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GHG emission factors for waste components produced, treated and recovered in the HSY area - Background document for the calculations

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1 Introduction

About three percent of Finland’s greenhouse gas (GHG) emissions are caused by waste management. This amount contains emissions from landfills, sewage sludge treatment and biowaste composting. Additionally, transportation of waste and waste incineration generate GHG emissions, but they are reported in the energy sectors GHG emissions. Preventing waste and reducing GHG emissions in municipal solid waste management was a part of the EU Life+ funded project Julia 2030 “Mitigation of and adaptation to the Climate Change in the Helsinki Metropolitan Area – From Strategy to Implementation”. The project aimed at major GHG emission reductions by the year 2030 and was based on the Helsinki Metropolitan Climate Strategy (YTV Helsinki Metropolitan Area Council 2007). One objective of Julia 2030 project was to produce GHG calculators for the assessment of the GHG emissions of waste treatment and recovery in the operating area of the Helsinki Region Environmental Services Authority (HSY). The calculators are aimed to be used by citizens and companies producing wastes and waste management professionals assessing the GHG emissions of waste management in the HSY.

For the purpose of the GHG calculators, the Finnish Environment Institute SYKE produced waste component specific GHG emission factors using LCA methodology. This document summarizes the calculation of these factors and can thus be used as a background document for the GHG emission factors used in waste management calculators Konsta, Petra, Martti and Emmi (Waste prevention…2011).

2 About LCA methodology

Life Cycle Assessment (LCA) is a comprehensive, quantitative approach where one assesses the emissions, resources consumed and pressures on health and the environment that can be attributed to different good(s) or service(s) taking into account their entire life cycle, from the ‘cradle’ to the ‘grave’. When an inventory has been collated of all the inputs and outputs, they are translated into indicators associated with different impacts such as resource depletion, climate change, acidification, or toxicity to plants, animals and people. Hence, the LCIA (life cycle impact assessment) step calculates the relative importance of each input and output for the different types of environmental problem.

LCA for waste management can be used for a range of applications, from assessing the benefits of avoiding a waste to evaluating different options for management systems. In the context of waste management facilities, an LCA considers the direct impacts of the operations on the environment (e.g. stack emissions from an incinerator). It also quantifies the indirect benefits of recovering materials and energy from the waste (e.g. through combined heat and power and ferrous metal recycling). LCA provides quantitative information which puts potential environmental advantages and disadvantages into perspective. (Manfredi & Pant 2011).

When performing LCA on a waste management system, the assessment starts from the waste being generated. Waste is taken into the system with zero emissions, i.e. the production of the material or product becoming waste is not included in the system. Hence the calculations are performed from a waste generation reference point rather than from a raw materials extraction point.

3 Calculating the GHG emission factors in the Julia 2030 project

In the Julia 2030 project we concentrated on the GHG emissions of waste components or materials identified as the most relevant ones for the use of the calculators. We included primarily the emissions of the three major greenhouse gases: carbon dioxide (fossil, CO_2), methane (CH_4) and dinitrogenoxide (N_2O). Carbon sequestration was not included in our calculations.To be able to allow all emissions to be compared on equal terms, we characterized the emissions of these gases according to their global warming potential (GWP): CO_2 has a GWP of 1, CH_4 has a GWP of 25 and N_2O has a GWP of 298 (IPCC 2007). We present the GHG emission factors resulting from our calculations in kg CO_2-eq. / t of waste component in table 1 of Annex 1. The GHG emissions are first reported as produced and avoided emissions in different phases of the waste treatment and recovery chain and the overall GHG emissions factor is given as the sum of the produced and avoided emissions.

