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Comparative Life-cycle Assessment

INEOS Bio Ltd

Seal Sands Waste to Biofuel Initial Plant

APPENDICES

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A.1.0 RED Methodology

A.1.1 Substitution Ratio for Bioethanol

The methodology for assessing the sustainability of biofuels contained in the Renewable Energy Directive (RED) indicates that the comparisons made on the basis of the relative energy content of the two types of fuel can be modified to reflect the useful work done by that energy provided some justification of the modifications made to the standard approach is supplied. This section outlines our methodology with regard to the substitution of bio-ethanol for petrol.

The value of ethanol to the motorist greatly depends on the fuel mixture that the vehicle uses. It is not true to say that 1 MJ of ethanol moves a vehicle an equal distance to 1 MJ of petrol. Attention must also be given to the relative densities of the two fuels – whereas liquid fuel is normally measured by volume, the two densities are somewhat different.

A review of the Brazilian biofuels industry confirms that ethanol has a motor octane number of 98, compared to 80 (gasoline). However, it has a lower calorific value than gasoline (lower heating values are 21.2 and 30.1 MJ / litre, or 26.8 MJ/kg and 43.6 MJ/kg, respectively).[1] The review compared the relative performance of petrol fuelled cars to vehicles fuelled solely on ethanol, as follows:

> *On the basis of higher heating value, ethanol has only 67% of the energy content compared with the same volume of gasoline. However, since it has a motor octane number higher than gasoline, it can be used in engines with a higher compression ratio (12-to-1, compared with the 8-to-1 ratio typically found in gasoline-fuelled engines). As a result, ethanol-fuelled engines are approximately 15% more efficient than motors using gasoline, which compensates to some extent for the lower energy content per unit volume. Typically, one would require approximately 20% more ethanol than gasoline per kilometre driven.*

The calculation of the relative lower heating values per unit volume, and accounting for the net efficiency gain, indeed leads to a figure of around 23% more ethanol than petrol required per unit volume. However, the differing liquid densities mean that on a mass basis, 1.32 kg of ethanol is needed to substitute 1 kg of petrol. Our model uses this assumption, reflecting the greater fuel requirement for vehicles fuelled solely with ethanol when compared to petrol vehicles.

In the UK, ethanol is likely to be blended before being used in a vehicle, rather than being used neat. A typical blend is known as an "E5 blend" – consisting of 5% ethanol mixed with 95% petrol. The AA suggests that although E85 vehicles are being manufactured in this country, E5 is suitable for use within normal vehicles and for the

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[1] Goldemberg J. (2008) The Brazilian Biofuels industry, Biotechnology for Biofuels, 1, pp6, available from http://www.biotechnologyforbiofuels.com/content/1/1/6

foreseeable future set to be the primary market for vehicle ethanol in the UK. A comparative review of energy and greenhouse gas balances of biofuels carried out The Ecole Polytechnique Federal de Lausanne indicated that several studies have shown that the consumption of E5 in litres is slightly less than gasoline consumption for the same service (e.g. 100 km), despite it's lower calorific value.[2] This substitution ratio assumption *may*, therefore, understate the benefits associated with bio-ethanol substitution when the fuel is being used within this blend. However, our view is that a conservative assumption is appropriate in this type of comparative assessment since it reduces the chances that the assessment will be accused of bias.

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[2] ENAC / ICARE / LASEN (2008) Estimating energy and greenhouse gas balances of biofuels, concepts and methodologies, a working paper; February 2008, available from http://lasen.epfl.ch/webdav/site/lasen/shared/Estimating_Energy_and_GHG_balances.pdf

A.2.0 Waste Systems Analysis

A.2.1 Avoided CO_2 Emissions from Energy Generation

All waste management processes consume, and in many cases, generate energy. Where energy is generated, it can be considered to replace a requirement for equivalent amounts of heat and power from other sources. The carbon intensity of an energy source is the quantity of greenhouse gas emissions associated with generating the energy. Where emissions are avoided as a result of generating energy from waste, assumptions regarding which source of energy is considered to have been displaced are important in determining the overall greenhouse gas benefits associated with power generation.

