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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: IF0154
2. Project title: A preliminary assessment of the greenhouse gases associated with growing media materials
3. Contractor organisation(s): Warwick HRI, University of Warwick
4. Total Defra project costs (agreed fixed price): £ 29,633
5. Project: start date .... 01 April 2008

   end date 13/02/2009

6. It is Defra's intention to publish this form.
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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

The main aim of the study was to assess the carbon footprint of selected growing media materials; this has been achieved. In the process of achieving this aim the research also highlighted that a number of difficulties exist when assessing the GHG emissions of organic materials. We ask that the reader should remember that this is a preliminary assessment of the subject which has revealed a number of methodological and interpretation issues which will require further research to resolve and, as a consequence, the results and conclusions presented here should be treated with caution.

Defra is committed to reduce the horticultural use of peat in order to meet the UK Lowland Raised Bog Habitat Action Plan. The aim is for the market for soil improvers and growing media to be 90% peat free by 2010. Progress towards this target is being monitored via Defra project WC04019 (Wallace et al., 2007).

Professional use of peat based growing media has already been reduced due to pressure from the multiple retailers. However, over the same period the amateur market has increased its demand and now accounts for 69% of peat use and it is this sector where the biggest reductions in peat use are now sought. Unfortunately, previous messages on the negative impact of peat extraction on biodiversity have not resulted in major changes to consumer behaviour, so additional actions are required that may have greater resonance. The action proposed here is to quantify the greenhouse gas (GHG) emissions associated with the production, processing, transport and use of selected growing media materials. If the emissions associated with peat alternatives were measurably smaller than peat, this could provide a powerful tool to promote behavioural change within the amateur market. The term 'growing medium' is used to describe any material used in commercial horticulture or the amateur gardener market to grow plants; the materials studied were: peat, coir, green compost, bark, wood fibre, vermiculite and perlite.

The choice of calculation and reporting unit is important. Growing media are traditionally reported on and sold by volume, however their physical characteristics (bulk densities and moisture content) can vary, making comparisons difficult. One approach is to use weight as the functional unit. The advantage of this is that most of the data available on the production and processing of growing media materials is reported by weight as are emissions of greenhouse gases and we suggest that weight is easier to 'visualise' so consequently, the calculation unit used throughout this report is the metric tonne (1000 kg) at end-use stage of the life cycle

The GHGs assessed were carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O); the study reports these emissions by weight and volume using two different but related, methods: life cycle assessment (LCA) and carbon footprinting. LCA accounts for all GHG emissions while carbon footprinting uses offsetting. Theses alternative approaches use the same data but present the results differently which allows a different perspectives to be gained.

While assessment of the GHG emissions associated with the materials was relatively straight forward, interpretation of the results was not. Using the LCA approach, the materials can be grouped into three broad categories: Finnish peat, bark and green compost emit the greatest amounts of GHGs; vermiculite, wood fibre and perlite occupy the middle ground while Irish peat, UK peat and coir emits the least. The results are heavily influenced by one characteristics (carbon content) and one process factor (end use) although transport can be significant. The variation in carbon content was considerable: peat and bark contained 50% carbon while perlite and vermiculite contained none. Since 80% of the carbon within the organic materials is assumed to decompose within the IPCC 100 year time horizon, the CO_2 emitted within the 'end use' stage dominates the results. The footprinting approach reveals that green compost is responsible for little carbon dioxide and may even sequester more than it emits and that wood based materials are even better; peat emit more GHGs than all the materials except perlite and vermiculite.

Assessing the GHG emissions of organic materials introduces a number of issues that 'normal' footprint studies don't address. One of the major issues is how to treat the changes in materials composition through the various life cycle stages. The calculation of the 'true' carbon content is critical since overall emissions are heavily dependent on this value. This study has tried to resolve this dilemma by reporting all CO_2e emissions based on an end-use status, however, this approach does not work well with low density materials like perlite and vermiculite. It would be possible to report all emissions on a dry weight basis but the results would probably have little meaning to the industry and only serve to confuse the issue even further. This study illustrates the difficulty of assessing the GHG emissions associated with organic materials. A lack of reliable data and the inherent variability in material composition makes allocating a precise carbon footprint to the different materials used in growing media a difficult task.

The materials in this study were considered in their own right and no calculations have been undertaken on the different mixtures which are normal in commercial horticulture and becoming more accepted in the amateur market. In the professional market where mixes of materials are common and quality and repeatability are essential, the results are hard to interpret. The best approach is probably the one already used by many growers, combine materials, for example peat and bark, green compost and wood fibre, to ensure the best mix for the intended purpose.

The results demonstrate that studies of this type are heavily reliant on data availability and that a lack of, and variability, of data is difficult to overcome. We suggest that future work should concentrate on collecting primary data to quantify the carbon footprint of selected products (not materials) to obtain a better understanding of the GHGs associated with, and the environmental impact of, those products.

The study has also shown that the choice of methodology is critical in interpreting the results. We suggest that research is required to demonstrate how the reporting unit (weight, volume) can be used to present the results and influence the use of growing media products and how the analysis method (full LCA, offset) can be used by to reveal the environmental impact of growing media products. Methodology must be developed to take into account different boundaries, reporting units, carbon content, bulk density and moisture contents.

In terms of total GHG emissions the LCA approach supports the use of UK and Irish peat, and coir as growing media material, however, if the carbon neutrality of short-term materials and potential sequestration is taken into account then the opposite is true and compost, timber products and coir are the preferred materials. These opposing conclusions suggest that further policy work is required to clarify the terms involved in GHG reporting, the treatment of emissions from different sources and the different timescales. Given the complexity and difficulties involved in calculating and interpreting GHG emissions from growing media materials, we conclude that the major driver for reduced peat use should remain its 'non-renewability' and potential for long-term in-situ carbon storage rather than its emissions of GHGs.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:

- the scientific objectives as set out in the contract;
- the extent to which the objectives set out in the contract have been met;
- details of methods used and the results obtained, including statistical analysis (if appropriate);
- a discussion of the results and their reliability;
- the main implications of the findings;
- possible future work; and
- any action resulting from the research (e.g. IP, Knowledge Transfer).

1. Aims and Objectives

Defra is committed to reduce the horticultural use of peat in order to meet the UK Lowland Raised Bog Habitat Action Plan. The aim is for the market for soil improvers and growing media to be 90% peat free by 2010. Progress towards this target is being monitored via Defra project WC04019 (Wallace et al., 2007); the report reveals that the proportion of peat used in growing media and soil improvers has fallen to 46% of the total market (down from 64% in 1999).

Professional use of peat based growing media has already been reduced (accounting for 30% of the market in 2007, down from 33% in 1999) due to pressure from the multiple retailers. However, over the same period the amateur market has increased its demand and now accounts for 69% of peat use (up from 66% in 1999) and it is this sector where the biggest reductions in peat use are now sought. Unfortunately, previous messages on the negative impact of peat extraction on biodiversity have not resulted in major changes to consumer behaviour (Carlile, 2004), so additional actions are required that may have greater resonance; for example, WRAP[1] are currently undertaking a campaign to promote peat free compost. The aim of this work is to quantify the greenhouse gas (GHG) emissions (carbon footprint) associated with the production, processing, transport and use of selected growing media materials. If the carbon footprint of peat alternatives were measurably smaller than peat, this could provide policymakers with an additional tool to promote behavioural change within the amateur market.

2. Introduction

The term ‘growing medium’ is used to describe any material used in commercial horticulture or the amateur gardener market to grow plants in a container. The growing media industry uses a diverse selection of materials, used on their own or mixed with other materials. The organic materials include: peat, coir, green compost and timber industry by-products and the inorganic materials: vermiculite and perlite. Growing media are often formulated from a blend of different raw materials in order to achieve the correct balance of air and water holding capacity for the plants to be grown.

Requirements of a growing medium[2]:

- To provide anchorage for the plant
- To provide adequate air spaces for root respiration
- To hold sufficient available water
- To hold sufficient available nutrients
- To be free of plant pathogens, pests and weeds
- To be safe when handled by people

Growing media has to be physically, chemically and biologically stable from the time of production until the time of use (this can be many months for retail products). The bulk density (weight by volume) of the ingredients used is also important because this affects transport costs, a major part of the total cost of production, and can influence how easy the material is to handle, both manually and mechanically, during use.

The supply chain for growing media materials is very diverse. Peat sold in the UK comes from three main sources: England, the Republic of Ireland and Finland/the Baltic states. Green waste derived composts are all sourced from within the UK, forestry and industrial wood by-products are sourced, both from within the UK and overseas and coir is imported mainly from India and Sri Lanka. Perlite and vermiculite are mined and processed globally although the main sources are South Africa, Greece and the United States. In addition to different places of origin, many of the materials employ different production, processing and supply chains and GHGs are emitted at every stage of those supply chains.

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[1] www.wrap.org.uk/home_garden_schools_and_communities/working_with_consumers/peatfree.html
[2] www.growingmedia.co.uk

The study used existing data. Primary data on many aspects of mining, extraction and processing was difficult to obtain which resulted in secondary data being used in a number of calculations. Secondary data has been extracted from academic papers, 'grey' reports and the internet. The former two sources are referenced at the end of this report while internet references are given as footnotes to the text. All the data contained within this study is presented in good faith. However, given the complexities involved in the different supply chains and the different bulk densities and moisture contents that exist through those supply chains, the data and results remain open to other interpretations.

