A comparison of greenhouse gas flux from composting compared to landfill and fertilizer production.

BY KATE DE SELINCOURT
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Along with saving resources and nourishing the soil, an argument for composting is that it cuts greenhouse gas emissions. Although this assertion is now almost commonplace, it isn't so well-known how big the effect is. How does composting household waste compete with, say, cutting domestic car use, or installing home insulation? In quest of an answer I found a lot of dense and learned information, but not really any definitive answer. However I have got a rough sense of how composting can help avert greenhouse gas emissions, and it is this rough sense I hope to share.

I need to stress that almost all these figures are based on assumptions, and sometimes, frankly, guesses. I try to point out what the main assumptions are as I go along, and mention my sources, though there isn't room for all of them – do contact me if you want to know more.

I am sticking to one comparison - the greenhouse gas impacts of community composting domestic kitchen waste (KW), versus land-filling the organic waste and using fossil derived fertilizer and peat. I am assuming for now that home composting carries on much as before – a huge assumption, and not necessarily the most desirable scenario (as in, it would be good to increase it) but we have to start somewhere!

My focus is aerobic, in-vessel composting as that is what interests us at Dean Community Compost, as a system which we felt produced the most horticulturally useful product, and was most suitable for a local, smallish scale community enterprise.

To begin with, we'll consider one tonne of domestic kitchen waste at the doorstep, take it through landfill or aerobic composting in parallel, and compare the emissions from these rival scenarios step by step. I will then look at agriculture, and also the impact at the household level.

Greenhouse gas impacts will be given in CO_2 equivalents. The greenhou.se gases considered are carbon dioxide (produced by aerobic composting, and burning including of transport fuel) methane (produced by anaerobic decomposition eg. in landfill) and nitrous oxide. I equate 1 kg of methane with 21 kg of CO_2, and 1kg of nitrous oxide 310 kg CO_2 (nitrous oxide is an extremely potent greenhouse gas). Other emissions, such as nitrogen oxide NOx (contributor to acid rain), are minimized through the use of an invessel composting system and a biofilter (Hogg, Gibbs et al. 2007). Solid waste disposal accounts for around 33% of anthropogenic methane (CH_4) emissions and 0.5% and 1% of anthropogenic CO_2 and N_2O emissions respectively (Smith, Brown et al. 2001). As a result, a disproportionate emphasis has been put on methane in calculating emissions from the waste sector – other gasses are not included in the waste chapter of the guidelines for national inventories (IPCC 2001).

Step-by-Step Comparison
We consider three stages, (1) collection and transportation (2) waste processing and (3) downstream use.

(1) Collection and Transportation
For effective diversion of kitchen waste to composting it is well-established that a weekly collection is needed, and most community compost projects will need to operate their own vehicle to achieve this. If landfilled, the kitchen waste will be mixed in with all of the other refuse:

contributing significantly to the refuse vehicle payload but not, in this example, doing more rounds.

For our dedicated collection here we consider truck doing a round of 35 miles (56 km) to collect 2 tonnes KW at a time. If a 2 tonne truck does 20 miles to the gallon in normal running, and we assume its 1/3 less efficient in the stop-start conditions of a round, we get a figure of 10kg CO_2 equivalents per tonne – the same as the quoted by (Hogg, Gibbs et al. 2007; Knipe 2007) for transporting waste (in what we assume are larger vehicles, travelling further). For comparison we will attribute 5kg per tonne to the kitchen waste if adding to the burden of a residuals collection (probably necessitating extra trips from the transfer station, but not alteration to the structure of residual collections in this example).

Stage (1) Collection, transport	GG impact of KW on business as usual route	GG impact of KW composted aerobically in-vessel
Total emissions	5kg	10kg

Numbers are in kilograms of CO_2 per tonne of KW

(2) Waste Processing

There are a lot of assumptions to make for this stage! We have to estimate the composition of the waste, how quickly it decomposes, how much landfill gas gets captured, and how much of that is then used to displace fossil fuels in power generation (earning "get out of jail free" status for those emissions).