The choice of avoided generation has a major impact on the carbon balance of different waste management scenarios, as previous studies have shown.[3] If it is assumed that energy sources with a very high carbon intensity, e.g. coal-fired power stations, are being substituted, scenarios which are net generators of significant amounts of energy will appear more favourable. Alternatively, if the assumption made is that less carbon-intense sources – for example, nuclear or renewable energy sources – are substituted, then the credit associated with energy generation is reduced, and the net performance of systems generating relatively small amounts of energy is improved.

A.2.1.1 Electricity

The carbon intensity of an energy source is the quantity of GHG emissions associated with generating the energy. Where emissions are avoided as a result of generating energy from waste, or where energy is used by a process, assumptions regarding which source of energy is considered to have been avoided, or utilised, are important in determining the overall GHG benefit associated with power generation.

With a growing demand for electricity (unfortunately, most would add), where new facilities are being built to generate energy, and where these operate more or less continuously, it seems reasonable to argue that the avoided source of generation is the source, or mix of sources, deemed most likely to have been built in the absence of capacity arising through energy from waste infrastructure.

Our analysis indicates that the mix of new generation capacity is likely to be affected by a range of factors:

- ➢ Cost effectiveness of new build - under which CCGT remains a relatively favourable option (though this is dependent on gas prices);

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[3] AEA Technology (2001) *Waste Management Options and Climate Change*: Final Report, European Commission: DG Environment, July 2001; Profu (2004) *Evaluating waste incineration as treatment and energy recovery method from an environmental point of view*, CEWEP, May 2004

- Base load operation – most waste management facilities operate continuously, and so new facilities are most likely displace new *base load* capacity;
- The need for the UK to meet the targets set by the Kyoto Protocol and related guidance for planning authorities to help determine permissions for new power generation facilities;[4]
- The Renewables Obligation (RO), which includes targets, and provides incentives, for power suppliers to source energy from renewable sources;
- Energy security and increasing reliance on politically volatile or unstable states for fossil fuels, especially natural gas;
- Technological advances, both in terms of renewable energies and "clean coal" generation;[5] and
- Age of existing coal-fired power stations and their ability to meet the forthcoming regulatory requirements of the EU Large Combustion Plants Directive (LCPD).

As a result of the factors outlined above, determining the likely *marginal* source of electricity in the UK is extremely complex. Applications for new power generation facilities above 50 MWe output – or for gas-fired applications, above 10 MWe - must be submitted to the Department of Energy and Climate Change (DECC), and are listed on their website, as summarised in Table 1.[6]

Table 1: Summary of Planning Applications under Consideration by DECC

Technology	Number of Applications (Feb 2010)	Potential New Capacity
Total CCGT	9	10,675
Total Wind	14	3,087
Wave	4	457
Biomass (non-waste)	3	442
Waste	1	108
Coal	1	1,600

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[4] DCLG (2006) Planning Policy Statement: Planning and Climate Change (Consultation) – Supplement to PPS1, December 2006

[5] Usually involving some kind of carbon capture and sequestration

[6] https://www.og.decc.gov.uk/EIP/pages/applications.htm

Defra has suggested that for the purposes of policy evaluation, the marginal source of electricity should be taken to be CCGT gas plant, representing the trend in terms of recently commissioned power generation technology.[7] The carbon intensity figure used within the current analysis is based around electricity generated by a modern CCGT power station. We have assumed an efficiency of generation of 55% (the levels achieved by modern power stations today), and assumed natural gas has a calorific value of 39 MJ/m^3. The carbon intensity associated with electricity generation in this form is 0.330 kg CO_2 equivalent per kWh from the process itself with some 0.057 kg CO_2 equivalent per kWh from the pre-combustion process, giving a total of 0.387 kg CO_2 equivalent per kWh.