The study adopts a life cycle assessment (LCA) approach to quantifying resource flow and GHG emissions. The different life cycle stages (extraction, harvesting, processing, transport, use, etc.) of all the materials are identified and the operations, and associated GHG emissions, within each stage are accounted for. An inventory, to hold this information, is produced for each material. The recent introduction of PAS2050 (BSI) has provided a framework for the GHG determination for goods and services which the study initially tried to follow, however, there are aspects were the LCA approach and the PAS2050 approach differ. The LCA approach quantifies all GHG emissions however PAS2050 differs by treating peat and the other organic materials differently: all GHG emissions from fossil sources (peat) are accounted for but CO_2 is excluded from biogenic sources (green compost, bark, coir & wood fibre). In addition, stored carbon can be deducted from total emissions in PAS2050. The study assesses GHG emissions using the LCA approach but presents them using both methods.

The study includes five organic materials and two mineral materials which raises a number of issues. The organic materials are assumed to be incorporated into soil and to decompose at the end of their life cycle while the mineral materials do not; the carbon contained within the organic materials is partitioned: 80% is emitted as carbon dioxide while the balance is sequestered into soil. This assumption is not true in all instances since materials decompose at different rates and emit different percentages of carbon but the assumption is required for simplicity sake. Neither does this assumption take into account other methods of disposal, for example, to landfill where the organic may decompose and emit methane.

The growing media industry reports product and market share by volume; normally cubic metres. However, LCA studies (and PAS2050) use weight. The conflict between these two reporting units is resolvable but requires careful interpretation. The study uses weight for calculating resource flow and GHG emissions, but the results are reported using both weight and volume. This approach makes interpretation of the results difficult and very careful consideration should be undertaken before judging one approach to be better than the other, for both reveal different aspects of the materials behaviour.

3. Methods

3.1. Growing media materials

In 2007, the market for growing media was 6.6 million m^3 of which 3.0 million m^3 was peat and 3.6 million m^3 was alternatives (Wallace et al., 2007). The materials selected for this study account for greater than 90% of the total market (country of origin) and [market percentage in 2007]:

- Peat (UK, Ireland, Finland/Baltic states) [46%]
- Green compost (UK) [15%]
- Bark (UK & EU) [30%]
- Wood fibre (UK & EU) [1%]
- Coir (India & Sri Lanka) [0.5%]
- Perlite (Greece)
- Vermiculite (South Africa

Two common materials are excluded from the study: rockwool which is used in specialised glasshouse production, and spent mushroom compost since the amounts used are reducing. The analysis of growing media is based on ‘single material’ use; no mixes, e.g. peat/coir, are considered and any fertilizing value is excluded.

3.2. Project boundary

For any life cycle assessment or footprinting study, the definition of the production and consumption system boundaries can have a profound effect on the result, so it is important to define the exact boundary of the system and, if possible, to ensure that any comparisons made are fair. This study looks at a diverse range of materials, both organic and inorganic, which are manufactured from very different feedstocks. Consequently it is inevitable that problems and conflicts will arise; some of the issues are discussed in the sections 3.3 to 3.11.

3.3. Change in land use

Land from which peat has been extracted has undergone an obvious change in land use with subsequent emissions of GHGs. It is generally accepted that undisturbed peatlands sequester carbon dioxide (CO_2) and emit methane (CH_4) while abandoned peatlands, from which peat has been extracted commercially, emit CO_2 and nitrous oxide (N_2O) but not CH_4. In terms of CO_2, it is easy to conclude that peat extraction is a detrimental operation as it increases emissions and reduces sequestration, however, when the three main GHGs are considered together, it is hard to be so confident. In some locations, the global warming effect of the increased CO_2 emissions from abandoned peatland is less than the CH_4 emissions from undisturbed peatlands. This situation can be further complicated where drained peatlands have been used for forestry. The balance between what is perceived to be good or bad is a fine line and dependent on many environmental and climatic factors.

Peat is not the only growing media material which has land use change associated with its production; to some extent so do all the other growing media under study. Surface mining of perlite and vermiculite ores is an obvious example but forestry operations can also involve major changes in land use which can have long lasting effects on the landscape and associated GHG emissions.

PAS2050 considers land use change to be the conversion of non-agricultural land to agricultural land as a consequence of producing an agricultural product, as an input to a product on that land or as a consequence of changes in agricultural practice elsewhere; the PAS only includes emissions from land use change that occurred after 1 January 1990. Those criteria suggest that the PAS cannot be applied to land use change brought about from the production of growing media as both the classification and timescale are difficult to apply.

The original remit for this study included quantifying the GHG emissions associated with changes in land use for peat, perlite and vermiculite but excluded green compost and forestry materials. However, how the environmental burdens resulting from changes in land use are allocated to materials is still a topic which is under discussion within the wider research community and no consensus has yet been reached on the best approach. We suggest that the inclusion of emissions resulting from changes in land use would compromise the analysis of all the other life cycle stages and could add to (or subtract from) the carbon footprint of the materials, so subsequently it was decided to report on this topic where possible (peat) but to exclude the data from the final calculations.

3.4. Allocation of burdens

How the burden of GHG emissions are allocated to materials, co-products and waste materials is a dilemma. Where there is a single material from a process, e.g. as in peat extraction, perlite and vermiculite, all the burdens are allocated to the material. However, where the growing medium is based on a co-product (bark, wood fibre, coir) or on a waste material (green compost), it is hard to allocate a share of the burden. There is a line of argument that suggests that all the burden should remain with the primary material and that the co-product or waste should be free of burden. An alternative approach suggests that the burden should be proportionally applied, e.g. the energy required to extract the coir pith should be compared to that with extracting the coir fibre and coconut flesh and milk and the proportion that is relevant applied to the growing medium material. The approach used in PAS2050 (section 8.1.1.) is to allocation emissions to co-products where possible and this approach is used in this study.

3.5. Reporting unit, weight, bulk density and carbon content

The choice of functional (reporting) unit is very influential to the results. Growing media materials are traditionally reported on and sold by volume, however their bulk densities can be very different (Wever & van Winkel, 2004; Kang et al., 2004a; Kang et al., 2004b) making any comparisons difficult to interpret. For example, the bulk density of undisturbed peat varies with botanical composition, moisture content, its degree of decomposition, depth and location and values can be as low as 40 kg m^{-3} or as high as 400 kg m^{-3} (Parent & Ilnicki, 2003). The bulk density of milled and air-dried peat is lower but this status changes according to the production stage since peat normally undergoes compression before packaging and sale. These different physical characteristics combined with different processing techniques make it difficult to assign a single value to peat through the supply chain.

The bulk density of green compost also varies with feedstock material, time of the year, moisture content and degree of composting/maturation; Ward et al. (2005a,b) reported an average value of 551 kg m^{-3} across nine sites and twelve sampling dates although Wallace et al. (2007) use 600 kg m^{-3} in their monitoring scheme. Green compost has one other issue in that mass loss is an integral part of its production. Although it is possible to overcome some of the issues pertaining to bulk density by reporting the value at ‘end use’; in the case of green compost this could under-estimate the volume of feedstock material by up to 35%.

Table 1. Carbon content (dry weight), bulk density (fresh weight) and % dry matter of growing media materials

Material	% Carbon (dry weight)		Bulk density (kg m^{-3})		Dry matter (%)	
	At ‘end use’ stage	Range	At ‘end use’ stage	Range	At ‘end use’ stage	Range
Peat	50	45 \ 62	300	233 \ 424	37	27 \ 47
Compost	20	15 \ 30	550	400 \ 772	61	52 \ 69
Coir	50	10 \ 51	350	80 \ 600	20	-
Bark	50	49 \ 53	350	250 \ 450	54	35 \74
Wood fibre	50	50	120	95 \ 120	45	-
Perlite	0	0	90	45 \ 180	>99	-
Vermiculite	0	0	80	60 \ 120	>99	-

The difficulty of using volume is further highlighted where perlite and vermiculite are considered. Their crushed and sorted ores have bulk densities[3] between 1200 and 1450 kg m^{-3} yet the expanded final

[3] www.onemine.org/search/summary.cfm/Industrial-Minerals--Perlite-Industry?d=A1902A6E5116B9C743CB6D2C2A140E95A9D9BFA86710BBADC66A53DD1060CCAC24124&fullText=ore%20bulk%20density%20primary%20crusher

material has a low bulk density between 80 and 90 kg m^{-3}. Methods exist to overcome these difficulties; however, we suggest that adopting volume as the functional unit is confusing and open to many interpretations.

The approach in this study is to use weight as the functional unit. The advantage is that most of the data available on the production and processing of growing media materials is reported by weight as are emissions of GHGs. However, weight also has disadvantages, namely that the bulk densities and moisture contents of the different organic growing media vary which can cause problems for the logistics of growing media transport and use where volume, not weight, is the restricting factor. Analysis carried out as part of this project on four different commercially available horticultural peats reported bulk density values between 233 and 424 kg m^{-3} while dry matter ranged between 27 and 47%. We suggest that weight is easier to 'visualise' so consequently, the functional unit used throughout this report is the metric tonne (t), meaning 1000 kg, at end-use stage of the life cycle. This study uses average moisture contents for peat, composts, forestry materials and coir; but perlite and vermiculite are reported on a dry weight basis. We acknowledge that reporting by volume may be required so Table 1 lists the bulk density and moisture contents of the growing media at their 'end use' stage.

The carbon content of the individual materials is the single biggest influence on the release of CO_2 during the end use stage and, like bulk density, can vary greatly. Couwenburg[4] reported that dry peat has a carbon content of 45 to 60%, Hall[5] suggested 49 to 62%.

Ward et al. (2005b) reported an average carbon content of 21.3% across a range of green composts (18.0 to 25.4%); the same analysis reported that the average bulk density was 550 kg m^{-3} (range 456 to 671 kg m^{-3}) and an average dry matter of 61% (range 52 to 69%).

