An environmental assessment of mercury removal during lamp recycling

Recolight

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Executive Summary

Anthesis was commissioned by Recolight Ltd to carry out a high-level assessment of the greenhouse gas emissions associated with the recovery of mercury from spent gas discharge lamps, through distillation. The purpose of this study is to inform Recolight when deciding on the best waste treatment method for spent gas discharge lamps. In addition, this study can be used to better understand the environmental implications of the redrafted guidance on Best Available Treatment, Recovery and Recycling Techniques (BATRRT).

Anthesis have carried out an analysis on the mercury-recovery process through distillation, based on publicly-available secondary data. The work is based on a gate-to-gate product carbon footprint approach in line with the principles of the World Resource Institute's Greenhouse Gas Protocol.

Our study finds that the recovery of mercury by distillation from 10,000 2ft T8 fluorescent tube lamps (equivalent to 1 tonne) would emit approximately 21 $kgCO_2e$ (in the UK). Based on different modelling scenarios and assuming that none of the separated mercury is reused, which is representative of the prevailing market conditions; there are no environmental benefits associated with separating the mercury and CO2e emissions can be avoided through omitting this processing step. This is because all other end of life outcomes are the same, in either case.

It is important to note that the greenhouse gas emissions associated with the end-of-life processing of fluorescent lamps is a small fraction of the overall product footprint (Navigant Consulting (Europe) Limited, 2009). Modern fluorescent lamps were, for many years, among the most efficient light sources available and during their operational life, they can be expected to consume considerably less electricity than incandescent or halogen lamps. In a wider context therefore, the avoided greenhouse gas emissions associated with use of a fluorescent lamp (instead of a less-efficient alternative) are significant, regardless of whether the mercury is recovered at end of life.

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1 Scope of Study

This study models and compares the greenhouse gas emissions associated with two end-of-life scenarios, outlined below. Because the study is a comparison of two processes, only those life-cycle steps that differ from each other have been evaluated. The two scenarios are illustrated in Figure 1 and Figure 2 below. The area within the grey box in Figure 2 shows the processes, inputs and outputs that differ between the two scenarios. Only these elements have been considered within the scope of this study.

1.1 Scenario 1

In the non-recovery scenario, spent fluorescent or high-intensity discharge lamps are transported to a hazardous waste processing site where they are crushed or cut open. The glass and metal end caps are recovered for recycling, while the phosphor coating inside the glass (which contains most of the mercury) is dispensed into secure steel barrels for disposal as hazardous waste. Any mercury vapour released during the process is collected via sulphur-laden activated carbon filters, which are also disposed to hazardous waste.

1.2 Scenario 2

In the mercury-recovery via distillation scenario, lamps follow the same process but when the phosphor powder has been separated from the glass and metal end-caps, it is heated to over 500^{O}C in order to release the mercury contained within it. Once released, the mercury gas is oxidised to remove impurities. Finally, both the mercury gas and the phosphor powder are cooled using a condensation coil. The liquid mercury is dispensed to secure steel barrels, as is the waste phosphor and both are disposed to hazardous waste storage.

