CARBON FOOTPRINT FOR HAZARDOUS WASTE INCINERATION

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CARBON FOOTPRINT FOR HAZARDOUS WASTE INCINERATION

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SUMMARY: Kommunekemi A/S (KK) operates a large incinerator plant for hazardous waste in Denmark. The Carbon footprint takes offset in the ISO 14044 standard for LCA, but is limited to account for greenhouse gas (GHG) emissions. The LCA principles are based on consequential thinking which means allocation is replaced by relevant system expansions. The consequential approach also requires use of market marginal data instead of average datasets. The general model has been used since 2007 for annual environmental reportings. The Carbon footprint calculation tool has been tested on all specific waste streams incinerated at KK in 2011, which has shown the model to give consistent results. For KK the model will be further developed to cover new processes.

1. INTRODUCTION

The purpose of calculating a carbon footprint for the activities of KK is to provide the customers with reliable information on the GHG impact by discharging waste to KK. Since the carbon footprint covers a specific plant and specific waste types, it is possible directly to calculate the actual change in emissions that different waste types contributes to. The waste has to be discharged anyway, and therefore the actual GHG burden by using KK can be compared to other treatment options when transportation to the plant is added.

The greenhouse gas accounts were made for 3 parts of the operations at KK: the incinerator, the wet treatment plant and the straw-ash treatment facility. This article presents only the methodology and results covering the incinerator part. The system delimitation includes all operations at KK itself as well as upstream and downstream impacts caused by the activities at KK. The time span for the study is the nearest future where no major changes in the existing supply structures are expected. The consequential approach to LCA (Weidema, 2004) used in this study is generally not considered in other GHG models (WRI, 2004), (EPE, 2008), which use average data for energy use and production.

The perspective is KK as a service provider for managing industrial waste, which means that the studied service is the waste management itself. This implies that any operations before the waste generation are excluded as well as the transportation to the plant. But from the entrance gate to final treatment, all affected greenhouse impacts from upstream and downstream processes are included, which includes internal transportation, use of energy and chemicals as well as all avoided emissions by products sold from KK. This approach is in line with another Danish project on greenhouse accounts and carbon footprint including a recent Danish consensus and guide for carbon footprint accounting in the waste sector (Dakofa.dk, 2012).

The Incinerator treats most of the waste, and the related sale of energy as heat and electricity
represent an important part of the carbon accounts. Figure 1) shows the GHG-emission from the incinerator. It is noticeable that the provision of energy balances 50% of the CO₂ emissions from the waste incineration.

![Treatment of 1 tonne - Incineration 2011](image)

Figure 1). A breakdown of the carbon footprint for 1 tonne of waste at Kommunekemi in the waste incineration plant. By subtracting the avoided emissions below the x-axis from the emissions origination from waste, fuel and chemicals, an average emission in 2011 of 630 kg of CO₂ pr tonne waste is found.

2. PRINCIPLES OF THE CALCULATION

The aim has been to create a model that can be used by KK for annual environmental reports, but also by their customers to forecast and calculate the Carbon Footprint from any type of hazardous waste. The model is presently built on general data on calorific value, water and ash content in a specific waste stream, but more detailed information on composition of the waste can replace the generic data if available. The model is designed to represent the operational mode of the incineration plant at KK, in which the incineration is always maintained at constant high temperature (>800 C) by the use of a support fuel (oil-types). The model is applicable to any incinerator operated in this way.

The annual greenhouse gas reporting is part of the environmental reporting, and the average carbon footprint is calculated as CO₂ emissions per tonne treated waste. For specific waste types, the calculation of carbon footprint for every type is based on known chemical composition for each type. The tool is tested on all types of waste treated at KK in 2011, and the weighted average when summing up all waste types in 2011 has been checked against and found close to the total GHG emission reported from the incinerator for the same year (see section 3). A user friendly version of the calculator can be found at KK’s homepage (Kommunekemi.dk, 2012).
Figure 2). Flow model of the waste incineration plant – and principles for calculation of input-side CO2 emissions and the related energy usage. The fluegas plant is shown on the figure and it includes all use of chemicals. The dotted boxes show replaced energy supply.