Various workers have reported the physical properties of coir: Bhanu Prakash et al. (2007) found the carbon content to be 38%; VUAT reported 25%[6]; Meerow[7] gave 45 to 50% and Colla et al. found 51% however The Coir Institute reports a values as low as 10%[8]. This study uses 50%. The bulk density of coir varies with the life cycle stage. Newly extracted dry coir has a bulk density between 40 and 80 kg m^{-3} but is compressed for shipping and sale to 600 kg m^{-3} but then decompressed to 350 kg m^{-3} for use.

Generically, wood is assumed to contain 50% carbon (Lamlorn & Savidge, 2003; Forestry Commission[9]) although values for pine bark and wood fibre are harder to obtain. Johannes et al (2006) reported that dry pine bark contained 52% carbon while spruce branches contained 50%. The bulk density of pine bark is between 330 and 450 kg m^{-3} (commercial personal comm.) while wood fibre can have a bulk density between 95 kg m^{-3} (EKOFibre[10]) and 120 kg m^{-3} (commercial personal comm.).

Perlite is an mineral material and contains no carbon. The bulk density of expanded perlite depends on its particle density and grading[11] and ranges between 45 and 180 kg m^{-3}. Physically, vermiculite is similar to perlite. It contains no carbon and its bulk density[12] ranges between 60 and 120 kg m^{-3}.

The results are reported by the different life cycle stages: changes in land use (where applicable); extraction and harvesting; processing; transport and end use. The system boundary, as specified in PAS 2050, excludes all the GHG emissions associated with capital goods.

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[4] www.imcg.net/imcgnl/nl0702/kap05.htm
[5] www.viewsofscotland.org/snp_conference/PeatAudit-Guide.pdf
[6] www.vuatkerala.org/static/eng/advisory/agri/coconut/coirpith.htm (accessed 27/11/2008)
[7] flrec.ifas.ufl.edu/Hort/Environmental/Media_Nutrition/COIR%20potential.htm (accessed 27/11/2008)
[8] www.coirinstitute.com/coir_peat.htm (accessed 27/11/2008)
[9] www.forestry.gov.uk/forestry/infd-6vll5y (accessed 28/11/2008)
[10] www.ekofibre.com/products.html (accessed 27/11/2008)
[11] www.william-sinclair.co.uk/industrial/products/perlite (accessed 27/11/2008)
[12] www.william-sinclair.co.uk/industrial/products/vermiculite? (accessed 27/11/2008)

3.6. Emission factors

Emission factors (the amount of CO_2e emitted by different energy sources and transport types) vary from source to source and from country to country and by the capacity and fuel efficiency of the transport medium. Where possible the values used in this study are from official UK sources, mainly Defra.

Table 2. Direct emissions of CO_2e by fuel and transport type

Fuel or process	kg CO_2e	
Diesel (litres)	2.63	Defra, 2007
Electricity (kWh)	0.527	Defra, 2007
Natural gas (kWh)	0.206	Defra, 2007
Shipping – small bulk carrier (t km^{-1})	0.014	Defra, 2005
Shipping – large bulk carrier (t km^{-1})	0.007	Defra, 2005
Rail (t km^{-1})	0.03	Defra, 2005
Road freight (t km^{-1})	0.138	McKinnon, 2006
Passenger car (km)	0.20	Defra, 2007

3.7. Greenhouse gases

The Intergovernmental Panel on Climate Change (IPCC)[13] recognises twenty or more gases with global warming potentials (GWP). Only the three most significant are considered in this study: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). This study quantifies and reports the individual and total (carbon footprint, see section 3.8) greenhouses gases associated with selected growing media materials.

CO_2 production occurs from all the life cycle stages of growing media materials and arises from two main processes: natural (biological) processes and the combustion of fossil fuels (oil, gas and biomass) to produce energy. Emissions of CH_4 arise from natural processes associated mainly with undisturbed peatlands although CH_4 can be emitted if composting systems are allowed to go anaerobic and during coconut retting. N_2O is emitted naturally from land but emissions can be boosted by the application of fertilizers and returning high nitrogen containing organic material to land, for example, manures. This study has attempted to quantify the increases in CO_2 and N_2O, and the decreases in CH_4, that occur when peatlands are drained for extraction. However, fluxes of GHGs from peatlands vary with location, the height of the water table and temperature and it is notoriously difficult to obtain accurate data.

This study has assessed energy use (natural gas, diesel and electricity) within the extraction, processing, distribution and application life cycle stages. The treatment of energy sources within the study is not straight forward. The assumption is that all sources of electricity have the same CO_2 emissions associated with them. However, this may not always be true. Wood fibre production in Germany and coir production in India are both known to use renewable energy sources while the electricity used in Finnish peat production may have been produced by peat burning power stations. Accounting for the different CO_2 emissions associated with different energy generation systems is beyond the scope of this study.

The temporal boundary of this study is the IPCC's 100 year time horizon. This is adopted for a number of reasons: it is a standard reporting time frame used by a number of organisations and methods, including PAS2050 and it allows the issue that different growing media decompose at different rates to be overcome since it assumes that all organic material will decompose within a 100 years.

[13] www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.html

This study assumes that 80% of the carbon within any organic material will be lost as CO_2 within the 100 year time frame and that the remaining 20% is sequestered into the soil carbon store. An assumption of this type is necessary to explore how the carbon content of the different growing media effects overall emission of GHG emissions and sequestration of organic carbon since long term datasets are unavailable. This assumption is based on Campbell (2007) and US EPA (2007), however actual rates may be different.

3.8. Carbon footprint

The GHGs considered in this project are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Each of these gases has a global warming potential (GWP) based on the radiative forcing of a tonne of the gas over a given time period compared to a tonne of CO_2. The GWP over 100 years of carbon dioxide is 1, methane is 25 and nitrous oxide 298; so for example, one tonne of nitrous oxide has 298 times the global warming potential of carbon dioxide. The GWP value provides a method to allow direct comparison between the different gases and also allows the quantity of the gases to be summed and expressed as standard unit, the carbon equivalent (CO_2e) for reporting purposes. For example, a material which was responsible for emitting 1 kg each of CO_2, CH_4 and N_2O would have a carbon footprint (CO_2e) of 324 kg over the IPCC 100 year time horizon. A carbon equivalent value can also be referred to as a carbon footprint and has units of kg CO_2e.

3.9. Offsetting (treatment of different carbon sources and carbon storage)

PAS2050 describes offsetting as a 'mechanism for claiming a reduction in GHG emissions associated with a material through the removal of, or preventing the release of, GHG emissions unrelated to the life cycle of the material being assessed'. Offsetting is excluded within PAS2050 so that baseline GHG emissions can be established for materials without external factors being taken into account.

PAS2050 excludes offsetting, however, it does treat fossil carbon (peat) differently from biogenic carbon (green compost, bark, wood fibre, coir). CO_2 emissions associated with biogenic carbon may be excluded from the GHG totals but those associated with fossil carbon are included. Emissions of CH_4 and N_2O are still included for all materials. This is an ambiguous approach but it does illustrate how methodology can influence the results.

PAS2050 allows for biogenic carbon stored within products to be deducted from overall GHG emissions; this study extends the carbon storage to fossil products as well. This allows the carbon sequestered by the materials in the 'end of life' stage to be deducted from the final total.

This study reports the 'LCA' carbon footprint where all emissions are included in the final total and also an 'offset' carbon footprint which excludes emissions of carbon dioxide from biogenic materials and deducts emissions associated with stored carbon (section 5.2 and 5.4).

3.10. Packaging

This study does not consider the GHG emissions associated with any transport or retail packaging. All the materials examined in this study use, at some point in their life cycle, either polythene or polypropylene as packaging, either within the transport phase or retail phase of their life cycles. The difficulty in examining materials, rather than individual products, is the vast range of packaging types, materials and sizes in use. If product life cycle assessments are undertaken in the future then packaging should be included but the scope of this project excludes it. However, as an example of a worst case scenario, an assumption can be made that one tonne of peat is sold in 70 litre polythene bags and that the individual bags weight 0.1 kg; 1 kg of polythene is responsible for 8.4 kg CO_2 and one tonne of peat would require 48 bags resulting in emission of 40 kg CO_2 t^{-1}.

3.11. Data quality

This desk study used a number of different data sources to populate the GHG inventories. These range from peer-reviewed papers and published 'grey' reports to internet sources. Every effort has been made to ensure that the data contained with this report is accurate and it is used in good faith, however, errors and mistakes can occur and the University of Warwick does not accept any liability for these or for any consequences based on this information.

Data quality was variable. Due to the large number of unique sources, we cannot allocate uncertainty to any one set of data for individual life cycle stages nor can estimates of error across the whole life cycle be made. The study tries to provide some indication of variability by presenting a range of results but we acknowledge that is some instances, even this is not helpful.

However, to provide some guidance we have judged the data using a 1 to 5 scale, where 1 is very poor and five is very good. This is based on the author's expert knowledge and research; we estimate the following:

- Peat (3/5)
- Compost (4/5)
- Coir (2/5)
- Bark (3/5)
- Wood fibre (2/5)
- Perlite (1/5)
- Vermiculite (1/5)

4. Results

This section reports the GHG emissions associated with the different life cycle stages of the growing media materials. Sections 4.1 to 4.7 deal with the individual materials and sections 4.8 and 4.9 with the results by different reporting unit (weight and volume) and methodology (LCA and offsetting).

4.1. Peat

Source of material

Most of the peat used in UK growing media materials originates from the UK and the Republic of Ireland (approximately equal amounts from each). A small amount (<5%) is imported from Northern Europe, mainly the Baltic States (e.g. Lithuania and Estonia) and Finland. Around 3 million cubic metres of peat are used annually by the UK horticulture sector, most of this in growing media. The main markets for this peat are amateur gardener growing media products (for example Grow-Bags and Multipurpose Compost) and professional growing media products used by commercial nurseries.