A.2.1.2 Heat

Choosing the marginal source of heat, i.e. determining the greenhouse gas emissions which would be avoided as a result of provision of useful heat from waste management facilities, might be considered a simpler proposition than for electricity. It is true that this parameter has attracted less attention and controversy than the calculation of marginal electricity, but there is no shortage of considerations in reaching a workable and robust approach for our model.

Unlike electricity, future demand for heat in the UK is uncertain. Furthermore, DECC data relating to energy demand does not separate this into heat and power, and thus is not useful in the analysis of historical trends for heat demand.

For heat, more so than electricity, Profu emphasizes the importance of local conditions in determining what should be modeled as the marginal source.[8] Many other EU Member States have significant underground district heating networks, which could readily be switched from fossil fuels to heat from waste management processes. The vast majority of households in the UK, however, do not have similar connections to accept and monitor heat from a wider network.[9] Retrofit of such networks is very expensive, and is thus more likely where there is new build of houses. Heat can also be used in district cooling systems, which may become increasingly important in the future.

Use of heat in this way would usually result in the avoidance of emissions from domestic gas boilers, but in some cases electrical energy would be displaced. This latter source has highest penetration in densely populated apartment-style dwellings which do not often facilitate provision of space for dedicated boilers.

Demand for non-domestic heat comes not only from industry, but also from such organisations as schools, hospitals, shopping centres and entertainment venues. All

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[7] Defra (2006) Greenhouse Gas Policy Evaluation and Appraisal in Government Departments, April 2006

[8] Profu (2004) *Evaluating waste incineration as treatment and energy recovery method from an environmental point of view*, CEWEP, May 2004

[9] Although it should be noted that such networks do exist in parts of Sheffield, Nottingham, Glasgow and Southampton – the former two cities taking heat from waste incinerators

such organisations have a requirement for far fewer heat connections than would be needed for district heating. Thus one might assume that a large part of avoided emissions would be from the displacement of incumbent sources within these venues, i.e. industrial scale gas boilers.

For displacement of heat by gas boilers DECC uses a generic estimate for emissions of CO_2 equivalent of 0.21 kg/kWh, which is based upon an assumption of 90% efficiency.[10] Based upon the average efficiencies of both new domestic and new industrial boilers, we believe this to be a reasonable estimate.[11]

Heat generation from waste management facilities is generated continuously and would not always be capable of being utilised. The proportion of useful heat that is generated is taken into account by inclusion of a heat load factor.

The current analysis uses a figure of 60% for the heat load factor, developed on the basis of the annual useful supply potential shown in Table 2. The load takes into account the technology displaced and falls in heat demand during night-time and non-winter seasons. These assumptions also consider estimates of the possibility of using heat exchange technologies to provide cooling during summer months.

Table 2: Heat Load Scenarios

Technology Displaced[1]	Annual Useful Supply Potential (%)
Domestic Gas Boiler	50
Domestic Electric Heat	50
Industrial / Commercial Gas Boiler	60

Notes:

1. Assumes useful cooling can be supplied through heat exchangers in addition to displacement of heat

A.2.2 Energy Generation at Incineration Facilities

The efficiency of generation of electricity by an incinerator may be quoted gross, or net of any energy used in the plant itself. The energy use in the plant depends partly

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[10] DTI, Energy Trends (2003) *Special Feature CHP: Savings in carbon emissions resulting from the use of Combined Heat and Power*, April 2003

[11] It has been argued that a lower value should be used as many existing boilers are significantly old, and operate at far lower efficiency. However, as one might assume the likely replacement of these with new, efficient boilers, it is these that would be displaced by heat provided by waste management facilities

upon the nature of the flue gas cleaning system used, but also upon a range of other factors. The relationship to flue gas cleaning is important since it seems likely that as standards for abatement have improved, so the energy used in achieving those levels of abatement has increased also.

