced 231kg of paper sludge created during the de-inking, pulping manufacture and effluent treatment processes cannot be used to

generate heat in the site's waste-to-energy plant. Rather than being landfilled unwanted sludge is spread as a soil conditioner on nearby farmland. In the LCA model soil conditioner has been modelled as the avoided impacts of landfilling the same weight of paper. The avoided environmental impacts include the methane which would be released during decomposition if the paper were landfilled.

8. The distance travelled to supply sludge for use as soil conditioner is 50km.
9. The PTF purchased process energy figures do not include any differentiation of electrical and thermal energy. For the purpose of this report all of these energy requirements have been allocated to electricity consumption in the UK, using the UK grid electricity generation fuel mix (DTI, 2004).
10. The distribution of finished product is not included in the PTF report. The energy figures used for the distribution of virgin paper in the US PTF scenarios are based on doctorate research between 1997 and 2003 which estimated this requirement based on distribution in the UK (Hart, 2005).
11. The PTF transport energy requirements have been allocated evenly between road and rail. 40 percent of the UK rail network is electrified (Network Rail, 2004). This element (20 per cent of the total transport energy requirement) has been allocated to the UK electricity generation fuel mix. The other 60 percent is allocated to a diesel engine based on standard technology.
12. Road transport is allocated to a diesel truck based on standard technology and a mixture of urban and motorway travel.
13. Paper can only be recycled 4-6 times as after this the quality of the fibres is too poor for reuse. In the LPL system the quality of the recovered paper feedstock is maintained because it contains enough paper which has been recycled perhaps only once or twice, because of the virgin fibre which enters the system from other sources (i.e. other recovered paper). However, it might be necessary to introduce virgin wood or non-wood fibre into the LPL system to maintain quality if the general level of recycled fibre in UK graphics papers becomes significantly higher then at present (Hart *et al.*, 2005).

Impact assessment categories

The inventory is aggregated to show the contribution to a set of different environmental impacts. The CML 2 Baseline 2000 (Pre Consultants, 2004) impact assessment method has been used in this study. The impact categories are:

- **Abiotic Resource Depletion:** the depletion of finite global fossil and mineral resources by different activities.
- **Global Warming Potential (GWP)**: the contribution of the emissions to human-induced climate change.
- **Photochemical Oxidation (summer smog)**: contribution to forming oxidants such as ozone and the associated fine smog when pollutants are exposed to sunlight.
- **Stratospheric Ozone Depletion**: the effect of emissions in removing ozone from the upper atmosphere, thereby letting more damaging ultra-violet light through to the earth's surface.
- **Acidification**: emissions which can acidify land and water, for example by forming acid rain.
- **Human Toxicity**: the toxic effects of emissions on human beings.
- **Fresh Water Aquatic Ecotoxicity**: refers to the impact on fresh water resources and eco-systems resulting from emissions to soil, water and air.
- **Terrestrial Ecotoxicity**: the impact of emissions on land eco-systems.

- **Eutrophication**: the impacts of nutrient emissions to water, air and land. Eutrophication is the result of enrichment of water based eco-systems by nutrients and is responsible for the increased occurrence of algal blooms in fresh water during warmer months in the year (Environment Agency, 2004).

The full suite of impact categories within the CML 2 Baseline 2000 method includes marine aquatic ecotoxicity. In recent years problems have been discovered with the modelling of this impact category. For instance, future environmental impacts are not appropriately discounted and so stable compounds generate modelled environmental impacts over a very long timeframe. This issue is of particular importance with regard to certain emissions from fossil fuel based electricity generation, notably hydrogen fluoride. There are also some problems with the normalisation calculations for this impact category (Sim, 2004). In practice this means that the results from this category cannot be relied on. As a result this impact category has been omitted from the LCA impact assessment.

Normalisation

Normalisation can be used to aid interpretation of the results from a LCA. Normalisation usually involves dividing the impact category results by a reference value to provide a dimensionless normalised metric. The most common way of establishing the normalised value is to work out the impact categories for a particular region over a year, and if desired divide the result by the number of inhabitants in that region. The results in this report have been normalised using the Western Europe (1995) reference value for the CML methodology. This includes the 12 member states of the European Community in 1994 plus Switzerland, Austria and Norway. (Pre Consultants, 2004).

After normalisation all the impact categories are quantified in terms of dimensionless ratios. This enables immediate comparison. Thus the process of normalisation is useful for two reasons:

1. The relative size, and therefore significance, of the environmental burdens across different impact categories is highlighted.
2. The normalised results show the relative significance of the environmental burdens compared to the total Western European environmental loads.

For more information about this study please contact BioRegional Development Group.