The type of peat used in such products is usually sphagnum peat which is moderately decomposed and is sourced from peat bogs with suitable quality peat. It is not the same type of peat that is used for energy production in power stations but may originate from different layers in the same peat bog. The formation of the peat used in horticulture, in lowland raised mires, takes thousands of years and in the process large amounts of carbon are stored in peat and peat-based soils.

Changes in land use

Undisturbed peatlands are characterized by a high water table and full vegetation cover and are generally sinks for CO_2 and sources of CH_4, although the fluxes of both gases vary with temperature and the height of the water table; fluxes of N_2O from undisturbed peatland are minimal (Martikainen et al., 1993) and are controlled by the availability of nitrate.

The fluxes of GHGs from peatlands vary greatly and depend on their hydrology and ambient temperature. Peatlands can vary annually between being a source or sink for GHGs and it is only when a 100 year plus time horizon is considered that peatlands have been considered a sink for CO_2. Annual fluxes have been calculated by many workers but the variation contained in their results requires careful consideration when assessing whether a peatland is a source or sink. Sirin and Laine (2008) reviewing peatland GHGs reported emissions between 1,835 and 14,680 kg CO_2 ha^{-1} yr^{-1} with very high variations in fluxes; the same review suggested that boreal peatlands emit between zero and 700 kg ha^{-1} yr^{-1} of CH_4. A review by Cleary et al. (2005) reported that undisturbed Canadian peatlands typically emit 53 kg ha^{-1} yr^{-1} of CH_4 but sequester 991 kg ha^{-1} yr^{-1} of CO_2 . Moore et al. (2002) working on a raised bog in Ottawa reported sequestration of 2,202 kg ha^{-1} yr^{-1} CO_2. Laine et al. (2007) working on Irish lowland blanket bog found CH_4 fluxes to be between 11 and 193 kg ha^{-1} yr^{-1}. In summary, undisturbed peatlands are both a source, and sink of GHGs, often at the same time since differences in topology (hummocks and hollows), vegetation and the height of the water table means that one area may be emitting CO_2 while an area in close proximity may be sequestering it. Hummocks and hollows may also be emitters, or not, of CH_4.

Although the fluxes of CO_2 and the build up of peat in the last 10,000 years, might suggest that overall peatlands are a sink for GHGs, this is not always the case when the overall effect on global warming is assessed. Over a 100 year time horizon, the global warming potential of CH_4 is 25 times that of CO_2. Applying this GWP approach to Cleary's data reveals that the impact of CH_4 emissions (1,325 kg ha^{-1} yr^{-1} CO_2e) are greater than the carbon sequestration (991 kg ha^{-1} yr^{-1} CO_2e). Given the variability of GHG fluxes from peatlands, this is not always true but neither is it true to state that peatlands are always sinks for GHGs – they aren't. They always sequester carbon but emissions of other GHGs may be greater than the carbon sequestered. Strack et al (2008) suggested that over short periods (20 years) peatlands are overall sources of GHGs but are sinks when a 100 year time horizon is considered although this does not agree with Cleary's data.

Extraction and harvesting

Peatlands, from which peat is to be extracted, are drained so that the surface dries sufficiently to allow heavy machinery to be used, the surface vegetation is removed and the surface is levelled. Specialised machinery is used to loosen and surface-mill the peat which is then allowed to dry before being harvested using vacuum techniques; peat can also be harvested in blocks although this is more common for harvesting frozen peat in northern Europe. Peat not required for immediate processing is stockpiled for storage. Harvesting occurs during the drier summer months, typically between May and September. Imports from Europe into the UK tend to increase following wet summers in England, Ireland and Scotland and hence shortages in domestic supplies.

We have used two approaches to estimate the emissions of CO_2e associated with the extraction and harvesting phase of the peat life cycle. The first is a bottom up, component approach which seeks to identify, and quantify, every stage and to allocate a CO_2 equivalent (CO_2e) burden whereas the second approach uses overall values from the literature.

Drainage of peatlands for peat extraction results in increased emissions of CO_2 and N_2O and a decrease in CH_4 (Charman, 2002). Alm et al (2007) combined current and previous work and estimated that peatlands under peat extraction in Finland emitted 9,625 kg ha^{-1} yr^{-1} CO_2, 72 kg ha^{-1} yr^{-1} CH_4 and 3 kg

ha^{-1} yr^{-1} N_2O respectively. This equates to 12,313 kg CO_2e ha^{-1} yr^{-1}. In Ireland, Styles & Jones (2007) found a net increase of 2908 kg ha^{-1} yr^{-1} CO_2e after drainage. However, it should be remembered that these are peak emission rates and only representative of the years when peat is being extracted. This study uses an average of these two values and assumes that each hectare of peatland under extraction emits 7611 kg ha^{-1} yr^{-1} CO_2e per annum; based on a yield of 600 tonnes of peat per annum this means that each tonne is responsible for 13 kg CO_2e yr^{-1}. This value is higher than the IPCC's Tier 1 emission factors for land managed for peat extraction which suggest that emissions range between 733 and 4033 kg ha^{-1} yr^{-1} CO_2 and between 0 and 3 kg ha^{-1} yr^{-1} N_2O; methane emissions from drained peatlands are assumed to be insignificant (IPCC, 2006).

Land clearance, peat extraction and harvesting are mechanical processes, akin to operations undertaken in agriculture, on which a lot of the data is based. Installing drains, removal of surface vegetation and surface levelling are undertaken using hydraulic excavators and consume 200 litres of diesel per hectare while extraction, milling, harvesting and transport account for another 667 litres per hectare. Although the depth of harvested peat varies with location, we assume that during the operational life of peat extraction, a two metre depth of peat is removed, meaning that 20,000 m^3 is extracted per hectare. The bulk density of peat varies with location; we assume 300 kg m^{-3}. We calculate that the diesel used to extract and harvest a tonne of peat is responsible for 0.38 kg CO_2e.

Harvesting of peat can only take place during good weather so annual yields vary. We assume that 0.20 m depth is harvested annually. Harvested peat that is not required for immediate processing is stockpiled for later processing; these stockpiles emit CO_2 as the peat decomposes. Lapveteläinen et al (2007) suggested that, based on Finland's national GHG inventory, stockpiled peat can emit up to 1750 kg CO_2e ha^{-1} yr^{-1}; based on our harvest assumptions we estimate that this adds 6 kg CO_2e yr^{-1} to overall emissions.

The extraction and harvesting stage emits 19.38 kg CO_2e. However, the dry matter content of in-situ un-harvested peat is different to that at its end-use stage so therefore a multiplier is required to ensure that the data is comparable. We assume that in-situ peat has a dry matter content of 20%, compared to 37% at its end-use stage, so a multiplier of is 1.85 is applied. This equates to end-use stage emissions of 36 kg CO_2e t^{-1}.

Processing

After harvest, peat is transported to the growing media manufacturer's factory where it is stored and then graded (typically over 'star-screen' graders) to produce different size fractions. Peat can be compressed into bales or 'Intermediate Bulk Containers' (typically 1 or 2 m^3) for transport or may be shipped loose. Some peat is sold as the raw material to growers who mix their own growing media but the majority is blended with other materials, lime and fertiliser to produce growing media which are then transported by lorry to professional nurseries and retailers. This is typically supplied in bulk containers (large growers) or 70 litre plastic bags (small growers) or in a range of bag sizes for retail sale. Bagged growing media are stored and transported on wooden pallets with plastic shrink wrap and a plastic hood to keep them dry over winter as they are manufactured from October onwards for supply the following spring. This study was unable to establish a value for energy usage for peat processing, however it is assumed that it isn't large so is allocated a nominal value of 13 kg CO_2e t^{-1} yr^{-1} (this is the same as for screening bark for which data was available); the same multiplier for dry matter content is are applied which gives 24 CO_2e t^{-1} for the processing stage.

Excluding the dry matter multiplier, this bottom up, component approach suggests that the combined emissions for the extraction and processing stage are 60 kg CO_2e t^{-1}. This is more than double the value of 28 kg CO_2e t^{-1} reported by Cleary et al (2005) for the extraction and processing of Canadian peat.

Transport, distribution and retail

Most growing media manufacturers in the UK were originally sited close to the peat bogs that they owned, or had extraction rights to, and therefore are mostly located in northern England, Northern Ireland and Somerset. Those that import peat from the Baltic States and Finland are located near to ports for easier import of bulk peat although transport by road is currently preferred. We assume that distribution within the UK incurs 200 km by lorry, import from the Republic of Ireland, 600 km and from Finland, 2300 km; the CO_2 emitted by a lorry for those journeys is 28, 83 and 317 kg $CO_2e\ t^{-1}$ respectively.

Transport of material from wholesaler or retailer to the point of use by customers varies greatly; this study presents two scenarios: (1) for commercial customers, peat is transported in bulk bags by lorry over a distance of 100 km which this emits 14 kg $CO_2e\ t^{-1}$; for amateur customers, two 70 litre bags are transported over a distance of 20 km in an average diesel car which emits 95 kg $CO_2e\ t^{-1}$. Consequently, the emissions associated with all the transport stages can be between 42 and 412 kg $CO_2e\ t^{-1}$.

End of life

The end-of-life for the organic growing media materials over the IPCC 100 year time horizon is complete decomposition; in contrast to the non-organic materials, perlite and vermiculite, which do not decompose. For the purposes of this study, we assume that 20% of the carbon contained within peat is sequestered into the soil organic matter and that the remaining 80% is emitted as CO_2. The carbon content and bulk densities of the materials in this study (Table 1) vary greatly so an assumption of this type is required to avoid over complication. Each tonne of peat contains 370 kg dry matter of which 185 kg is carbon; 37 kg will be sequestered while the balance is emitted as 543 kg CO_2e.