ERM suggested gross efficiencies of 20-27% for conventional incineration with steam cycle electricity generation in a recent report for Defra.[12] Fichtner quotes a 'realistic range' for net electrical efficiency of 19-27%.[13] The highest figures we have seen quoted are those quoted in the context of the Belvedere Inquiry where it was claimed that a net efficiency of 27% would be achieved. This was based around assumptions of a thermal efficiency of 84% and an electrical efficiency of 35%. These are optimistic in the context of efficiencies currently achieved and are likely to be deliverable only at large operating scales. The Draft BREF note gave no case where the net export of electricity exceeded 18%.[14] A survey of 25 incinerators across Europe generating electricity only reported a maximum *gross* energy efficiency of 27.9% with a weighted mean efficiency of 21.8% across the 25 facilities (the mean *net* efficiency was given as 17.7%).[15] The current analysis uses a *gross* efficiency of 27% for facilities generating only electricity, reflecting the top end of the range quoted by ERM and the aforementioned survey, which was carried out by the Confederation of European Waste to Energy Plants (CEWEP).

Whilst CEWEP supplies maximum values for heat and electricity generation for facilities operating in CHP mode, the survey data does not directly supply any information regarding the ratio of heat to electricity produced at each of the facilities concerned. Where thermal facilities are concerned, and where steam turbines are used to generate energy, there is a trade-off between the generation of electricity and the generation of heat.

In its submission to the DTI as part of a review of the Renewables Obligation, ILEX assumed electrical output would be reduced at an approximate rate of 1 MW of electrical energy for every 4 MW of heat off-take.[16] Data from CEWEP gives the maximum heat output from surveyed facilities surveyed producing only heat as 92.7%, suggesting a theoretical ratio of 3.3 MW heat for every MW of electricity.[17] The

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[12] ERM (2006) Carbon Balances and Energy Impacts of the Management of UK Wastes, Defra R&D Project WRT 237

[13] Fichtner Consulting Engineers Limited (2004) The Viability Of Advanced Thermal Treatment Of MSW In The UK, ESTET, March 2004

[14] European Commission (2005*)* Integrated Pollution Prevention and Control, Draft Reference Document on the Best Available Techniques for Waste Incineration, Final Draft, May 2005

[15] Riemann I (2006) CEWEP Energy Report (Status 2001-2004): Results of Specific Data for Energy, Efficiency Rates and Coefficients, Plant Efficiency Factors and NCV of 97 European W-t-E Plants and Determination of the Main Energy Results, updated July 2006

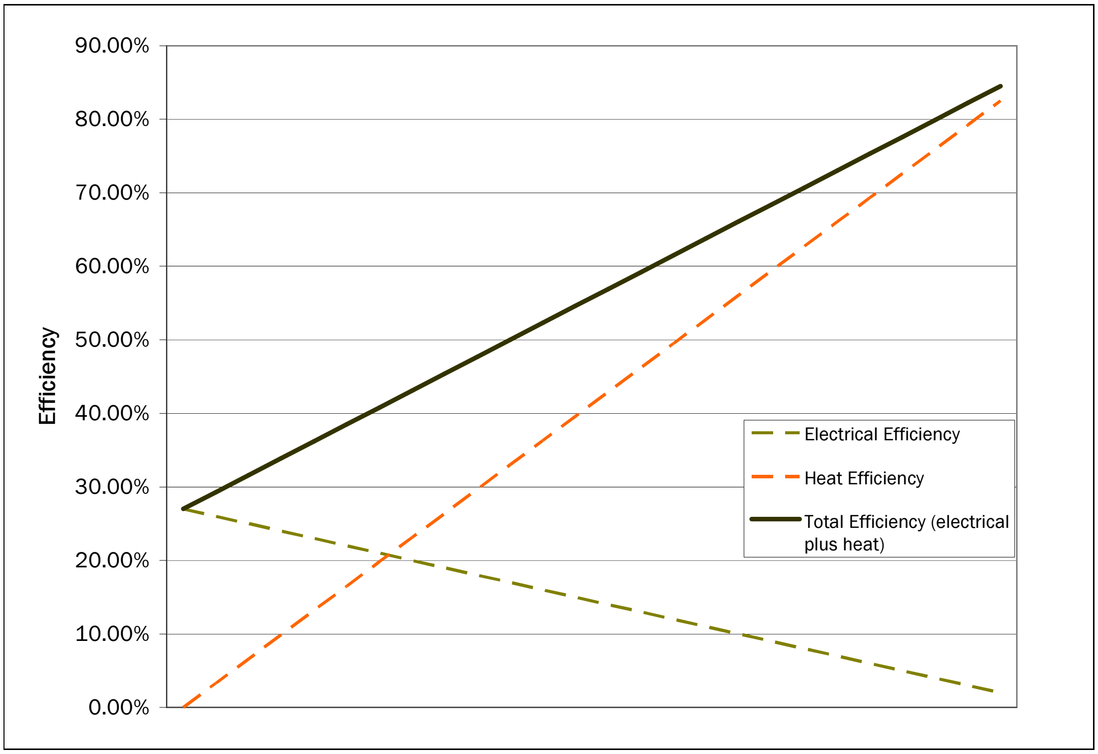
[16] ILEX Energy Consulting (2005) Extending ROC Eligibility to Energy from Waste with CHP, Supplementary Report to the Department of Trade and Industry, September 2005