Glossary of terms

CHP – combined heat and power
ISO – International Organisation for Standardisation
LCA – life cycle assessment
LPL – Local Paper Loop
PTF – Paper Task Force
WTE – waste-to-energy

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Bringing sustainability down to earth
Best Foot Forward

An Ecological Footprint Analysis of the Local Paper Closed Loop system for producing 100% recycled paper

Summary based on the results of a LCA research project completed by the University of Surrey for Bioregional

January 2005

Prepared by
Best Foot Forward Ltd.
email: mail@bestfootforward.com

Submitted to:

BioRegional Development Group
January 2005

Introduction
This report updates the initial ecological footprint analysis of the Local Paper Loop Life Cycle Assessment (LCA) undertaken in January 2002. The LCA has now been finalised and the updated ecological footprint analysis is presented here.

This report was prepared by **Best Foot Forward** (BFF) and submitted to the **BioRegional Development Group**.

Case Studies
All of the data and corresponding boundaries analysed in the LCA were adopted for the ecological footprint analysis. Best Foot Forward were asked to measure the ecological footprint of:

- Local Closed Loop Recycled Paper
- Local Open Loop Recycled Paper
- Imported Open Loop Recycled Paper
- Virgin Paper Landfilled
- Virgin Paper sent for energy recovery
- Virgin Paper with US waste management, and
- EC BREF standards for paper production (energy only).

BFF were also asked to provide contextual information in which to place the case study results. This information was:

- The UK ecological footprint per capita
- The UK paper ecological footprint per capita
- The office worker ecological footprint, and
- The office worker paper ecological footprint.

Method
Since the initial ecological footprint analysis in 2002, the ecological footprint methodology has been updated and is currently being globally standardised. This process is being led by the Global Footprint Network (www.footprintnetwork.org), of which BFF is a founding partner. The latest standard methodology is from the National Footprint Accounts 2001 (GFN, 2004), published in summary in WWF's Living Planet Report 2004 (Loh & Wackernagel, 2004).

BFF's Stepwise™ methodology used for this analysis is standardised with the latest Global Footprint Network / WWF 2004 ecological footprint method. The functional unit is global hectares (gha) per tonne of paper.

Results

All of the case studies were analysed based on:

- **Total Production Energy**
  This includes direct energy for production and energy embodied in the products, such as chemicals, used in the production process.
- **Transport**
  This includes distribution of paper products and where appropriate, collection and waste handling (for example ash delivery).
- **Fibre Requirements**
  This includes the fibres required for paper production, whether recycled or virgin.
- **Waste management**
  This includes the resource requirements of the waste management process used. Recycling is not an end of life process and is credited with 0 gha.

Ecological Footprint (gha/tonne)	1) Local Closed Loop Recycled	2 Local Open Loop Recycled	3) Imported Open Loop Recycled	4) Virgin Landfilled	5) Virgin with Energy Recovery	6) Virgin with US Waste Mgmnt
Total	**0.14**	**0.18**	**0.55**	**1.83**	**1.56**	**1.77**
of which…						
Production Energy	0.13	0.13	0.50	0.58	0.31	0.53
Transport	0.01	0.05	0.05	0.07	0.07	0.07
Fibre	0	0	0	1.17	1.17	1.17
Waste Mgt.	0	0.00014	0.00017	0.00122	0.00104	0.00118

Table 1: The ecological footprints of the different paper management options

1. Local Closed Loop Recycled Paper

Closed Loop recycling means that customers who are supplied with the paper product (Evolve recycled paper) also have paper waste collected, which goes back into the paper production process. Production energy is supplied via CHP and a Waste-to-Energy plant.

2. Local Open Loop Recycled Paper

Open Loop recycling means that customers who are supplied with the paper product do not necessarily have paper waste collected, to re-enter the paper production process. In addition, the paper that is recycled may be distributed further. Production energy is assumed to be the same as Local Closed Loop paper.

3. Imported Open Loop Recycled Paper

The same boundaries apply as for the Local Open Loop recycled paper, with several exceptions. Firstly, transport is increased to account for the import distance and secondly, production energy is switched to grid electricity.

4. Virgin Paper Landfilled

To compare with recycled paper, conventional paper produced from virgin wood resources is considered. Here the virgin paper is thrown away after use. Production energy is supplied by grid electricity

5. Virgin Paper sent for energy recovery

Conventional paper produced from virgin fibres and sent for energy recovery after use.

6. Virgin Paper with US waste management

Conventional paper produced from virgin fibres and managed according to US waste management methods.