The landfill site doesn't save much energy if kitchen waste is diverted (Fisher, Collins et al. 2006), but aerobic composting does need power. Powering large plant leads to around 20kg CO_2 per tonne processed (Smith, Brown et al. 2001). To allow for diseconomies of scale (smaller units lose more heat, etc) I am using a figure of 30kg CO2 emissions per tonne processed.

For anyone interested, more details of these assumptions are in the box:

Dry matter content kitchen waste	30% ***
Carbon content dry matter	45% ***
Carbon loss (ie organic matter decomposing to gas) in first 6 months (active composting) stage –both scenarios	60% ***
Carbon loss over next 99 years landfill	A further 26% of the original C. Discount for delayed release 50%*
Carbon loss over next 99 years (compost on soil)	A further 30% of the original, Discount for delayed release 50%
Landfill gas composition	60% methane 40% CO2 by volume
Composting gas emissions	100% CO2
N2O from decomposition	Some given off by composting, some generated when landfill gas is burned. No actual figures available for either!
Landfill gas capture	55%* (literature range 40% to 85%)
Ratio landfill gas used for generation/flared**	40/60**

* EU wide estimate (Smith, Brown et al. 2001) ** www.ecotricity.co.uk ***(IPCC 2001)

These assumptions have a major impact on the final result, and many learned papers assume "better" performance for landfill than I do (Smith, Brown et al. 2001; Hogg, Gibbs et al. 2007), ending up with less of an advantage for composting. However, these sources' calculations include future years in which they anticipate landfill being better run than the present. I believe my figures are a fair reflection of current practice.

For long-term decomposition, I am assuming 3/4 of the remaining organic matter in compost, (2/3 in landfill), decays very slowly (half life of around 20-100 years) and the remaining 10 (or 15%) of the original carbon is effectively stable and sequestered, an approach similar to the guidelines for national greenhouse gas inventories (IPCC 2001). If all of the carbon contained in the compost is released as CO_2, the maximum of emissions possible would be 150kg CO_2 equivalents, according to the framework of the (IPCC 2001). This amount is not included, the section on downstream use discusses further.

I am further assuming that in over the long term, in a landfill, the same proportions as before decompose to methane, and are collected and used. This is a slow process and holds carbon in the ground for a useful amount of time (even though in landfill it is otherwise useless and indeed probably a menace). I therefore "discount" a proportion of these emissions, on the grounds that the carbon is staying out of trouble for a while.

Stage (2) Waste Processing	GG impact of KW landfilled	GG impact of KW composted
Decomposition short term	760 kg	300kg
Ancillary emissions (processing)	2kg	30kg
Decomposition of remainder over long term ie up to 100 years	165kg	75kg
Total emissions	927kg	415kg

Numbers are in kilograms of CO_2 per tonne of KW

(3) Downstream Use

I am assuming that the tonne of kitchen waste can be composted to produce 300kg (or 300kg more in a mixed system) of fine, useful compost (The normal figure is 400-450kg compost/tonne waste).

Food waste compost might end up in various locations. In our well-run community composting systems, I will assume that some goes to commercial horticulture and some is returned to householders; in each setting about half is used to grow vegetables, replacing fertiliser, and half mainly on flowers beds or in pots, planters and hanging baskets -- that is, as a substitute for peat and fertiliser. Further arguments for reusing waste to boost soil organic matter may be found in a review in this issue.

Peat mining is not only destructive in itself, but the peat, which is fossil carbon, then oxidises rather rapidly once in the dry, airy conditions of a plant pot. Peat is less dense than compost, so our 300kg compost has the same volume as 132kg peat. Nonetheless, 130kg peat degrades to 110 kg CO2 (Smith, Brown et al. 2001). Similarly, on arable land, current industrial techniques reduce carbon content of European soils by 50% in 20 years, and major EU directives are attempting to maintain fertile soil and avoid desertification. Depending on the agricultural techniques, addition of compost may increase the carbon content, of soils (Favoino and Hogg 2008) or untilled soil may even sequester greenhouse gas and other atmospheric pollution (Singer 2008). For these reasons, we will not add further emissions from compost.