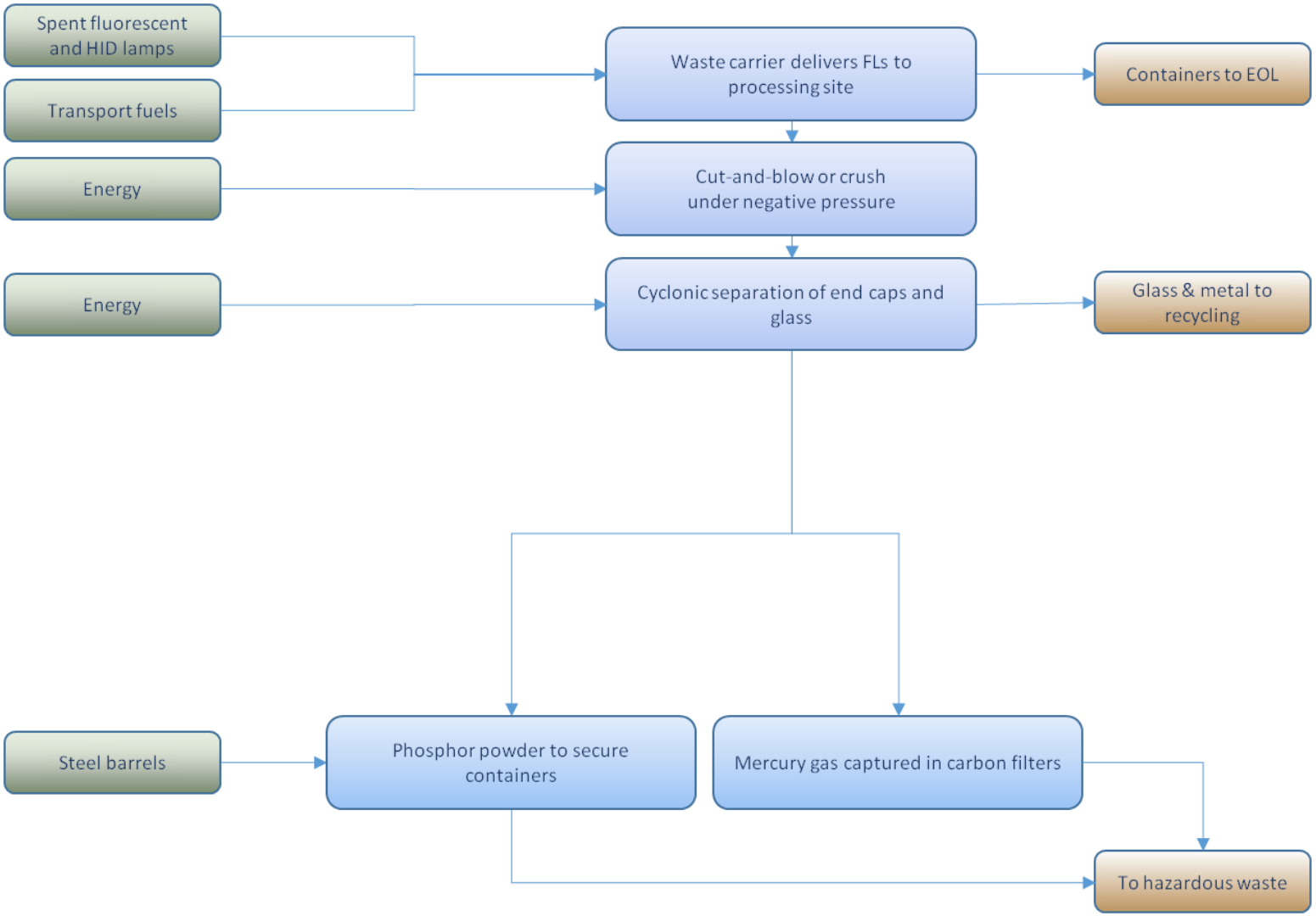

Figure 1 End-of-life processing without mercury recovery (Scenario 1)