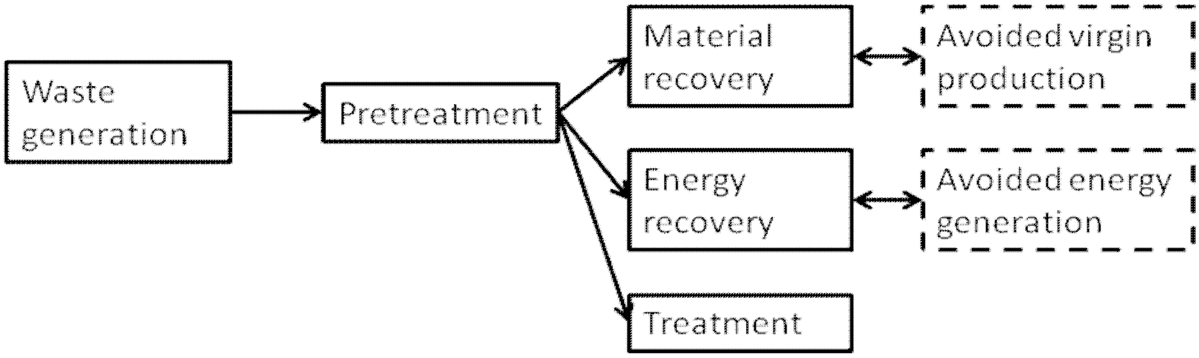

Figure 1. Life cycle phases included in the screening LCA.

We calculated the GHG emissions caused by the management of different waste components (including collection and transportation, treatment and recovery of waste). We assessed the benefits of waste recovery by calculating emissions avoided from virgin production or energy generation (Fig. 1). When a material is recycled, it is used in place of virgin inputs in the manufacturing process, rather than being disposed and managed as waste. When a material is recovered as energy, it can be used in place of other fuels, preferably fossil fuels, in the energy generation. Thus the avoidance of these virgin processes can be assessed as a benefit to the waste recovery. No emissions were assessed for waste generation.

The calculation of GHG emissions for all waste components was based on current information from the waste composition and municipal waste management of the Helsinki Metropolitan Area (HSY). Also the avoided processes (both for material and energy recovery) were determined on the basis of the local situations. GHG emission factors were determined for: mixed municipal solid waste (treatment options landfilling or incineration; currently landfilling), biowaste, paper, cartons, metals, glass, plastics, wood, energy waste, waste of electric and electronic equipment (WEEE), construction and demolition waste, municipal waste water sludge and hazardous waste. General descriptions of these components are given in table 2 of Annex 1.

The waste treatment and recovery chains and the processes assumed to be avoided by the recovery of waste are described in the following sections. The data used for the calculations were gathered from literature and other public documents, but to some extent also from not published planning documents or personal communications from e.g. the HSY experts. The data sources, modeling values and critical assumptions made for the calculations are summarized in table 3 of Annex 1.

Emissions from the collection and transportation of the waste components were also calculated on the basis of the distances estimated for the wastes generated in the HSY area. The impacts of waste collection were estimated to be 4.5 kg CO_2-eq./t for each waste component included. The descriptions of the distances and vehicles used for transportations are summarized in table 4 of Annex 1.

4 Treatment and recovery of waste components in the HSY area

4.1 Mixed municipal solid waste

In the HSY area, mixed municipal solid waste is currently disposed off at landfill. The GHG emissions of waste disposed off at landfills depend on the conditions in the landfill and the composition of waste. The landfilling of mixed waste was modeled by assuming the mixed waste to include 21% of biodegradable waste producing landfill gas (LFG) when degrading, 71% of the produced LFG being collected and 10% of the methane escaping the collection system being oxidized in the upper layer of the landfill. The LFG was assumed to consist of 47% of methane and having an energy content of 12 MJ/kg LFG. The amount of energy recovered from LFG was 1.6 GJ/t of mixed waste. This LFG is utilized to produce electricity in a gaspowerplant, and this electricity was assumed to replace electricity purchased by the HSY. (IPCC 2000).