4.2. Green compost

Source of material

Garden (green) wastes are collected from municipal kerbsides in the UK, taken to civic amenity sites by the public or are delivered to composting sites by landscaping businesses. Although the majority of organic wastes collected are green wastes, other waste types can be included in composts including clean wood, paper and card and food; there can be issues concerning potential physical, biological and chemical contaminants as well as visual appearance for some of these materials. As food wastes can provide excess nutrients and salt content in end materials, these materials are not usually included in composts destined for inclusion in growing media although small amount of food wastes included in kerbside collections, e.g. meat-excluded catering wastes, may be technically acceptable for inclusion into composting where the materials are to be used in growing media. Approximately 322,000 cubic metres of green compost is used annually in UK growing media (Wallace et al., 2007).

Collection

The collection systems employed incur greenhouse emissions during transport. There is debate about the relative benefits of weekly versus fortnightly collection schemes and the distances involved in collecting green waste vary depending on the area and mix of urban and rural housing. For the purposes of this study, we use an average of the values presented by Forbes et al (2001) which is 9.1 litres of diesel consumed per tonne of material collected.

Loss of mass during the composting process varies with feedstock material but can be as high as 40%[14], however our calculations are based on a more conservative 35%. We suggest that every tonne of green

[14] www3.imperial.ac.uk/pls/portallive/docs/1/33773704.PDF

compost produced required 1.54 tonnes of feedstock material which means that 14 litres of diesel is required per tonne which equates to 37 kg $CO_2e\ t^{-1}$.

Processing

Green wastes are normally composted in simple windrow systems although there are examples of in-vessel composting e.g. at Viridor Waste Management Ltd's Beddington site in London. Where feedstocks include catering wastes or meat contaminated commercial and industrial food wastes, an in-vessel system is mandatory. This study is based on a windrow system.

There are two different sources of CO_2 in the processing stage: (1) loss of carbon as respiration as a result of the biological degradation of the material and (2) emissions produced from the mechanical handling of the material through the reception, shredding, composting, screening and dispatch processes. Based on our assumption that 35% of the original feedstock material is lost during composting, this equates to 540 kg green waste containing 108 kg carbon which is responsible for the emission of 396 kg CO_2. Diesel use for mechanical handling is based on an average of two studies (Campbell, 2003 and personal comm. from Simpro, UK) and indicate that it requires an average of 4.5 litres to produce a tonne of green compost, which emits 12 kg $CO_2e\ t^{-1}$. The total for the processing stage is therefore 408 $CO_2e\ t^{-1}$.

Transport, distribution and retail

Green compost has two distinct markets: on its own as an application to agricultural land as a soil conditioner or blended with other growing media materials. The first market is excluded from this study but the latter process is normally undertaken by the growing media company, rather than a composting company, and frequently involves the compost being transported although the distances are rarely significant; this study assumes a nominal distance of 50 km by lorry which emits 7 kg $CO_2e\ t^{-1}$. Distribution and retail are assumed to be the same for all growing media materials and a value of between 44 and 125 kg $CO_2e\ t^{-1}$ is used (see peat section 3.1 for details).

End of life

For the purposes of this study, we assume that 20% of the carbon contained within green compost is sequestered into the soil organic matter and that the remaining 80% is emitted as CO_2. The carbon content and bulk densities of the materials in this study (Table 1) vary greatly so an assumption of this type is required to avoid over complication. Each tonne of green compost contains 610 kg dry matter of which 122 kg is carbon; 24 kg will be sequestered while the balance is emitted as 358 kg CO_2e.

4.3. Coir

Source of material

The coir pith used in horticulture is normally a by-product of coir fibre production from India and Sri Lanka although dedicated operations to supply horticultural coir are becoming more common. Approximately 31,000 cubic metres is used annually in UK growing media (Wallace et al., 2007).

Extraction and harvesting

The pith is extracted from the layer of fibrous pulp that protects the coconut. Coconuts are split, either manually or mechanically, to remove the edible part and then husks are processed for coir. There are three different approaches to pith extraction: sprinkling and shredding, retting or mechanical decortication. Fresh water soaking is preferred in the Indian State of Tamil Nadu as the material is of a higher quality although retting is still practiced in the Indian State of Kerala and in Sri Lanka although it is declining in popularity. There is a limited amount of mechanical decortication carried out in India.

The sprinkling process involves dampening down the husks twice a day with fresh water for a two week period which softens the husks prior to mechanical or manual shredding. This process relies mostly on manual labour but we allow a nominal 2 kg CO_2e t^{-1} to cover the use of diesel for material handling and water pumping. In retting, the remaining fibrous pulp is soaked for an extended period to allow it to soften. Retting can take between two weeks and six months depending on the ripeness of the fruit and the type of retting system used. Retting is an anaerobic process in which the binding material in the coconut husk is decomposed to allow easy removal of the fibre; 9 kg of CH_4 are emitted per tonne of husk retted[15] and an average husk contains 70% coir dust which equates to 6.3 kg CH_4 or 158 kg CO_2e t^{-1}. In decorticating, the husk is shredded to extract the coir. This process uses an electrically driven machine emitting 26 kg CO_2e t^{-1}. All the other processes rely to a large extent on manual labour but we allow a nominal 2 kg CO_2e t^{-1} to cover the use of diesel for material handling. Coir for UK horticulture use comes from both India and Sri Lanka and probably uses a combination of all three methods. In summary, emissions can range between 4 and 160 kg CO_2e t^{-1} depending on the method employed.

Processing

After extraction, the fibres are separated from the pulp, washed and dried; again this process can be achieved by hand or by machine. The coir pith used in horticulture is a by-product of the more valuable coir fibre. In the past, coir pith (dust) was classified as a waste material and stockpiled, however, now that its horticultural value has been recognised those piles have reduced and the majority of coir pith supplied into the horticultural industry is freshly extracted. Depending on the age of the stockpile it is likely that some decomposition has taken place but no data on CO_2 emissions has been identified so this possible source is excluded from the analysis. The amount of processing, and therefore the energy inputs, varies depending on the age and source of the pith. The CO_2 emissions associated with the processing are minimal and difficult to quantify; we assume a nominal 5 kg CO_2e t^{-1}. The pith is dried and compressed into bales before transport; this adds 35 kg CO_2e t^{-1}.

Transport, distribution and retail

Transport of coir is based on bulk transport by sea into Felixstowe (11,000 km) and some road transport at either end (150 km). We calculate that this stage contributes 98 kg CO_2e t^{-1}. Distribution and retail are assumed to be the same for all growing media materials and a value between 44 and 125 kg CO_2e t^{-1} is used.

End of life

Before use, the pith requires reconstituting by soaking in water and may also require washing and chemical buffering before use; we allow a nominal 2 kg CO_2e. For the purposes of this study, we assume that 20% of the carbon contained within coir is sequestered into the soil organic matter and that the remaining 80% is emitted as CO_2. The carbon content and bulk densities of the materials in this study (Table 1) vary greatly so an assumption of this type is required to avoid over complication. Each tonne of coir contains 200 kg dry matter of which 100 kg is carbon; 20 kg will be sequestered while the balance is emitted as 294 kg CO_2e.

[15] www.kerenvis.nic.in/files/pubs/SOE_05/chapter2_p13-34.pdf (2005 State of the Environment Report)

4.4. Bark

Changes in land use

Commercial forestry does not necessarily involve any major changes in land use but that depends on whether the land area has always supported forestry or has been changed from another type of land use. Forestry does incorporate major disturbances at harvest and replanting, however, that only happens every 30 to 60 years. This study assumes that any GHG emissions associated with changes in land use are minimal in comparison to the carbon sequestered in forest soils and the timber itself.

Harvesting

Bark used in growing media in the UK is either a by-product of UK forestry operations or imported (mainly from southern Europe by ship and road). Approximately 455,000 cubic metres of bark are used annually in UK growing media (Wallace et al., 2007); this value is a 16% increase on the 2005 volume due to continuing demand for reduced peat products, especially in the retail growing media market. The main types of bark used in UK horticulture are pine and spruce. The former is particularly favoured to increase aeration in growing media. No data could be found relating to GHG emissions from bark production and harvesting so the following estimates are based on Sonne (2006) who reported the results of an LCA from the Pacific North West. Under a 50 year rotation on Douglas Fir, each cubic metre of harvested timber was responsible for 28 kg CO_2e. Allocating a proportion of those GHGs to the bark is difficult but based on an average timber bark content[16] of 13% we suggest that 4 kg CO_2e is emitted for every tonne of bark.

Shredding and screening

There are several large bark distributors in the UK who supply to growing media and mulch manufacturers. Processing is either a single or dual stage operation. All bark is screened to produce chips of a consistent size which can maintain their structure in a growing medium for several years and hence maintain aeration within the medium; some bark is milled prior to screening although this is a minority. Finer grades are used in propagation media and for peat dilution; coarser ones (>10mm) for potting of larger trees and shrubs. High quality growing bark may have to be screened several times in order to remove the 'fines' which would otherwise block drainage pores in the end product.

The bark fines are used in lower specification products and for partial peat replacement. Bark and brash materials are used at 15-100% of the total growing media mix. Spruce bark is more stringy and harder to separate from the 'white wood' beneath it and is used as a cheaper alternative to pine bark in growing media. Other by-products from the timber industry forestry operations are also used in horticulture on a small scale, for example sawdust is being increasingly utilized.

The screening and packing process is normally powered by electricity and/or diesel and an average operation emits 13 kg CO_2e t^{-1} of bark (commercial personal comm.).

When bark is used in a growing medium there is some immobilisation of nitrogen by micro-organisms during decomposition of the bark and therefore a small amount of extra nitrogen fertiliser can be added to the growing medium to counteract this. This can give rise to emissions of N_2O but they are minimal and not considered further.