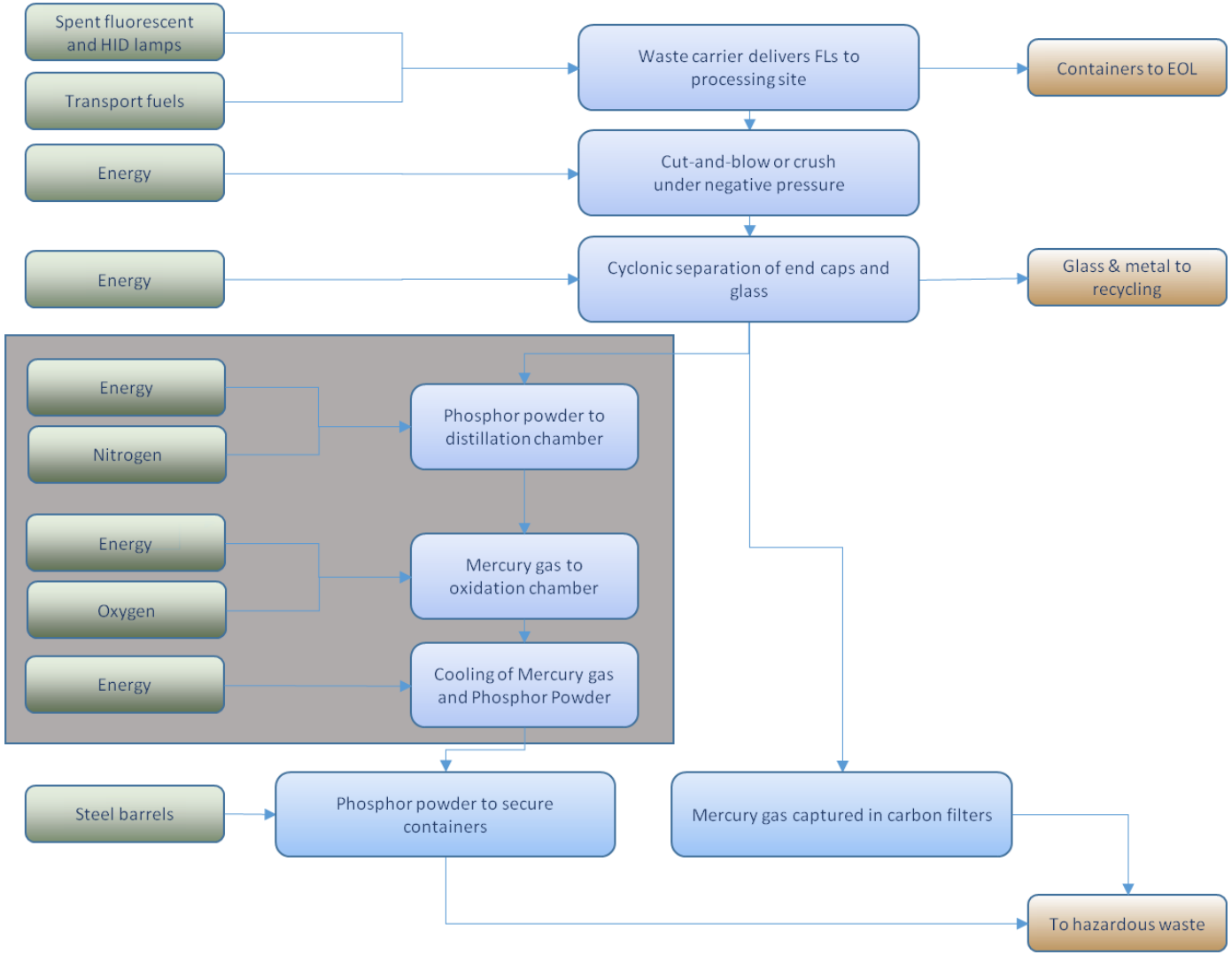

Figure 2 End-of-life processing with mercury recovery (additional processes are denoted by the grey shaded area) (Scenario 2)

2 Register of Assumptions

2.1 Process flow

The processes above have been defined as being representative of a typical process flow, rather than describing the exact process at a specific site. Several variations may occur in how lamps are processed at specific locations. For example:

- lamps may be crushed before being delivered to the waste processing site;
- the phosphor powder may be transported to a different site during processing
- packaging conventions may vary between sites
- loaded carbon filters may be shredded and input to the mercury distillation process

The impact of such variations has been considered and is not expected to significantly affect the conclusions of the study. The results of this study are not valid for processing operations where the process differs significantly from the scenarios described above.