[17] This is simply calculated as the ratio of the maximum gross efficiency of heat generation relative to the maximum gross electrical generation efficiency of 29.7%

maximum heat output for any of the surveyed facilities operating in CHP mode was 83.9%, whilst the maximum electricity output for the CHP facilities was 26.9%. This suggests a ratio of 3.1 MW heat for every MW of electricity. However, the German Waste Incineration Association suggests that the ratio should be rather lower at 2.3 MW heat for each MW of electricity, based on the data from German facilities (the majority of which operate in CHP mode).[18] It is not clear, though, whether the German figures speak in terms of gross or net generation, or indeed, whether they take into account the heat load effect (in other words, these figures may relate to the electricity and heat actually put to a useful purpose).

The relationship between the electrical efficiency, heat generation efficiency and total generation efficiency (as outlined above) is shown graphically in Figure 1.

Figure 1: Electricity, Heat and Total Efficiency – Facilities Operating in CHP Mode



Our energy generation efficiencies for facilities operating in CHP mode are based on the average electricity production for CHP facilities surveyed by CEWEP, using the higher ratio in the CEWEP report of 3.3 MW heat per MW electricity to calculate the heat production. We assume a total system generation efficiency of 66%, with electrical and heat generation efficiencies of 10% and 56% respectively.

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[18] Available from www.itad.de

A.2.3 Gas Capture at Landfill Facilities

There is some debate with regard to both the efficiency of landfill gas capture and the proportion of the gas that is used for energy generation. Of these, the gas capture rate is both the most sensitive and the most contested component.

A previous assessment undertaken by Eunomia used a gas capture rate of 50%, an approach based upon two studies conducted on behalf of Defra by LQM and Enviros.[19] A study conducted by ERM on behalf of Defra, however, assumed a 75% capture rate over the 100 year timeframe assessed.[20] A subsequent ERM report acknowledged that if one moved the analysis beyond this (somewhat arbitrary) timeframe, lifetime capture rates might be around 59%.[21] Documentation supplied with the Golders model indicates that the expert review group formed as part of that study considered that 85% of the gas would be collected during the gas utilisation phases, and a lifetime 75% gas capture rate appears to have been suggested upon that basis.[22]

The wider literature suggests a range of estimates for the efficiency of gas collection with a distinction being made between instantaneous collection efficiencies and the proportion of gas that can be captured over the lifetime of the landfill.[23] Whilst instantaneous collection rates for permanently capped landfilled waste can be as high as 90%, capture rates may be much lower during the operating phase of the landfill (35%) or when the waste is capped with a temporary cover (65%).[24] In addition, gas collection is technologically impractical towards the end of the site's life. The Intergovernmental Panel on Climate Change (IPCC) has recently stated that lifetime gas capture rates may be as low as 20%.[25] We would consider, however, that

