Fra: Schou, Lone
Sendt: 11. marts 2009 09:00
Til: Jakobsen, Dorte Skjøtt
Emne: VS: Response to Questions on GPRC [SEC=UNCLASSIFIED]

Vedhæftede filer: Attachment B1 Bridle letter 26 Feb 09.doc; Attachment B2 SIA to Bridle GPCR110608.pdf; Nolan ITU HCB Rpt 1-2A.pdf; Overview_Attachment A_B 110309.doc
til sagen - tak lone

Fra: Reville, Barry [mailto:Barry.Reville@environment.gov.au]
Sendt: on 11-03-2009 07:54
Til: Schou, Lone; Madsen, Søren R. N.
Cc: Hall, Damien
Emne: Response to Questions on GPRC [SEC=UNCLASSIFIED]

Dear Lone
Thank you for your recent emails regarding Orica's export application.
In your email of 20 February 2009, you raised some issues regarding the consultation process carried out by SIA in the preparation of its report into Australia's capacity to treat the Orica HCB legacy stockpile.

Subsequently, in your email of 5 March 2009, you mentioned that Mr Trevor Bridle has provided you with a copy of his letter to Minister Garrett.

Our responses to the specific issues you have raised, which are contained also in Mr Bridle's letter, are provided in the attached documents:

- Overview, Attachment A, Table 1, Attachment B
- Attachments B1, B2.

You have asked also for a copy of the Orica commissioned Nolan ITU report which evaluated the environmental cost of a GeoMelt facility. The report, which is entitled *Environmental Analysis of Local vs. Overseas HCB Management Options, September 2005* is attached to this email.

If there is anything further that you require, please do not hesitate to contact me or Damien.
Best regards
Barry
<<Attachment B1 Bridle letter 26 Feb 09.doc>> <<Attachment B2 SIA to Bridle GPCR110608.pdf>> <<Nolan ITU HCB Rpt 1-2A.pdf>> <<Overview_Attachment A_B 110309.doc>>

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26 th February, 2009

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The Hon Peter Garrett AM MP,
Minister for the Environment, Heritage and the Arts,
PO Box 6022,
Parliament House,
Canberra, ACT 2600th

Dear Minister,

Subject: Misinformation and damage done to the reputation of the Gas Phase Chemical Reduction Process for HCB destruction

I feel compelled to formally write to you to object to the Misinformation and damage done to the reputation of the Gas Phase Chemical Reduction (GPCR) process. Inaccurate and misleading claims have once again been repeated in the Sustainable Infrastructure Australia (SIA) Report *"Orica Hexachlorobenzene Waste Stockpile: Independent Assessment Report"*, January 2009, commissioned by your department.

Misinformation regarding the efficacy of the GPCR process, appears to have been sourced from Orica, and has been "regurgitated" in many publications and oral presentations regarding the proposed export of Orica's HCB waste, including in this latest SIA report.

While I was contacted by SIA, I was not specifically asked to comment on the efficacy of the GPCR technology for the treatment of HCB waste. If I had been I would have been able to correct the misleading information published in the SIA report.

Misinformation By repeating this, the SIA report is severely tarnishing the excellent reputation of the GPCR process, which has received very favorable reviews and support by reputable agencies such as UNEP, UNIDO and the U.S. EPA.

Before commencing my private consulting practice I was the Technical Director of Environmental Solutions International Ltd (ESI) in Perth, WA. In this role I was instrumental in bringing the GPCR process to Australia, via formation of a partnership with the technology developer, Dr Doug Hallett of Canada. In fact it is interesting to note that a Federal Government NPDP grant was awarded to ESI to help establish a commercial-scale facility in WA GPCR and that the then Environment Minister (Ros Kelly) GPCR visited a demonstration plant in Michigan and consulted with the U.S. EPA before approving this funding.

During its seven year operating life in the Kwinana GPCR process successfully destroyed the majority of WA's hazardous waste stream, which comprised mostly high strength Scheduled Wastes (Pesticides and PCBs).

On behalf of Dr Hallett's company (Hallett and Environmental Technology Group Inc), I made numerous attempts to brief the Hazardous Waste Technical Group (HWTG), which provides independent advice to your department, however, I was never given the opportunity to present factual information on the process to the GPCR HWTG.

Consequently, I arranged a meeting with Orica (19th February, 2008) to apprise them of the status of the technology and to explore the potential of using the Orica GPCR process for the destruction of their HCB waste in Australia.

The outcome of this meeting was that Orica would not consider any use of technology which was not **currently** operating to treat hazardous waste. In addition, Orica would NOT concede that they had been providing misleading information regarding the efficacy of the GPCR process in relation to the processing of 7 tonnes of HCB waste their (a commercial-scale trial was conducted GPCR on Orica's HCB waste in Kwinana in April 1999).

The specific GPCR Misinformation regarding the process that I am referring to and which is quoted in the SIA report, includes:

In section 4.4.3 of the report, SIA state that the GPCR process treated primarily "low concentration" OC wastes. This is not true; WA most of the wastes were treated pure DDT and PCBs with high-strength wastes. In fact, during its operational life, the GPCR facility Kwinana treated in much of eastern Australia's high-strength Scheduled Wastes, WA DEP after obtaining approval to do so.

In section 4.4.4 of the SIA report it is stated that the commercial HCB trial was not successful in that the process of organic residue left. This is not true as the residue from the process was the inorganics present in the mixed HCB waste. In HCB all the trials the GPCR process achieved in excess of 99.99999% destruction of HCB and the inorganic residue from the process met regulatory requirements for landfill disposal. In this section SIA say again incorrectly say that GPCR was predominately used to treat low strength wastes.