2.2 Input materials

The inputs to the mercury recovery process can vary according to the waste being treated. In this study we assume a function unit of 10,000 2ft T8 fluorescent lamps (equivalent to 1 tonne). The composition of such a lamp has been analysed (Tan, Song, & Li, 2015) and this inventory has been used to determine the mass of mercury-laden phosphor powder that is to be treated. Clearly, in a real-world application, the waste inputs are likely to consist of many types of lamp. The quantification of variations in greenhouse gas emissions according to input composition is beyond the scope of this study.

The bulk density of the crushed phosphor powder is assumed to be similar to that of fresh tri-phosphor powders, based on literature from crushing machine manufacturers. A simple average of three common tri-phosphor powders is used.

2.3 Treatment procedures

This study includes the energy consumption of the mercury recovery process (including generation and transmission impacts); the manufacture and consumption of nitrogen and oxygen during the heating processes; and the generation and use of compressed air. Emissions associated with the production, transmission and consumption of electricity are based on UK grid. For the batch-processing calculation, energy inputs are based on specific heat calculations and ignore any heat losses, or the heat of oxidation. It is therefore likely that the batch process represents an under-estimate of the true electricity demand.

2.4 Offtake markets and post processing destinations

Due to a lack of data it is assumed that the number and volume of steel barrels used for hazardous waste storage is the same in both scenarios. The quantification of emissions associated with the production and transportation of the barrels is therefore outside the scope of the study.

While both the mercury and the phosphor can exit the process in a suitable state for re-use, current market conditions mean that resale of either product is unlikely. This study therefore assumes that 100% of the recovered mercury and the spent phosphor powder are stored as hazardous waste. Should market conditions change, this assumption would need to be revisited.

3 Methodology

The calculation approach within the model follows the principles outlined in the World Resources Institute's GHG Protocol for product carbon footprints. In case a more precise result is required at a later date, the data within the model can easily be upgraded to enable full compliance with the standard. Secondary data has been sourced from manufacturer's literature, the Ecoinvent database and peer-reviewed literature.

The model is based on three separate calculations, each adopting a different approach. The first two calculations are based on information taken from equipment manufacturer's literature. The third is based on a published LCA.

1. Method One represents a large-scale continuous process, and uses manufacturer's estimate of energy consumption. Oxygen and nitrogen consumption are based on data from the second process.
2. Method Two represents a small-scale batch process, most likely to be used for waste phosphor powder. Energy use is based on specific heat calculations and no allowance is made for heat losses or the heat of oxidation. This is therefore expected to provide a low estimate of the value.
3. The final calculation provides a sense-check of the other two by quantifying the overall emissions associated with recycling of fluorescent lamps at industrial scale, using actual data from a plant in China. As this final calculation does not separate out the distillation energy from crushing, separating and other energy uses, it is expected to be the largest value.

The results are calculated in an Excel workbook, provided as an annex to this report. To enable comparison, all results are presented as a common functional unit, namely the greenhouse gas emissions resulting from the recovery of mercury from 1 tonne of spent 2ft T8 fluorescent lamps (assumed 10,000). This type of lamp was chosen because it is commonplace, an inventory was available and it is assumed to be representative of the input material used in lamp recycling plants.

4 Results

The results are shown in table 1 below.

Process	kg CO_2e / tonne
MRT Continuous	20.75
MRT Batch	16.02
Chinese LCA (indicative upper limit)	140.42

Table 1 Summary Results

As expected, the highest value is that based on real data collected from a Chinese lamp recycling plant. However as it is not possible to separate out the energy used for distillation from other processes, this value is not considered in the final results and is provided for context only.

The two MRT processes provide comparable values, although given that the energy model for the batch process excludes oxidation, it is considered that the results from the continuous process can be considered the most representative.

Based on these results it can be said that the recovery of mercury by distillation from 10,000 2ft T8 fluorescent lamps in the UK is responsible for emitting approximately 21 kg CO_2e.

5 References

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6 Document Control

Version	Date	Author	Changes	Approved
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