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[19] Eunomia (2006) A Changing Climate for Energy from Waste? Final report to Friends of the Earth, May 2006; LQM (2003) Methane Emissions from Landfill Sites in the UK, Report for Defra, January 2003; Enviros, University of Birmingham, RPA Ltd., Open University and M. Thurgood (2004) Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes, Final Report to Defra, March 2004

[20] ERM (2006) Impact of Energy from Waste and Recycling Policy on UK Greenhouse Gas Emissions, Final Report for Defra, January 2006

[21] ERM (2006) Carbon Balances and Energy Impacts of the Management of UK Wastes, Defra R&D project WRT 237. December 2006

[22] Golder Associates (2005) Report on UK Landfill Methane Emissions: Evaluation and Appraisal of Waste Policies and Projections to 2050, report for Defra, November 2005

[23] Anderson P (2005) The Landfill Gas Recovery Hoax, Abstract for 2005 National Green Power Marketing Conference; USEPA (2004) Direct Emissions from Municipal Solid Waste Landfilling, Climate Leaders Greenhouse Gas Inventory Protocol – Core Module Guidance, October 2004; Brown K A, Smith A, Burnley S J, Campbell D J V, King K and Milton M J T (1999) Methane Emissions from UK Landfills, Report for the UK Department of the Environment, Transport and the Regions

[24] Spokas K, Bogner J, Chanton J P, Morcet M, Aran C, Graff C, Moreau-Le Golvan Y and Hebe I (2006) Methane Mass Balance at 3 Landfill Sites: What is the Efficiency of Capture by Gas Collection Systems? Waste Management, 5, pp515-525

[25] IPCC (2007) Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Metz B, Davidson O R, Bosch

landfills in the UK are somewhat better engineered than in the general (global) case, although a recent report by the European Environment Agency uses the IPCC figure.[26]

Our model assumes that waste which has been pre-treated (e.g. through an aerobic stabilisation process) will behave differently in landfill with respect to the generation of landfill gas, and that pre-treated wastes will therefore ultimately require a different form of gas management in landfill.

We have assumed a landfill gas capture of 50% for untreated wastes, in line with the lifetime capture rates suggested in the wider literature for well-managed landfills (such as those currently operating in the UK).

A.2.4 Biogenic CO_2 Emissions

A.2.4.1 The Methodological Issue

A key issue in the assessment of GHG emissions from waste treatment technologies is whether or not non-fossil CO_2 (otherwise known as biogenic CO_2) should be included.

Under international GHG accounting methods developed by the Intergovernmental Panel on Climate Change (IPCC), non-fossil CO_2 is considered to be part of the natural carbon balance and therefore not a contributor to atmospheric concentrations of CO_2.[27] The rationale behind the IPCC's decision is that non-fossil carbon was originally removed from the atmosphere via photosynthesis, and under natural conditions, it would eventually cycle back to the atmosphere as CO_2 due to degradation processes. Climate change, however, is attributed to anthropogenic emissions, which impact this natural carbon cycle.

As regards waste, the Guidelines from IPCC state that the following should be reported: [28]

> *Total emissions from solid waste disposal on land, wastewater, waste incineration and any other waste management activity. Any CO_2 emissions from fossil-based products (incineration or decomposition) should be accounted for here but see note on double counting under Section 2 "Reporting the National Inventory." CO_2 from organic waste handling and decay should not be included.*

PR, Dave R, and Meyer L A (eds)), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., pp 60*0*

[26] Skovgaard M, Hedal N, Villanueva A, Andersen F and Larsen H (2008) Municipal Waste Management and Greenhouse Gases, ETC/RWM Working Paper 2008/1, January 2008

[27] Intergovernmental Panel on Climate Change. *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3, Pg. 6.28, (Paris France 1997).