2.1 Principles and data sources for carbon footprint for KK

The goal is to calculate accounts of total CO2 emissions and related savings by energy production and carbon footprint per tonne for specific types of waste. The CO2 emission is calculated as the average CO2 emissions per tonne of waste in section 2, and the two calculations are compared in section 3. The calculations are based on following:

- The mode of operation for the hazardous waste incinerator with constant high temperature underlies the calculation principles, i.e.:
  - The input of waste for incineration is supplemented with variable input of support fuels that could be used for other purposes on the market.
  - The energy output is, thus, not affected by change in the character of waste input, but only related to total annual waste amounts.
- The Energy consumption and production based on KK internal data and external marginal data for the receiving system for electricity (the Nordic grid) and heat (district heating in the city of Nyborg).
- The CO2 emission by incineration of waste is based on measurements of surplus oxygen and CO emissions.
- All use of support chemicals for flue gas cleaning is included.
- Internal and external transportation are included from reception at KK gate to final disposal.
- Transportation before arrival to KK is not included in the accounts.
- Emissions from landfilling of ashes and slags are not included (but believed to be insignificant).
2.1.1 KK green reports and internal data
Most data from KK are published in the green reports as the volumes of waste treated and energy sold as electricity and heat. Other data such as internal transportation, use of chemicals etc. are extracted from economic accounts to be used in the greenhouse gas reporting. Especially measurements for self-control of emissions in the flugas are used for estimating the CO2 originating from the mixed waste sources. The performed measurements are continuously logging the oxygen surplus and CO content. This is related to the volume of input air which makes it possible to calculate total CO2 emissions from the plant. Since the support fuel use is known, the CO2 emissions originating from the waste can be calculated on an average basis, and related to one average tonne waste. The values found from 2007 to 2011 are in the same level as generally used in other references (EPE, 2008).

2.1.2 Electricity and heat – marginal data
About 50% of the output heat from the incinerator is used for energy production purposes via steam production (ending up as both heat and electricity), the other ends in the fluegas. The steam output is used to produce electricity for the public grid (21%) and for district heating (61% in Nyborg). About 18% is lost – especially during the summer with low heat demand. The calculation of the saved CO2 emissions is based on the actual market marginal for electricity – which in Denmark is mainly coal based condensed power production. In Nyborg the situation is as in many other areas of Denmark that the district heating grid is being expanded to replace natural gas heating. This is why natural gas in district heating plants is used as the heat marginal for the heat delivered from KK.

2.1.3 Ecoinvent background data
The chemicals used at the incinerator at KK are used for fluegas cleaning. The most important is limestone, which originates from Danish sources, and the energy use for processing and transportation is based on information from the producer (Faxe kalk, pers. Comm. 2010). For external transport data is used from Ecoinvent, which is also the case for shipments of flyash to deposits in Norway.

Table 1. The most important data for the GHG accounting at KK

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 emissions waste</td>
<td>KK measurements and calculations (2011)</td>
<td>0,58 kg of CO2 per kg mixed waste</td>
</tr>
<tr>
<td>Electricity production</td>
<td>Marginal emission from DK electricity (Dakofa; 2011)</td>
<td>1,0 Kg CO2 pr kWh</td>
</tr>
<tr>
<td>Heat marginal</td>
<td>Marginal emission from natural gas (Dakofa; 2011)</td>
<td>0,056 kg CO2 pr MJ</td>
</tr>
<tr>
<td>Lime stone for fluegas</td>
<td>(Faxe kalk, pers. Comm. 2010)</td>
<td>0,045 kg CO2 pr kg limestone</td>
</tr>
</tbody>
</table>
2.2 Calculator input data

The calculations are based on

- Customers knowledge about contents in waste for incineration (heat values and chemical composition)
- Four calculation steps according to the 4 steps and the used values are shown in table 2:

1) Heat value, water and ash content (experimental),
2) Halogen/clorine content (experimental)
3) Average or actual chemical composition (calculation),
4) Lost and sold energy on plant level from average green accounts (calculation) -

2.2.1 Heat value, water and ash content

Liquid waste that are received at KK is (if not known) tested for the lower heat value, and water content, residue content and clorine content. This information is used as input in the CO2 calculator. The low heat value of the waste causes saved fuel and CO2 from fuel. The saved energy is corrected water evaporation and heating of inert material that are discarded.

2.2.2 Halogen content as clorine

The halogens are mainly chloride which forms HCl in the emissions which has to be neutralized by use of limestone. The CO2 emission from limestone production originates from the Danish producer (Faxe kalk).

2.2.3 Average CO2 value and specific chemical CO2 content

The average value of CO2 emissions per MJ from waste is found by calculating the CO2 content from typical chemicals incinerated at KK. The CO2 emission is calculated from the chemical composition and the energy content based on the estimation described by in literature (Schwanecke, 1976).