Estimating how much fertiliser compost can displace is very hard indeed. Opinion varies about how much of the N,P & K in compost is available to plants, and about how much artificial N growers think they can leave off composted soils. Some sources (including WRAP) count the entire N,P&K content of compost, others only the soluble fraction. In addition, growers may not always reduce their fertiliser use as much as they could even when using compost.

Fertilizer manufacture uses a lot of fossil fuel, but estimating this is difficult too because it depends a lot on the process used. WRAP estimated the artificial fertiliser to replace 100% the N,P & K in the compost from 1 tonne food, would cost 57kg in CO_2 emissions to manufacture (James 2008).. Calculations using other sources (Stephens 1991), indicate a figure at least half of this, though some suggest less such as just 10kg CO_2 per tonne kitchen waste (Smith, Brown et al. 2001)

Compromising between the variety of sources I will suggest that the nutrients in one tonne of compost would replace fertiliser equivalent to around 33kg in emissions from manufacture. Because it is unlikely that growers would always reduce fertiliser use exactly, and they are likely to err on the side of over-fertilising, I will allow only 75% of this possible substitution of fertiliser to take place, giving avoided emissions from fertiliser manufacture of 25kg/tonne KW

There has been a lot of talk recently about the greenhouse gas impacts of growing biofuels. One of the factors cited is the decay of artificial N-fertilisers to nitrous oxide (N_2O), an extremely potent greenhouse gas (Vogtmann 2007). Recent research suggests this is a bigger effect than had previously been realised.

We assume "The N in compost does not give rise to N_2O emissions because the N in compost is mineralised slowly" (Smith, Brown et al. 2001).

Estimates of N_2O release vary from 1-5% of the N in applied fertiliser per year (IPCC 2001). If we assume compost contains, 4% dry weight of nitrogen, and that approx 10 tonnes KW make one tonne compost dry matter, we get a figure of 4kg N in compost /original tonne KW.
How much fertiliser does this replace? Again, using our 75% substitution rate, I will assume this replaces 3kg N fertiliser. Recent research suggests this might give off 5%, ie 190g N_2O, equivalent to around 60kg CO_2 (Smith, Brown et al. 2001).

Stage (3) Downstream Use	GG of peat and fertilizer	GG impact of KW composted
Peat/compost decay	55kg	0kg more, covered above however you use it
Fertiliser manufacture	25kg	0kg more, covered above
Fertiliser/compost N2O emission	60 kg	equivalent to landfill
Total emissions	140kg	0kg

Numbers are in kilograms of CO_2 per tonne of KW

Step by Step Results

Now if we add up all the emissions in each table, we can compare the greenhouse gas consequences of the two possible routes for dealing with kitchen waste.

Stage	GG impact of KW landfilled	GG impact of KW composted
(1) Collection, Transport	5 kg	10 kg
(2) Waste Processing	927 kg	415 kg
(3) Downstream Use	140kg	0kg
Total	1070kg	425kg

Difference: 645kg CO_2 equivalent saved per tonne KW collected, composted and used in growing, compared to landfilling fertilizer production. Equivalent for average household producing 180kg of waste per year is 116kg CO_2

These figures are reasonable, when compared to (IPCC 2001; Smith, Brown et al. 2001; Hogg, Gibbs et al. 2007; Favoino and Hogg 2008; Schleiss 2008). On source has estimated significantly lower emissions associated with both landfilling and centralized composting from data in Australia (Lundie and Peters 2005), their results are shown below.

	Composting	Landfill
Collection	20.9	54.9
Processing	71.4	390.1
Further Transport	170.3	0.0
Total	285.7	450.5

Figures in kg CO_2 equivalent per tonne KW

If all my assumptions were correct, that would give an advantage for composting of food waste, then using the compost as a genuine aid to gardening/growing, of about 2/3 of a tonne CO_2 equivalent per tonne waste.