[16] www.ruraltech.org/projects/conversions/briggs_conversions/briggs_ch11/chapter11_combined.pdf

Transport, distribution and retail

Transport of raw bark from forest to processing is based on two systems. (1) Importation of bark from northern Spain incurs road transport at either end (100 km) and bulk transport by sea into Avonmouth (1,100 km); we calculate that this emits 22 kg CO_2e t^{-1}. (2) Road transport within the UK of 200 km is responsible for 28 kg CO_2e t^{-1}.

Distribution and retail are assumed to be the same for all growing media materials and a value between 44 and 125 kg CO_2e t^{-1} is used.

End of life

For the purposes of this study, we assume that 20% of the carbon contained within the bark is sequestered into the soil organic matter and that the remaining 80% is emitted as CO_2. The carbon content and bulk densities of the materials in this study (Table 1) vary greatly so an assumption of this type is required to avoid over complication. Each tonne of wood bark contains 540 kg dry matter of which 270 kg is carbon; 54 kg will be sequestered while the balance is emitted as 793 kg CO_2e.

4.5. Wood fibre

Source of material

Wood fibre used in UK growing media is mostly imported from Germany or Northern Ireland. Wood fibre is relatively expensive to import because it cannot be compressed in the same way as peat or coir and this has restricted its use in the UK despite its useful characteristics as a peat replacement. Around 48,000 cubic metres of wood fibre were used in growing media in the UK in 2007 (Wallace et al., 2007). Wood fibre is produced from wood chips (approximately 2 cm in length) that are a by-product of forestry operations, sawmills and chipboard manufacture, being produced from off-cuts and smaller pieces of timber (Schmilewski, 2008). We allow a nominal 5 kg CO_2e t^{-1} to cover the use of diesel for material handling.

Processing

There are two methods used to produce wood fibre: mechanical and steam. Mechanical processing is used in Germany and Northern Ireland. Wood chips are retruded (the fibres are pulled apart) to produce a fluffy and low density material. Steam processing is mainly used in France where the wood chips are subjected to steam under high pressure which expands the fibres in the wood to produce the same fluffy, low density material. The production process uses energy to transport the wood chips from the saw mills to the wood fibre plant as well as energy (electricity) for the actual manufacturing process. In Germany, a proportion of the production electricity can be derived from wind energy. Wood fibre is naturally pale in colour but is sometimes dyed by addition of natural products to give it a darker appearance required by end customers. It is typically used at 30-50% of the growing media mix for ‘reduced peat’ substrates. Mechanical processing emits 32 kg CO_2e t^{-1} (commercial personal comm.).

Transport, distribution and retail

Wood fibre is imported by road and ferry from Germany or Northern Ireland so the emissions associated with transport are based on two scenarios: (1) A journey from Lägerdorf to Birmingham, a distance of 1070 km; this emits 148 kg CO_2e t^{-1} and (2) a journey from Ireland, a distance of 200 km which emits 28 kg CO_2e t^{-1}. Distribution and retail are assumed to be the same for all growing media materials and a value between 44 and 125 kg CO_2e t^{-1} is used.

End of life

For the purposes of this study, we assume that 20% of the carbon contained within wood fibre is sequestered into the soil organic matter and that the remaining 80% is emitted as CO_2. The carbon content and bulk densities of the materials in this study (Table 1) vary greatly so an assumption of this type is required to avoid over complication. Each tonne of wood fibre contains 450 kg dry matter of which 225 kg is carbon; 45 kg will be sequestered while the balance is emitted as 661 kg CO_2e.

4.6. Perlite

Changes in land use

Perlite is a generic term for naturally occurring siliceous rock which when heated to a suitable point in its softening range will expand from four to twenty times its original volume. Perlite is produced in Greece, China, the United States, Japan and Turkey and is extracted from open-cast mines and then crushed, dried, milled, graded and shipped to expansion (heating) plants worldwide[17]. Surface mining involves great changes in land use, however, unlike peat extraction it has no obvious burden of GHG production. It is likely that removing the over-burden, prior to blasting, increases emissions of both CO_2 and N_2O, but for how long and in what quantity is difficult to quantify. However, the amounts involved are assumed to be small per tonne of material produced and are not investigated further.

Extraction and processing

A dual approach is employed to quantify emissions of GHGs. The first is a bottom-up, component approach. A theoretical surface mining operation[18], based on 5000 tonnes of ore a day, uses diesel, electricity and blasting powder and emits approximately 9 kg CO_2e t^{-1}. A similar value is obtained from The United States Department of Energy[19] report which states that mining and processing one tonne of limestone requires 9.4 kWh t^{-1} (based on diesel and electricity) which emits 5 kg CO_2e t^{-1}; this study assumes an average of the two values of 7 kg CO_2e t^{-1}.

Secondary processing

Crude perlite rock contains embedded water which when quickly heated to above 871°C, causes the crude rock to expand as the water vaporizes. The expanded particles are moved out of the furnace and cooled, graded and packed.

Information on the production and processing of perlite in the public domain is limited, especially with regard to the emission of GHGs. The literature provides some estimates of the energy required and the CO_2 emissions produced during perlite production. Ecobuild[20] state that the embedded energy of perlite is 230 kWh m^{-3}, however, the bulk density of perlite varies according to grade, being between 45 and 180 kg m^{-3}, which when converted to CO_2 emissions (using the natural gas coefficient) suggests the range is between 0.24 and 0.97 kg^{-1} CO_2 per kg of perlite. Ken Wiener representing the Perlite Institute[21] (personal comm.) suggested that the range is 0.27 to 0.41 kg CO_2 kg^{-1} of expanded perlite while Schlosser et al. (2003) found that horticultural perlite emitted 0.43 kg CO_2 kg^{-1} perlite. The Green Building Challenge Handbook[22] suggests 0.52 kg CO_2 kg^{-1} for expanded material and the US EPA[23] estimates an average of 0.87 kg CO_2 kg^{-1} of perlite. We assume the average of all these sources and calculate that one tonne of expanded perlite is responsible for 601 kg CO_2e t^{-1}. Data on the energy

[17] www.epa.gov/ttn/chief/ap42/ch11/bgdocs/b11s30.pdf
[18] costs.infomine.com/costdatacenter/miningcostmodel.aspx
[19] www1.eere.energy.gov/industry/mining/pdfs/stone.pdf
[20] www.egt.bme.hu/!Tananyagok/ecobuild/greenmat/f6_005.htm
[21] www.perlite.org/
[22] www.gbc-ziegelhandbuch.org/eng/main.asp?Menu=3
[23] www.epa.gov/ttn/chief/ap42/ch11/bgdocs/b11s30.pdf

consumption used during expansion was difficult to source so we adopt the second, overall approach, to quantify CO_2 emissions; 65 kg CO_2e t^{-1} is allocated to extraction and primary processing and 536 kg CO_2e t^{-1} to expansion.

Transport, distribution and retail

We assume that perlite ore is shipped from Greece to the UK for processing, a distance of 5500 km by sea and 100 km by road which emits 91 kg CO_2e t^{-1}. Distribution and retail are assumed to be the same for all growing media materials and a value between 44 and 125 kg CO_2e t^{-1} is used.

End of life

End use is different to the preceding organic materials. Perlite is a mineral material and contains no carbon and is considered a stable substrate under normal conditions. Deterioration (decomposition) of perlite does not release any GHGs.

4.7. Vermiculite

Changes in land use

Vermiculite is found in various parts of the world. Locations of the predominant commercial mines are in Australia, Brazil, China, Kenya, South Africa, USA and Zimbabwe. Vermiculite mines are surface operations where ore is separated from other minerals, and then screened or classified into several basic particle sizes[24]. Mines are open cast, so the mining operation begins with the removal of the over-burden before blasting and collection of the ore can take place. Like perlite ore, mining of vermiculite does incur some changes in land use. It is likely that removing the over-burden, prior to blasting, increases emissions of both CO_2 and N_2O, but for how long and in what quantity is difficult to quantify. However, the amounts involved are assumed to be small per tonne of material produced and are not investigated further. As vermiculite ores are extracted from dry and mainly barren landscapes, the mining operation is considered to be GHG neutral.

Extraction and processing

The crude ore is crushed and screened at the mine and the raw vermiculite is separated using various wet or dry techniques. The separated material, vermiculite flakes, are sorted into size fractions using air tunnels and subsequently dried from 15 to 20% moisture down to 2 to 6%. These vermiculite concentrates are transported by truck or train to the nearest port, from where they are shipped globally[25]. We assume that vermiculite ore is shipped from South Africa by rail and by ship to the UK for processing. Flakes for UK exfoliation are derived principally from mines in South Africa and the USA[26].

At the exfoliation plant, the flakes are fed through a vertical furnace lined with ceramic bricks and as they fall down the furnace, they pass through one or more burners fired by natural gas. The temperature inside the furnace reaches approximately 540-810°C, which is sufficient to make the trapped water in the flakes flash to steam and cause the flakes to expand into worm-like particles. At the bottom of the furnace, the particles slide down an inclined plane. This delays the exit of the particles from the furnace and allows the vermiculite to be heated further in order to reach full expansion. Other exfoliation plants may use different furnace configurations, but the general sequence of operations is similar.

The hot, expanded vermiculite particles are then drawn up a vertical tube by a vacuum. Any small stones or other solid contaminants are too heavy to be carried upward by the gentle flow of air and fall

[24] www.vermiculite.org/aboutvermiculite.htm
[25] www.enotes.com/how-products-encyclopedia/vermiculite/
[26] www.defra.gov.uk/environment/ppc/localauth/pubs/guidance/notes/pgnotes/pdf/minpg3-7.pdf

out the bottom of the tube. The air flow also acts to cool the hot vermiculite which is then screened and packed into paper or polythene bags prior to shipping. This study assumes that mining and screening of the ore is the same as for perlite, so 65 kg CO_2e t^{-1} is allocated to extraction and primary processing and 536 kg CO_2e t^{-1} to expansion.