In the future, the mixed municipal solid waste will be incinerated, hence the GHG emission factor was calculated also for incineration. The energy content of mixed waste was estimated at 10 GJ/t, the emission factor for mixed waste incineration 40 kg CO_2-eq./GJ (Statistics Finland 2011) and the energy yield 8.1 GJ/t. Incineration produces 260 kg ashes per each ton of waste incinerated. 85% of the ashes are classified as non-hazardous waste and 15% as hazardous waste. All ashes are landfilled. According to the current plans, mixed waste will decrease the use of coal as fuel with 30% from the current situation (Karjalainen 2009, Anderson 2010).

4.2 Biowaste

Biowastes are composted at the HSY waste treatment centre of Ämmässuo in Espoo. Twigs and brushwood, which are collected separately, are chipped into the stabilizing material of the composting mass. Garden waste acts as a drying agent in the composting process, hence no additional stabilizing material is needed. Of the degradable carbon (65% of weight) some 3% was estimated to end up as methane. The end product is used in landscaping as a surface material either for landfill sites or outside landfill sites. The substrate commonly used in landscaping is a mixture of sand, nutrients and organic material, which may be either biowaste compost or peat. Biowaste was hence assumed to replace peat in this landscaping substrate.

4.3 Paper

Separately collected paper is baled, processed and loaded at the Paperinkeräys Oy sorting plant (energy use follows the assumptions of HSY's purchased electricity). The baled paper is delivered to a paper mill for de-inking and reuse in newsprint manufacturing thus decreasing the need for forestry operations and thermo-mechanical pulp (TMP) production. On one hand, TMP production is very electricity-intensive, but on the other hand, the process produces heat as a by-product. When TMP production decreases the need for purchased electricity decreases. Simultaneously, however, the need for additional heat (from the power plant of the mill) increases, and also the fuel mixture used at the power plant changes. When less virgin wood materials are used, less biofuels are produced at the paper mill and thus the need for fossil fuels for the power generation at the paper mill increases. The paper mill data used for modeling newspaper recycling were based on the UPM-Kymmene Group Kaipola Mill in the year 2001. They were updated in 2008. The data included the Kaipola Mill energy production and water treatment and the manufacture of chemicals used at the mill, the production of fuels and the generation of heat and electricity. (Dahlbo et al. 2005).

4.4 Cartons

Separately collected cartons are baled at the Paperinkeräys Oy sorting plant (energy use follows the assumptions of HSY's purchased electricity). The baled cartons are transported to a recycling mill in Pori, where they are used in the manufacturing of core board instead of virgin fibres. Core board is used for the manufacture of various cores and tubes used in e.g. paper, textile and yarn and plastic film industries. In practice, core board is always manufactured from recycled fibres. Hence the benefits of recycling (avoided emissions) were here assessed from the production of a similar product, namely fluting, from virgin fibres. The emissions avoided by recycling were calculated to be the difference in the emissions of the fluting process compared to the emissions of the core board process. The raw materials for core board are 83% recovered fibre and 17% virgin fibre (Niininen 2011). From one ton of collected cartons, 95% is used for core board manufacturing and 5% (reject) is recovered as energy (Bacher 2011). The reject was assumed to consist of 50% fibres and 50% plastics and was assumed to compensate the use of natural gas in a co-combustion plant. The data used for modeling the core board and fluting manufacturing are based on data from the Stora Enso Oyj. For core board the data include 250 km transportation for baled cartons, pulping of fibres, manufacturing of core board and the use and production of energy. For fluting the data include forestry operations for pulp wood production, manufacturing of fluting and the use and production of energy. (Niininen 2011).

4.5 Glass

Separately collected glass is crushed, cleaned, sorted and utilized in the manufacturing of glass wool and glass containers (e.g. jars and bottles). A share of separately collected glass is used in earth works. According to the data from year 2007 the reuse in glass wool manufacturing accounted for 38% of the recovery, reuse in packaging 53% and use in earth works 9%. The avoided emissions of the recovery of glass were based on comparing the emissions from a process using 100% virgin material against using 72% recycled glass in glass wool production and 38% recycled glass in containers production (Vares & Lehtinen 2007). All recovery of glass was assumed to take place in Finland.