Further Discussion

At the household level (the "average" household being 2.4 people), we can take the national figures for kitchen waste currently in residuals of around 30% (Parfitt 2008) or around 250kg per year). Most households participating in a KW collection tend to put in a bit less, perhaps about 180kg per year – some will always remain stuck to the yoghurt pots I suppose; although just maybe, when people see all the waste in the caddy, they also try to eat a few more of their leftovers. South Somerset Sort It! campaign has found evidence that this is a real phenomenon. Where collection rates are higher than this there is always the worry that waste is being diverted from home composting, so we couldn't count that as a greenhouse gas saving anyway.

In-vessel composting on a community scale does not enjoy the economies of scale of a big collection vehicle and massive composting plant (aerobic or anaerobic). However, these costs turn out to be quite small. Meanwhile, if a community scheme can beat a bigger scheme on participation rates, then the benefit from higher diversion quickly outweighs the carbon cost of less efficient plant. It is pushing the maths severely to say just how much, but I feel a community scale achieving upwards of 5% better participation/diversion rates than large scale system, has already broken even. In fact of course in most places you are still only competing with landfill.

Note that the scale of the savings makes it well worth putting on another vehicle, driving round to door-knock, etc. It might at first seem disappointing that transport contributes relatively little to waste processing's carbon footprint, as we often claim that proximity gives us the environmental advantage. But in fact proximity does indeed give us an advantage far more powerful than mere truck miles – for proximity, along with community ownership, are surely invaluable in delivering high participation rates, and also "associated benefits" flowing from genuine participation and participant education.

Taken from the angle of each participating household rather than each generated tonne, participating in your local kitchen waste composting system saves annual emissions of about 116kg CO_2 equivalent/year. (This is 50kg/head: for a family of four, this translates to 200kg CO_2 equivalent saved. This is equivalent to driving about 1000km ie 600+ miles.)

A truly community composting project which captures the imagination of users might be able to engineer other valuable changes. A household might begin to home compost the 60kg of garden waste which is sneaked into the average year's dustbins. Another 50-odd kg CO_2 saved. And to stop burning the 30-odd kg prunings and brush that many households bonfire annually – another 50kg. Perhaps you can get them to include 25kg or so of unrecyclable paper and card in with the food waste each year—or into their home compost. Another 20kg saved.

Seeing the scraps in the caddy, understanding where it is going, hopefully even receiving compost back, might raise awareness of both food waste and possibilities of food growing. Rising food prices tied to rising oil prices are highlighting the huge carbon footprint of our food, recently estimated by WRAP as 4.5 tonnes of CO_2 (James 2008) equivalent for each tonne of food we buy. A supply of compost to gardeners might kick-start home food production, adding a further tier of carbon savings.

I am going to allow our happy householders to grow a modest 20kg of veg a year. This will be almost carbon-free, and could avert a useful 80kg of CO_2 emissions. Alternatively, or better, additionally, they might be a bit more careful with just 1lb (400g) of food each week, and eat it before its sell by date. Another 80kg CO_2 saved per year.

Our service, combined with consciousness raising, support and maybe a little light shredding, has enabled enthusiastic householders to cut their carbon footprint by 116+50+50+20+80+80 = about 400kg CO_2. If they are inspired to sort out their other recycling), clamp down further on the food waste (especially meat, fish and dairy) and increase the growing some more, it could rise to more like 600kg. And of course for a bigger household, eg a family of four, the savings could be proportionately higher, say one tonne. This is a big increase on the 225kg for direct participation, but not unreasonable for a keen household taking up the ethos of community composting.

This is a modest dent in each household's overall emissions, but still worthwhile I think. New Scientist recently attributed just over 9 tonnes CO_2 equivalent of UK emissions to each British individual, 36 tonnes for a family of four (Pearce 2007). Simply composting all kitchen waste represents a cut of ½ to 1% of this. Enthusiastic participation in all the related activities prunes emissions by 2-3%. Not massive, but on the other hand, that tonne of CO_2 saved per family is equivalent to driving the family car 2780 miles less per year (50 miles less a week) – or even, equivalent to half the electricity-related emissions of the household! So actually - it is a worthwhile achievement!

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