Transport, distribution and retail

We assume that vermiculite ore is transported 700 km by rail within South Africa, then shipped to Europe for processing, a distance of 11,200 km by sea and 200 km by road; this emits 127 kg CO_2e t^{-1}. Distribution and retail are assumed to be the same for all growing media materials and a value between 44 and 125 kg CO_2e t^{-1} is used.

End of life

Like perlite, end use is different to the preceding organic materials. Vermiculite is a mineral material and contains no carbon and is considered a stable substrate under normal conditions. Deterioration (decomposition) does not release any GHGs.

4.8. Material GHG emissions by weight

GHG emissions are reported using two approaches. Table 3 reports all GHG emissions per tonne of material while Table 4 adopts the PAS2050 approach in which CO_2 emissions associated with biogenic carbon sources are excluded and carbon storage is taken into account (see section 3.9 for details). In the results and discussion that follow, the former is referred to as the LCA approach while the latter is the offset approach. In the offset approach the CO_2 emitted during composting of green waste and decomposition of the biogenic materials is excluded, and the carbon stored at the ‘end of life’ stage is deducted from total emissions.

Table 3. Greenhouse gas emissions (LCA approach) for selected growing media at end-use stage; reported by weight (kg CO_2e t^{-1}) [the use of ’\’ indicates the range of values]

	Extraction & harvest	Processing	Transport	End of life	Total
Peat (UK)	36	24	42 \ 123	543	645 \726
Peat (Ireland)	36	24	97 \ 178	543	700 \ 781
Peat (Finland)	36	24	331 \ 412	543	934 \ 1015
Green compost	37	408	51 \ 132	358	854 \ 935
Coir	4 \ 160	40	142 \ 223	294	480 \ 717
Bark	4	13	66 \ 153	793	876 \ 963
Wood fibre	5	32	72 \ 273	661	770 \ 971
Perlite	65	536	135 \ 216	0	736 \ 817
Vermiculite	65	536	171 \ 252	0	772 \ 853

Table 4. Greenhouse gas emissions (offset approach) for selected growing media at end-use stage; reported by weight (kg CO_2e t^{-1}) [the use of '\' indicates the range of values]

	Extraction & harvest	Processing	Transport	End of life	Carbon storage	Total
Peat (UK)	36	24	42 \ 123	543	-136	509 \ 590
Peat (Ireland)	36	24	97 \ 178	543	-136	564 \ 645
Peat (Finland)	36	24	331 \ 412	543	-136	798 \ 879
Green compost	37	12	51 \ 132	0	-88	12 \ 93
Coir	4 \ 160	40	142 \ 223	0	-73	113 \ 350
Bark	4	13	66 \ 153	0	-165	-82 \ 5
Wood fibre	5	32	72 \ 273	0	-165	-56 \ 145
Perlite	65	536	135 \ 216	0	0	736 \ 817
Vermiculite	65	536	171 \ 252	0	0	772 \ 853

4.9. Material GHG emissions by volume

GHG emissions are reported using two approaches. Table 5 reports all GHG emissions by volume while Table 6 adopts the PAS2050 approach in which CO_2 emissions associated with biogenic carbon sources are excluded and carbon storage is taken into account (see section 3.9 for details); in the results and discussion that follow, the former is referred to as the LCA approach while the latter is the offset approach. In the offset approach, CO_2 emitted during composting of green waste and decomposition of the biogenic materials is excluded, and the carbon stored at the 'end of life' stage is deducted from total emissions.

Table 5. Greenhouse gas emissions (LCA approach) for selected growing media; reported by volume (kg CO_2e m^{-3}) [the use of '\' indicates the range of values]

	Extraction & harvest	Processing	Transport	End of life	Total
Peat (UK)	11	7	13 \ 37	163	194 \ 218
Peat (Ireland)	11	7	29 \ 53	163	210 \ 234
Peat (Finland)	11	7	99 \ 124	163	280 \ 305
Green compost	20	224	28 \ 73	197	470 \ 514
Coir	1 \ 13	14	50 \ 78	103	168 \ 208
Bark	1	5	23 \ 54	278	307 \ 337
Wood fibre	1	4	9 \ 33	79	92 \ 117
Perlite	6	48	12 \ 19	0	66 \ 73
Vermiculite	5	43	14 \ 20	0	62 \ 68

Table 6. Greenhouse gas emissions (offset approach) for selected growing media; reported by volume (kg CO_2e m^{-3}) [the use of '\' indicates the range of values]

	Extraction & harvest	Processing	Transport	End of life	Carbon storage	Total
Peat (UK)	11	7	13 \ 37	163	-41	153 \ 177
Peat (Ireland)	11	7	29 \ 53	163	-41	169 \ 194
Peat (Finland)	11	7	99 \ 124	163	-41	239 \ 264
Green compost	20	7	28 \ 73	0	-48	7 \ 51
Coir	1 \ 13	14	50 \ 78	0	-26	40 \ 79
Bark	1	5	23 \ 54	0	-58	-29 \ 2
Wood fibre	1	4	9 \ 33	0	-20	-7 \ 17
Perlite	6	48	12 \ 19	0	0	66 \ 73
Vermiculite	5	43	14 \ 20	0	0	62 \ 68

5. Discussion

The discussion concentrates on two main issues: reporting unit and reporting approach. Although data availability and quality were not as good as could have been hoped for, the assessment of GHG emissions for growing media materials was relatively straight forward; however presentation and interpretation of the results is complicated. In order to provide the 'full picture', the results are reported and discussed using four different approaches: by weight; by weight with offsetting; by volume; and by volume with offsetting – 'by weight' and 'by volume' represent full LCA carbon footprints while the 'offset' footprints follow PAS2050 methodology. Both approaches are equally valid and provide a different perspective of the same data; there is no right or wrong. The approaches to offsetting are presented section 3.9 of this report. A full explanation of the 'offset' approach can be found in PAS2050 (BSI).

5.1. Carbon footprint by weight

The following discussion relates to the raw materials using in growing media. However, since growing media are rarely composed of just one raw material, it is important to consider how the results could be related to the mixes used within gardening and commercial horticulture.

The materials can be grouped into three (arbitrary) categories based on their carbon footprint: (1) <500 kg $CO_2e\ t^{-1}$, (2) between 500 and 750 kg $CO_2e\ t^{-1}$ and (3) >750 kg $CO_2e\ t^{-1}$; category (1) contains coir, category (2) contains peat (UK), peat (Ireland) and perlite while category (3) contains peat (Finland), green compost, bark, wood fibre and vermiculite.

The headline result is that GHG emissions are heavily influenced by one characteristic (carbon content) and one life cycle stage (end of life) although transport for the low density materials can be significant. The variation in carbon content is considerable: peat and bark contain 50% carbon while perlite and vermiculite contain none. As 80% of the carbon within the organic materials is assumed to be emitted within the IPCC 100 year time horizon, the CO_2 associated with the 'end of life' stage dominates the results; if perlite and vermiculite are excluded, the 'end of life' stage accounts for on average 71% of all GHG emissions (Table 3).

The extraction and harvesting stages shows considerable variation which is a result of both natural (biological) and anthropological emissions. Natural emissions include CO_2 emitted from the decomposition of peat under peat extraction and CH_4 from the retting process used to break down the coconut husk to enable extraction of the coir fibres. Since the harvesting of coconuts (coir) is almost exclusively performed using manual labour, coir could be expected to contribute little to GHG emissions, yet the opposite can be true. In contrast, peat extraction is assumed to emit large quantities of GHGs whereas in practice they are relatively low (excluding the carbon contained within the peat). The mining of ore for perlite and vermiculite is heavily industrialised and performed on a large scale; however, large scale operations bring economies of scale. On average, the extraction and harvest stage accounts for 5.0% of total GHG emissions (range 0.4 to 13.7%).

The processing stage is where differences between the materials become even more apparent. Again emissions of GHGs are associated with both biological and man-made processes. The production of compost is a biological process and emits large quantities of CO_2 but for the other materials this stage is dominated by man made emissions. The amount of processing required shows large variations, e.g. bark only requires screening for size (the burden of stripping the bark is allocated to round wood production) yet the mineral materials (perlite and vermiculite) undergo very energy intensive processing. Of the organic materials, the production of green compost emits the greatest amount of GHGs, based as it is on biological decomposition. Perlite and vermiculite, which require heating to a high temperature in gas fired furnaces, emit the highest emissions during processing. On average, the processing and transport stage accounts for 22.6% of total GHG emissions, although the range is considerable (1.4 to 69.0%).

Transport, distribution and retail

This section brings together the various transport stages within the material life cycle. This includes transport between extraction and processing, between processing and retail and post retail. It contains large variations in type of transport and distances and therefore emissions. Distance itself is not a big contributor to GHG emissions as dense materials travelling long distances, as in ore from South Africa, come by bulk carrier and emit relatively little CO_2 per tonne kilometre. The choice of transport type is more relevant. To transport a tonne of peat from Finland by road emits double the CO_2 compared to bringing a tonne of vermiculite ore from South Africa.

Transport of growing media to the end user also shows great variation. Delivery in bulk bags by lorry is nearly three times more efficient than collection of two bags by private car. On average, the transport stage accounts for 21.1% of total GHG emissions, although the range quite large (10.2 to 30.5%).