4.6 Metals

Separately collected metals from regional collection points are transported to a recycling facility, where steel, aluminum and copper are separated and delivered to use in metals manufacturing. The separately collected metal fraction consists commonly of 53% tin-coated steel, 24% aluminum, 15% stainless steel and 9% others. The recycling of metals reduces emissions from virgin, ore based, metal production. (Kuusiola 2010).

4.7 Plastics

Plastics from households is either collected as energy waste or mixed waste. Separately collected plastics for recycling thus includes plastics from groceries, companies, offices and other facilities producing large amounts of homogenous plastics. To some extent plastics is reused e.g. in plastic bag and pipe manufacturing, but data on the proportions of different uses is lacking. Hence it was assumed that all separately collected plastics is reused in plastic profile manufacturing replacing impregnated wood (Korhonen & Dahlbo 2007).

4.8 Wood

Separately collected wood is chipped and delivered to small district heat plants for energy recovery (Myllymaa et al. 2008). The energy yield in such small plants is generally high, here 90% yield was assumed. Wood was assumed to replace oil as fuel.

4.9 Energy waste

Energy waste consists primarily of wood, paper, cardboard, carton packaging and plastics collected from groceries, hospitals, restaurants and offices. It may also include small amounts of separated energy waste from households. The average energy content of energy waste was estimated at 20 GJ/t and the content of biobased materials such as wood, paper fibre or other at 80% (Partti & Tönnes 2009). The energy waste is utilized at an industrial combined heat and power (CHP) plant, where it was assumed to replace natural gas.

4.10 Construction and demolition waste

The composition of construction and demolition (C&D) waste was estimated on the basis of information gathered from different operators in the HSY area. 67% of the C&D waste was estimated to be mineral waste (concrete), 13% wood, 14% mixed solid waste, 2% metals, 1.5% tyres, 1.6% energy waste, 0.9% cartons and 0.1% hazardous wastes. The mineral waste, i.e., concrete is crushed and utilized in earth works instead of gravel. Iron is separated from concrete and transported to be used in metals manufacturing. Tyres are crushed and used for earth works instead of gravel. For the other fractions of C&D, we assumed the treatment and recovery chains described in this document under the specific waste components.

4.11 Waste electrical and electronic equipment

The collection and recovery of waste electrical and electronic equipment (WEEE) are under the responsibility of the producers. In Finland some 9 kg of WEEE were collected per person per year (Ingatius et al. 2009). Large appliances make up about half the mass of scrap collected. Other large WEEE components by mass are computer and telecommunications devices, and consumer electronics, which both make up about 21 % of the collected WEEE. Cathode ray tubes (CRT) from old TV-sets and computer monitors are included in these device groups. Based on the collected masses the smallest device groups are small appliances, lighting, electric and electronic tools, toys, leisure and sports equipment, medical devices, control and surveillance devices, and automats. These make up about 7 % of the collected scrap. The composition of the scrap varies very much, both in and between different groups of devices. Pretreatment of WEEE is done manually for separating cables, plastics, toner cartridges, printed circuit boards, hazardous wastes etc. Further processing is usually mechanical, including reduction of the size of the components and classification and separation of materials to ensure a better recovery. Additional options are X-ray separation, chemical immersion-floating, and whirlpool separation.

Data on different processes in the WEEE-dismantling chain were not available, but the energy consumption of the mechanical pretreatment was estimated to vary between 0.2–0.7 GJ/t WEEE.

The share of different materials in WEEE was estimated based on statistics and literature (Ignatius et al. 2009). Approximately 25% of the weight of WEEE is plastics, some of which is recycled into plastics production, some is incinerated and some is landfilled. No data was available on the share of different treatment or recovery options for plastics. Hence, in estimating the emissions avoided due to recycling of WEEE, only recovery of metals (approximately 62% of the weight of WEEE; iron, copper, aluminium) and glass (approximately 6% of the weight of WEEE) were considered. From the calculated total amount of emissions avoided, the share of metals recycling was almost 98%.