2.2.4 Energy losses and avoided energy on plant level

The 3 first steps calculate the energy and CO2 balances on the input side of the incinerator. To calculate the total carbon footprint the losses to the exhaust gas and gains by energy recovery on the energy output side has to be added from the KK carbon footprint every year, latest from 2011.
Table 2. The most important data for each calculation step for carbon footprint at KK

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saved fuel based on lower heat value of waste</td>
<td>Measured heat value evaporation of water and heating up inert materials is subtracted</td>
<td>- 0.078 kg CO2 per MJ 0.3432 kg CO2 per kg water</td>
</tr>
<tr>
<td>Water and ashes reducing heat value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clorine content</td>
<td>Limestone used for fluegas cleaning of HCL</td>
<td>0.687 kg CO2 per kg Cl</td>
</tr>
<tr>
<td>Chemical composition to calculate CO2 emission</td>
<td>Se calculation principle in 2.2.3</td>
<td>0.073 kg CO2 per MJ</td>
</tr>
<tr>
<td>Energy losses and recovery from average carbon footprint at KK</td>
<td>Average CO2 pr kg waste at KK 2011; - CO2 credits by energy sale from KK in 2011</td>
<td>0.579 kg CO2 per tonne waste 0.183 kg CO2 per tonne waste</td>
</tr>
</tbody>
</table>

3. CO2 EMISSIONS FOR ALL WASTE TYPES TO KK IN 2011

3.1 Input data

3.1.1 All waste for incineration

For 2011 KK has performed a calculation of the CO2 emissions from about 100 different product codes, which are grouped in 12 major classes of waste. Each code is described based on physical properties (liquid or solid, in containers or bulk, viscosity), relevant chemical characterization (haz class) and demands to handling. For each product code a value for energy content, content of halogens, water and expected solid residues has been estimated. These data are used in the CO2 calculation model described in section 2.2. The results for the most common types of waste (out of 100) are shown as carbon footprint (kg CO2 per tonne of waste) in figure 3 in next section.

3.1.2 Total for all waste types for incineration compared to the average carbon footprint

For each waste type treated at KK, the carbon footprint is multiplied with the annual treated amount, and the average per tonne treated waste is calculated. For 2011 the GHG reporting as shown in section 2.1 gave as the result a carbon footprint of 630 kg per tonne of waste. Using the method in section 2.2, calculating a carbon footprint for each waste type based on estimated properties, resulted in a weighted average footprint of 609 kg per tonne of waste, which gives a deviation of about 3.3% between the 2 different methods.
4. RESULTS AND DISCUSSION

The purpose of calculating a carbon footprint for the activities of KK is to provide the customers with reliable information on the GHG impact by discharging waste to KK. Since the carbon footprint covers a specific plant and specific waste types, it is possible directly to calculate the actual change in emissions that different waste types contributes to. The waste has to be discharged anyway, and therefore the actual GHG burden by using KK can be compared to other treatment options when transportation to the plant is added.

But by comparing to other plants, one must make sure that GHG footprints from other plants are calculated in the same way. Generally GHG-protocols as (WRI, 2004) and (EPE, 2008) uses average data for energy inputs and outputs. This typically gives lower emissions values for energy inputs and outputs, since a share of electricity use and production originates from low CO2 sources af wind, hydro or nuclear power. By setting the marginal electricity production to the actual market responder, which is a coal fired power plant without heat production, the values both on the input and output side is much higher – for the Danish electricity market about twice as high. In the case of KK the difference between the marginal approach and the average figures is less than 10%, because the input and output side evens out the GHG impact from energy use and production (Kommunekemi.dk, 2007).

Going through the waste types at kommunekemi, it is clear that hardly any includes biogenic matters. For the GHG calculations this means that a distinction between biogenic and fossil waste types is not relevant. But as a principle including or excluding biogenic CO2 is important for other waste types. A general trend in Denmark is to include the biogenic CO2 in CO2-emissions and uptake by biological processes in LCA studies. This is done to analyse the GHG consequenses of different Carbon management systems.

In the case of Hazardous waste incineration at KK, water content in the waste shows to be the
most important factor to affect the carbon footprint of a waste type, which for some might not be surprising. Chlorine is the most common halogen content compound – and gives a noticeable contribution to the Carbon footprint as well.

Further developments in the calculator will be to include other waste contents. Some metals from containers should be included, since some can be recycled and thereby contribute to a better carbon footprint if recycled. Also completely different treatment options for specific waste fractions to recover fertilizers as potassium and phosphorous has a carbon footprint, which can be calculated using other tools than the one used for the incineration process.

Overall the GHG calculator and the general carbon footprint complement each other since the different calculation approaches yields the same result within a few percents deviation. The final test is to measure the CO2 emissions over a year and compare them to the average footprint.

5. CONCLUSIONS

- In the case of KK the difference by calculating a Carbon footprint per tonne of waste is not much affected by the choice of energy marginals for input/output, but in comparison to other plants the marginal should be used if possible to give a correct picture of differences in the performance.
- The inclusion of biogenic CO2 does not change the picture either since very little hazardous waste is biobased, but is highly relevant for other waste types and should be included.
- Water content in waste is the most important factor to affect the carbon footprint of hazardous waste incineration.

ACKNOWLEDGEMENTS

The principles of calculation the carbon footprint as described in above, will an important inspiration for the environmental impact assessment in the ongoing research project TOPWASTE. We would like to gratefully acknowledge the financial support of the Danish Strategic Research Council to the TOPWASTE project.

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