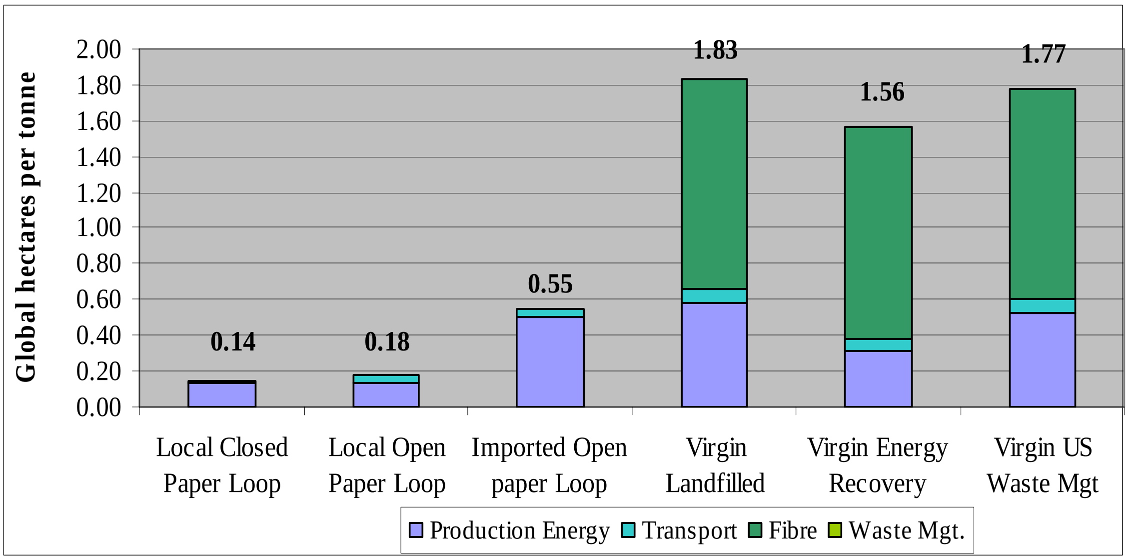
7. EC BREF standards for paper production

This comparison has not been completed, as BioRegional were unsure of the value of this comparison due to boundary uncertainty. The data was also of a different format and details of the fuel mix were not available.

The Total Ecological Footprint of Graphics Paper

The ecological footprint per tonne of graphics paper was found to vary between 0.14 gha to 1.83 gha, depending on the production system (case study). Figure 1 shows the ecological footprint results of all the case studies. The 'Local Closed Paper Loop' paper was the lowest ecological footprint of all paper types. Of the virgin papers, that sent for energy recovery had the lowest ecological footprint. The 'Local Closed Paper Loop' ecological footprint was 91% lower than the ecological footprint of virgin paper sent for energy recovery.

Figure 1: The ecological footprint per tonne of paper, by production system (case study)



How the choice of paper affects the total ecological footprints of office workers and every person in the UK are explored below.

Paper & Ecological Footprints of Office Workers

BioRegional supplied an estimate that office workers consume, on average, 64 kg of graphics paper per year. Of this, 47 kg is uncoated, woodfree graphics paper. Therefore, the average office worker, assuming 47 kg of 'Virgin US Mgt.' paper and 17 kg of virgin graphics paper (BFF, 2004 unpublished), has a graphics paper ecological footprint of **0.13 gha**.

If all 64 kg of graphics paper consumed by office workers was supplied by 'Local Closed Paper Loop' paper, this could reduce the graphics paper ecological footprint of an average office worker from 0.13 gha to 0.009 gha; a reduction of 93%.

Looking beyond the estimated average, Best Foot Forward's *Corporate Stepwise™* service (BFF, 2004 unpublished) gives a range of total ecological footprints for office workers of between **0.53 gha** and **2.1 gha**. Total paper consumption accounted for between **8%** and 2**8%** of the ecological footprint.

Paper & Ecological Footprints of UK Citizens

BioRegional provided average paper consumption per capita for the UK, of **210 kg**. Of this, the biggest category at **37%**, or **77 kg per capita** is graphics paper. Of graphics paper, uncoated woodfree paper accounted for **34%**, or **27 kg per capita**. Therefore, uncoated woodfree graphics paper accounts for **13%** of UK paper consumption per capita.

The current UK total ecological footprint per capita is **5.43 gha per capita** (Loh & Wackernagel, 2004). Of this, the average ecological footprint of all paper consumption is estimated to be **0.35 gha per capita**, or **7%** (BFF, 2004 unpublished). This is derived using the average paper consumption of **210 kg per capita** and BFF's Stepwise™ methodology.

The three recycling systems analysed are included within the term 'uncoated woodfree' paper. These systems varied by whether the paper is produced via a closed loop, open loop system, and whether it is imported. The consumption of 27 kg of uncoated, woodfree paper corresponds to a UK per capita ecological footprint of between **0.004 gha per capita** for closed loop and **0.015 gha per capita** for imported open loop. For comparison, the UK per capita ecological footprint would increase to **0.047 gha per capita** for 27kg of imported virgin paper with US waste management.