4.12 Hazardous waste

Hazardous waste is a very heterogeneous waste component. It can include wastes such as paints, solvents, oils, heavy metals, contaminated soils, household appliances, batteries, accumulators, etc. Due to lack of data, only hazardous wastes that are suitable for incineration were assessed. According to the data on wastes generated in the HSY area, around 70% of the hazardous wastes are incinerated (Tönnes 2009). The emission factor for hazardous waste incineration was derived from the largest operator (Ekokem 2008). No avoided emissions were included. This overestimates the emissions from hazardous waste treatment, due to the fact that some of the energy produced compensates for other energy production. Data on the share was, however, not available.

4.13 Municipal waste water sludge

Municipal waste water sludge is digested and composted. The anaerobic digestion process produces 694 MJ energy/ t of sewage sludge. 260 MJ of this energy is electricity, which replaces the use of grid electricity purchased by the HSY. The solid reject of digestion is composted and this compost product was assumed to replace peat in landscaping substrate similarly to biowaste compost.

5 Limitations and sources of uncertainty

When applying the GHG emission factors estimated for the HSY area, some limitations need to be considered.

The factors only consider treatment and recovery chains for waste components; no impacts were hence assessed for waste minimization, although from an environmental point of view, waste not produced reduces impacts of both waste management and product manufacturing. The GHG emission factors are based on the waste management options valid for the waste produced in the HSY area. They are not applicable to other areas as such.

The GHG emission factor for mixed waste incineration is based on the planning documents for the Vantaa Energy waste incineration plant. The realization of the plant and the activity of incineration may differ from plans; hence the factor should be reassessed when incineration has been started.

The composition of the separately collected paper fraction varies depending on the type of the place where waste is generated. Households produce a mixture of newspapers, magazines, envelopes and office paper, while offices commonly collect white office paper separately. White office paper can be reused in e.g. tissue paper, while mixed paper is reused in newsprint. The benefits gained by recycling may vary between different reuse options. Here the paper fraction was assumed to be mixed papers and reused for newsprint manufacturing.

The benefits of cartons recycling were assessed using fluting as the virgin product compensated. This was justified by the fact that the manufacturing of fluting is a similar process as the manufacturing of core board. The consumption of energy in fluting manufacturing is higher than for core board and hence benefits are high. Since core board is in practice always made from recovered fibres, it is questionable whether fluting is the right product to estimate the benefits with, since it may give an overestimation of the benefits. On the other hand, again, no benefits were assessed from the wood left to grow in the forest due to use of recovered fibres, thus our estimate may be an underestimate.

Glass was assumed to be recovered in Finland for packaging, glass wool and earth construction. However, a new recovery concept for glass, namely foam glass, is emerging. If the concept penetrates the market in larger volume than at present, the effects on the GHG emission factor for glass waste must be reassessed.

Hazardous waste is a very heterogeneous waste component. It can include wastes such as paints, solvents, oils, heavy metals, contaminated soils, household appliances, batteries, accumulators, etc. The GHG emission factor given here is only valid for hazardous wastes that are incinerated. Hence it should not be used for e.g. equipment or devices, contaminated soils nor metals classified as hazardous waste. In addition, the factor overestimates the emissions from hazardous waste incineration, due to the fact that some of the energy produced compensates for other energy production. This was not included in the factor.

The composition of WEEE was calculated on the basis of literature on the composition of different equipment and devices belonging to WEEE, data from the treatment chain were not available. The share of metals recovered may have been estimated too high and hence the benefits calculated also too high, but on the other hand no recovery was assessed for plastics although some plastic fractions are sold for reuse in plastic manufacturing and some are recovered as energy. The WEEE GHG emission factor is currently reassessed in an ongoing research project, which will be finalized in spring 2012.

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