End of life

For the organic materials the end use stage dominates overall GHG emissions and the amounts emitted are greatly dependent on the carbon content of the material although both bulk density and moisture content also effect emissions. The results are based on three main assumptions: (1) that 80% of the carbon contained within the individual materials is emitted as CO_2 within the IPCC 100 year time horizon; (2) that the carbon content of the materials, as stated in Table 1, is correct and (3) it is reasonable to include final decomposition within the study.

Although short term decomposition rates vary with material (and lignin concentration), we assume that a 100 year time horizon should be sufficiently long to ensure that all the materials, including the lignins have been decomposed by the soil microbes and that 80% of the carbon present in the materials has been emitted as CO_2. As we have used the IPCC's 100 year global warming potential values to calculate the overall carbon footprints, a 100 year decomposition period seems reasonable. Using this approach, those materials with a high carbon but low moisture content emit the greatest amounts of CO_2 while high carbon and high moisture materials emit less. On average, the end use stage accounts for 71.2% of total GHG emissions (0 to 90.5%).

However, all the organic materials, especially peat and green compost, display variation in their carbon contents, for example, the carbon content of peat ranges from 45 to 62% and green compost 15 to 30%. The source (peat) and processing (green compost) greatly influence the GHG emissions associated with the materials. Assuming a carbon content of 50%, there is little to separate peat and wood materials since the end use stage dominates their footprint; peat from England or Ireland emits less $CO_2e\ t^{-1}$ than bark from Spain.

Assessing the carbon footprint of organic materials introduces a number of issues that 'normal' footprint studies don't address. One of the major issues is how to treat the changes in materials composition through the various life cycle stages. The problem is illustrated using the carbon content of peat. Undisturbed peat has a moisture content of approximately 90% and the carbon content of dried peat is approximately 50%; this means that one tonne of undisturbed peat contains 50 kg carbon; however, this status only applies to undisturbed peat. Peatlands are drained to allow them to dry prior to harvesting and the milled peat is air dried prior to sale; assuming that the peat bought for use in horticulture has a moisture content of 63%, one tonne contains 185 kg carbon. The calculation of the 'true' carbon content is critical since the overall carbon footprint is heavily dependent on the value. This study has tried to resolve this dilemma by reporting all CO_2e emissions based on an end-of-life status, however, this approach does not work well with low density materials like perlite and vermiculite. It would be possible to report all emissions on a dry weight basis but the results would probably have little meaning to the industry and only serve to confuse the issue even further.

5.2. Offset carbon footprint by weight

One subject that is not addressed by LCA is how to treat the different forms of carbon. Organic carbon can roughly be divided into two categories, based on its age. Fossil carbon (normally taken to mean coal, oil and gas) is considered a non-renewable source while biogenic (or living) carbon sources (wood, coir and green compost) are considered renewable sources. The assumption is that consumption of fossil carbon adds to atmospheric carbon dioxide while biogenic carbon is essentially neutral. Peat is something of a dilemma as it is both living and dead. It is not fossil carbon since it has only formed in the last 10,000 years yet neither is it a renewable source within a realistic time horizon. Finland, which combusts large quantities of peat to generate energy, considers peat to be a long term renewable fuel although the Intergovernmental Panel on Climate Change (IPCC, 2006) and EU Commission[27] do not agree with this position. The discussion over whether peat is a fossil or biogenic carbon source is not strictly relevant to this study but it does illustrate how treating peat as fossil carbon and the other organic growing media as biogenic carbon can alter how the results are perceived and interpreted.

PAS2050 (5.3.1 & 5.3.2) states that CO_2 emissions from fossil carbon sources (their classification includes peat) shall be included in the material inventory but that CO_2 emissions from biogenic carbon sources (all the other growing media materials) should be excluded; non-CO_2 emissions (CH_4 and N_2O) should be included for both fossil and biogenic carbon sources. Adopting this approach within this study excludes CO_2 emissions from any composting processes but includes CO_2 emissions from peat extraction. All end use CO_2 emissions from non-peat organic growing media are excluded since they are considered to be from biogenic carbon sources.

It is also possible to offset the carbon sequestrated in soil against CO_2 emitted during production. For example, one tonne of peat contains 185 kg carbon and during the end-use stage the fate of that carbon is divided between 148 kg emitted as CO_2 and 37 kg sequestered into the soil. This sequestered carbon can be converted to CO_2e (136 kg) and offset against the other emissions produced during the life cycle of the material. Table 4 illustrates the results.

Adopting this approach changes the results completely. Vermiculite, perlite and peat emit far more CO_2 than they sequester while, in contrast, green compost, coir, bark and wood fibre do not. The best materials to sequester carbon are those materials with high carbon contents, bark and wood fibre, but even green compost, which has a lower carbon content, is close to being carbon neutral. Coir, which hasn't been retted, is also a good option. This approach confirms that peat always contributes to GHG emissions since its potential rate of carbon sequestration is not enough to compensate for the large amounts emitted during the transport and end use stages. Although perlite and vermiculite do not emit CO_2 during their end use stage neither do they sequester carbon so the GHGs emitted during their production and transport stages ensure that they are always contributors to global warming.

5.3. Carbon footprint by volume

Most growing media is sold on a volume, not weight, basis and Defra's own statistics on growing media use are formulated by volume. The benefits of using volume to report the results of this study would be: (1) it is the accepted reporting unit and the industry are therefore familiar with it and (2) it would be easy to calculate the carbon footprint of the whole sector since Defra's use statistics are collected by volume. The argument against using volume as the functional unit in this study are threefold: (1) bulk density varies inter and intra material and although there may be some value in comparing peat and green compost on a volume basis it is difficult to see how this would work with the very low density materials like wood fibre, perlite and vermiculite; (2) CO_2 coefficients emissions for transport are generally based on weight not volume and (3) weight is more widely used across industry and government. Presenting the results on a volume basis alters the carbon footprint of the materials and how their GHG burden is perceived (Table 5).

[27] www.europarl.europa.eu/oeil/DownloadSP.do?id=12718&num_rep=6041&language=en

Unsurprisingly, the volume approach reveals the influence of material bulk density. Those growing media with lower bulk densities: coir, wood fibre, perlite and vermiculite, generally have the lowest carbon footprints. This approach also disguises the differences between the three peats and bark. On this basis there is little difference between Finnish peat and bark and although green compost may emit less GHG on a weight basis, its higher bulk density disguises this fact and it easily emits the most CO_2e m^3.

5.4. Offset carbon footprint by volume

This approach confirms what the previous offsetting approach had already shown. All the organic materials, with the exception for peat, are close to being carbon neutral and can sequester carbon under certain conditions.

6. Conclusion

The main aim of the study was to assess the carbon footprint of selected growing media materials; this has been achieved. In the process of achieving this aim the research also highlighted that a number of difficulties exist when assessing the GHG emissions of organic materials. We ask that the reader should remember that this is a preliminary assessment of the subject which has revealed a number of methodological and interpretation issues which will require further research to resolve and, as a consequence, the results and conclusions presented here should be treated with caution.

Primary data on all aspects of the supply chain was difficult to source; either because it was not available (extraction and processing of peat, coir, forestry products and ores) or because commercial confidentially made companies reluctant to provide it. Where data was available, the inherent variability in the composition of the organic materials made calculation of a precise carbon footprint a difficult task since a single parameter, for example, bulk density, can introduce variability into the results.

The LCA approach (all GHGs emitted from all life cycle stages) shows that coir, UK and Irish peat emit the least GHGs. Green compost is a better option than Finnish peat as are bark based materials; however, the range of the results also suggests that under some circumstances the opposite may be true. For example, an offset approach gives a completely different perspective to the same data. Peat, perlite and vermiculite have large carbon footprints while green compost, coir and the wood products have low footprints, or under some circumstances, can sequester carbon. Both approaches are equally valid but their interpretation provides two different answers. Which is correct depends on the ambition (and scale) of the question. If a full understanding of the contribution of growing media GHGs to global warming is required then the LCA approach is correct. However, if the requirement is to calculate the GHG emissions from goods and services to PAS2050 standards then the offset approach is correct.

The materials in this study have been considered in their own right and no calculations have been undertaken on the different mixtures which are normal in commercial horticulture and becoming more accepted in the amateur market. No account has been taken of the natural nutrient value of the different materials or the effect that adding additional nutrients would have on emissions of GHGs. In the commercial market where mixes of materials are common and quality and repeatability are essential, the results are hard to interpret. We suggest that the best approach is probably the one already used by many growers, combine materials, for example peat and coir, green compost and wood fibre, to ensure the best mix for the intended purpose. If this approach could be influenced by the results from this study with the intention of using the mix with the lowest carbon footprint, then so much the better.

The results demonstrate that studies of this type are heavily reliant on data availability and that a lack of, and variability, of data is difficult to overcome. We suggest that any future work should concentrate on collecting primary data to quantify the carbon footprint of selected products (not materials) to obtain a better understanding of the GHGs associated with, and the environmental impact of, those products.

The study has also shown that the choice of methodology is critical in interpreting the results. We suggest that research is required to demonstrate how the reporting unit (weight, volume) can be used to present the results and influence the use of growing media products and how the analysis method (full LCA, offset) can be used by to reveal the environmental impact of growing media products. Methodology must be developed to take into account different boundaries, reporting units, carbon content, bulk density and moisture contents.

In terms of total GHG emissions the LCA approach supports the use of UK and Irish peat, and coir as growing media material, however, if the carbon neutrality of short-term materials and potential sequestration is taken into account then the opposite is true and compost, timber products and coir are the preferred materials. These opposing conclusions suggest that further policy work is required to clarify the terms involved in GHG reporting, the treatment of emissions from different sources and the different timescales. Given the complexity and difficulties involved in calculating and interpreting GHG emissions from growing media materials, we conclude that the major driver for reduced peat use should remain its ‘non-renewability’ and potential for long-term in-situ carbon storage rather than its emissions of GHGs.

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References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.