[28] Understanding the Common Reporting Framework, in IPCC (u.d.) Revised 1996 IPCC Reporting Guidelines for National Greenhouse Gas Inventories, Reporting Instructions (Volume 1), Hadley Centre, Bracknell

Specifically regarding waste incineration, the same guidelines state that reporting should include:

> *Incineration of waste, not including waste-to-energy facilities. Emissions from waste burnt for energy are reported under the Energy Module, 1 A. Emissions from burning of agricultural wastes should be reported under Section 4. All non-CO_2 greenhouse gases from incineration should be reported here as well as CO_2 from non-biological waste.*

Given the above, then it is worth reporting what is set out regarding energy. The following are to be reported:

> *Total emissions of all greenhouse gases from all fuel combustion activities as described further below. CO_2 emissions from combustion of biomass fuels are not included in totals for the energy sector. They may not be net emissions if the biomass is sustainably produced. If biomass is harvested at an unsustainable rate (that is, faster than annual regrowth), net CO_2 emissions will appear as a loss of biomass stocks in the Land-Use Change and Forestry module. Other greenhouse gases from biomass fuel combustion are considered net emissions and are reported under Energy. (Sum of I A 1 to I A 5). Incineration of waste for waste-to-energy facilities should be reported here and not under Section 6C. Emissions based upon fuel for use on ships or aircraft engaged in international transport (1 A 3 a i and 1 A 3 d i) should, as far as possible, not be included in national totals but reported separately.*

Methane (CH_4) is also derived primarily from non-fossil carbon during degradation processes. However, CH_4 emissions from landfills are counted within GHG inventories. The rationale provided by the IPCC can be described as follows:[29]

> *CH_4 emissions from landfills are counted - even though the source of carbon is primarily biogenic, CH_4 would not be emitted were it not for the human activity of landfilling the waste, which creates anaerobic conditions conducive to CH_4 formation.*

Currently, convention appears to be shaped by IPCC's approach to dealing with non-fossil carbon in the reporting of Greenhouse Gas Inventories by different countries.

The crucial point here is that for the purposes of IPCC reporting, non-fossil CO_2 from incineration is effectively not reported – an approach also recommended by the French waste management industry.[30] Although it could be argued that this convention of ignoring non-fossil CO_2 is appropriate within the inventory context, it

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[29] USEPA (2004) *Greenhouse Gas Emission Factors for Municipal Waste Combustion and Other Practices*

[30] L'Entreprises pour L'Environnement, *Protocol for the quantification of greenhouse gas emissions from waste management activities*, September 2006, Nanterre, France

has perhaps erroneously been applied to comparative assessments between waste management processes.[31]

Whatever the merits or otherwise of not reporting biogenic CO_2 for the purpose of national inventories, in comparative assessments between processes, it cannot be valid to ignore biogenic CO_2 if the different processes deal with biogenic CO_2 in different ways. Given that different processes often deal with non-fossil CO_2 in different ways, and that the atmosphere does not distinguish between molecules of GHGs depending on their origin, the omission of non-fossil CO_2 from analyses appears dubious. The need to include biogenic CO_2 is well recognized by some of those involved in life-cycle assessments, such as Finnveden *et al.*:[32]

> *The practise to disregard biotic CO_2-emissions can lead to erroneous results (Dobson 1998). Let us consider an example to illustrate this. Let us compare incineration and landfilling of a hypothetical product consisting of only cellulose. When incinerated, nearly 100 % of the carbon is emitted as CO_2. However, in the inventory, this emission is often disregarded as noted above. If the product is landfilled, approximately 70 % of the material is expected to be degraded and emitted during a short time period, mainly as CO_2 and CH_4 (Finnveden et al. 1995) (The short time period is here defined as the surveyable time period). Again the emitted CO_2 is normally disregarded, although the CH_4-emissions are noted. During the surveyable time period, 30 % of the carbon is expected to be trapped in the landfill. There is thus a difference between the landfilling and the incineration alternatives in this respect, in the incineration case all carbon is emitted, whereas in the landfilling case some of the carbon is trapped. This difference is however not noted, since the CO_2-emissions are disregarded and this is in principle a mistake. Additionally, the biological carbon emitted as CH_4 in the landfilling case is noted and will discredit this option. It could be argued that a part of the global warming potential, corresponding to the potential of the same amount of biological carbon in CO_2, should be subtracted from the landfilling inventory.*