According to this study, the UK ecological footprint per capita of graphics paper (77 kg per capita) could vary between **0.01 gha per capita** (100% closed loop) and **0.19 gha per capita** (assuming 27 kg 'Virgin US Waste Mgt.' paper and 50 kg virgin graphics paper (BFF, 2004 unpublished)); or between **3%** and **54%** of the average UK per capita ecological footprint of paper, or **0.2%** and **3.5%** of the average UK per capita ecological footprint.

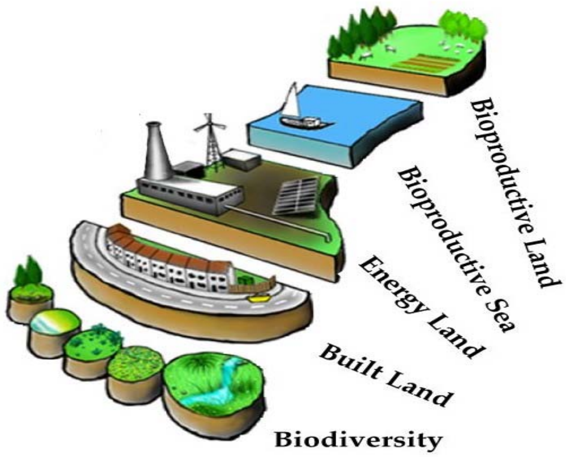
Appendix 1 – Ecological Footprint Analysis

What is ecological footprint analysis?

Co-originated in the early 1990's by Professor William Rees and Dr. Mathis Wackernagel, ecological footprint analysis has rapidly taken hold and is now in common use in many countries at national and local levels; for example, the UK, Mexico, the United States, Canada, Holland, Denmark, Sweden, Norway, Italy, Spain and Australia. The ecological footprint of a region or community can be said to be the bioproductive area (land and sea) that would be required to sustainably maintain current consumption, using prevailing technology. More recently ecological footprint studies of organisations and processes have become more popular indicators of sustainability.

For the purposes of the ecological footprint calculation, land and sea area is divided into four basic types; bioproductive land, bioproductive sea, energy land (forested land and sea area required for the absorption of carbon emissions) and built land (buildings, roads etc.). A fifth type refers to the area of land and water that would need to be set-aside to preserve biodiversity (see Figure A1).

Figure A1: Land types used for ecological footprint analysis



Example 1: A cooked meal of fish and rice would require bioproductive land for the rice, bioproductive sea for the fish, and forested 'energy' land to re-absorb the carbon emitted during the processing and cooking.
Example 2: Driving a car requires built land for roads, parking, and so on, as well as a large amount of forested 'energy' land to re-absorb the carbon emissions from petrol use. In addition, energy and materials are used for construction and maintenance.

The Stepwise™ methodology

The Corporate Stepwise™ ecological footprint calculations in this report follow the Stepwise™ methodology. The methodology, developed by Best Foot Forward (see Chambers et al, 2000), uses a 'component' (or 'bottom-up') approach to perform ecological footprint analysis. Though different data sources are used, the calculation method is wholly compatible with the 'compound' (or 'top-down') approach used by Wackernagel et al. in the Footprint of Nations studies (1997, 1999, 2000, 2002 and 2004), which uses international trade statistics.

The Stepwise™ methodology, wherever possible, uses full life cycle impact data to derive ecological footprint conversion factors for key activities ('components'). For example, to calculate the ecological footprint of wood consumption, the bioproductive space and energy for forest operations and wood processing are accounted for (Table 8). This conversion factor is then applied to the cubic metres of wood consumed. Using this component approach enables the calculation of ecological footprints at any level – for a product, organisation, activity or region.

Table A1: An example analysis for the ecological footprint of wood (per cubic metre)

	Factor	Units	Data
A	**Carbon per m^3**	tonnes C/m^3	0.05
B	**Carbon responsibility***	%	71%
C	**World carbon absorption**	tonnes C/ha/yr	1
D	**Energy equivalence factor**		1.38
E	**Yield**	tonnes/ha	2.10
F	**Wood conversion factor**	tonnes/m^3	0.60
G	**Production waste factor**		1.54
H	**Forest equivalence factor**		1.38
	((A*B*D)/C) + ((1/(E/F))*G*H) =		
	Ecological footprint	**gha/m^3**	**0.65**

*CO_2 emissions assimilated by the sea are excluded from the ecological footprint, which leaves approximately 71% of emissions.

A similar approach is used to derive a range of ecological footprint component values, representing the main categories of impact, before summing them to calculate a total ecological footprint for paper.

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