A number of other - more recent - reports similarly take the view that the biogenic CO_2 emissions should be included when accounting for the climate change impacts of biomass energy generation and waste management facilities.[33]

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[31] For example, ERM (2006) *Carbon Balances and Energy Impacts of the Management of UK Wastes*, Final Report for Defra, December 2006

[32] G. Finnveden, J. Johansson, P. Lind and A. Moberg (2000) *Life Cycle Assessments of Energy from Solid Waste*, FMS: Stockholm

[33] See, for example: Rabl A (2007) How to Account for CO_2 Emissions from Biomass in an LCA, International Journal of Life Cycle Assessment, 12, pp281; Searchinger D, Hamburg S, Melilo J, Chameides W, Havlik P, Kannen D, Likens G, Lubowski R, Obersteiner M, Oppenheimer M, Robertson G, Schlesinger W and Tilman D (2009) Fixing a Critical Climate Accounting Error, Science, 326, pp527-528

The IPCC Guideline regarding emissions related to energy requires further analysis in the context of refuse-derived fuels (RDF). If the biomass portion of RDF is included under the definition of 'biomass fuels', then whether or not CO_2 emissions should be included (for inventory purposes) would appear to depend on the sustainability of the production of that biomass. Considering the heterogeneous mix of biological material contributing to the biomass portion of waste, the task of determining what is or is not sustainably produced would be extremely difficult. Should a comparison of the GHG intensity of waste management processes relative to traditional fossil fuel generation be undertaken, this might be a worthy approach.

In the IPCC Guidelines, in theory, this would not be of significance if one was confident that the reporting of inventories under the Agriculture, Forestry and Other Land Use (AFOLU) Section took adequate account of all the effects of waste-related activities on changes in soil carbon, carbon in the existing forest stock, etc. Using, as a convention, the assumption that non-fossil carbon dioxide is unimportant risks, however, ignoring the matter of the potential significance of changing the rate of flux of carbon dioxide from non-fossil sources into the atmosphere. Clearly, burning biomass leads to the immediate release of carbon dioxide. However, composting biomass leads to the production of compost which, on application to soil, increases the carbon stock, and releases the carbon over an extended period of time.[34] Recycling paper and card may lead to additional net sequestration of carbon in the forest stock according to one US study, suggesting that a full accounting system for the recycling of biomass and of timber based products might reveal rather greater benefits than are suggested by many conventional life-cycle studies.[35]

A.2.4.2 Impact on Results of the Inclusion of Biogenic CO_2 Emissions

Figure 2 shows that the INEOS Bio process performs better than the other residual waste treatment options even when biogenic CO_2 emissions are included. However the process does not perform as well against some of the competing technologies for biowaste when comparisons are made using this approach.

In the case of garden waste, where the material is treated using a windrow composting system a proportion of the carbon is effectively sequestered in the soil as part of the humus. In contrast, the INEOS Bio process causes the release of all the biogenic carbon contained within the material. The result is that, when biogenic CO_2 emissions are included, the INEOS Bio process has an equivalent GHG performance to windrow composting. It should be acknowledged, however, that for the same total emissions, composting produces a growing medium, which might not find a suitable market, while the INEOS Bio process produces a marketable road fuel.

For biowaste, whilst INEOS Bio continues to perform better than the IVC process when biogenic CO_2 emissions are included, it performs relatively less well against the AD

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[34] See Enzo Favoino and Dominic Hogg (2008) The Potential Role of Compost in Reducing Greenhouse Gases, *Waste Management Research,* 2008; pp. 26; 61

[35] USEPA (2006) *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*, September 2006

options. The latter process does not degrade the lignin-based materials. Although this results in less energy being generated, it also leads to lower biogenic CO_2 emissions.

Figure 2: GHG Emissions per Tonne of Waste – Including Biogenic CO_2 Emissions