In section 4.4.5 of the report, SIA do not state that the one with high dioxin emission result occurred when, at the request of Orica, the rate exceeded the processing capacity of the scrubber to remove the HCl generated by the process. It was the this presence of HCl, which when combusted, that generated the dioxins. It appears that this information was obtained GPCR from Orica, with no independent attempt by SIA Orica to verify these statements, for example, with input from Dr Doug Hallett. Extensive independent testing and analysis has confirmed that dioxin emissions from the GPCR process are **well** below international standards

In section 4.4.6 of the SIA report it is stated that the residues from the GPCR process, when processing Orica's HCB waste, contained more than 2 mg HCB / kg. I believe this is NOT correct but have been unable to source the reference material from Orica to confirm where this value comes from.

We would like you to ensure this incorrect information is amended in the SIA report. It is a great shame that your Department's report has contributed to the further spreading of false information about a very worthy and appropriate technology that could successfully destroy Orica's HCB waste.

I look forward to you response on this matter as soon as possible to prevent any further damage to the commercial GPCR technology.

Sincerely,
Trevor Bridle
Principal Consultant

OVERVIEW

In March 2008, the Department of the Environment, Water, Heritage and the Arts (the Department) engaged Sustainable Infrastructure Australia (SIA) Pty Ltd to undertake an assessment of Australia's capacity to treat Orica's HCB waste stockpile.

The SIA report is an independent, technical, expert report. It required the gathering of technical information from the holders of that information, in this case, each of the waste disposal technology providers or facility operators throughout Australia and Orica, which had commissioned many tests of the feasibility of dealing with the HCB waste over the past years.

An independent assessment was necessary so that we could provide our Minister with independent, unbiased advice regarding current and future options for disposal of the Orica HCB waste stockpile.

The information in **Attachments A** and **B** and **Table 1** demonstrate that SIA underook, as part of its assessement of Australia's capacity to treat Orica's HCB legacy waste stockpile, an extensive, thorough and unbiased consultation process, and that this process included approaches to the operators or owners of all the technologies examined.

SIA has confirmed that its assessment process included:

- an extensive analysis of literature, technical reports and materials;
- telephone conferences, site visits and face to face meetings with key stakeholders, including relevant State regulatory authorities and available treatment technology providers in Australia; and
- an in depth analysis of the data and information obtained as part of these consulations.

In particular, and in reference to the claims brought to your attention by the Danish Society for Nature Conservation on behalf of the National Toxics Network, SIA has confirmed that, in seeking information into the Gas Phase Chemical Reduction (GPCR) process and its suitability for treating the Orica HCB waste stockpile, SIA wrote in June 2008 seeking comments on the GPCR section of its draft report to:

- Mr Trevor Bridle from Environmental Solutions International, and
- Mr Craig McEwan, the former Operations Manager for ELI Eco Logic Australia Pty Ltd.

Further details regarding the extent of SIA's consultation processes are provided in **Attachment A**, **Attachment B** and in **Table 1**.

The extensive consultation process undertaken by SIA ensured that, during the preparation of the report, each technology provider or owner was given the opportunity to provide input and comments to SIA in regards to the technical content of the report before the report was finalised.

SIA also has confirmed that before finalising the report, and to ensure the report's accuracy, SIA sought comments from each of the owners of the waste disposal facilities and that all comments provided by the facility owners were assessed by SIA and where relevant, the report was updated.

YOUR QUESTION ON THE CONSULTATION PROCESS:

Sustainable Infrastructure Australia Pty Ltd (SIA) was commissioned by the Department of the Environment, Water, Heritage and the Arts (the Department) to prepare an independent assessment report to review all current available technologies in Australia that would potentially be able to treat the Orica HCB stockpile.

The consultation process undertaken by SIA included the following:

- an extensive assessment of literature, technical reports and materials as provided by the Department, Orica, consultants and treatment technology providers;
- an in depth analysis of the data and information obtained;
- a series of telephone conferences, site visits and face to face meetings with stakeholders, including relevant State environmental planning authorities as well as available treatment technology providers; and
- the drafting of the SIA report.

As part of the assessment and drafting process, SIA approached each of the technology providers or owners, as well as Orica and asked them to:

- review the draft sections of the report which related to their technologies;
- provide written comments to SIA who would then assess the comments before including them, as appropriate, in the report.

This process ensured that technology providers and Orica had the opportunity to provide comment to SIA and the Department in regards to the technical content of the report during the preparation of the report.

At the conclusion of this lenghty consultation process, SIA provided the final report to the Department, which in turn (after further consultation wiht the technology providers) provided the report to you in the Danish Environmental Protection Agency. It was then provided to the Danish Broadcasting Corporation and the Danish Society for Nature Conservation.

Following its release in Denmark, the report was provided to the Australian technology providers which had been assessed, and under a Freedom of Information request, *The Australian* newspaper, which subsequently published an article on the subject. The report is now available upon request from the Department.

Further details regarding the extent of SIA's consultation processes are provided in **Table 1.**

Consultation regarding the Gas Phase Chemical Reduction Process (GPCR) and comments by Mr Trevor Bridle are dealt with in **Attachment B.**

TABLE 1

COMPANY	TECHNOLOGY	SIA Contact	Response
BCD Technologies Pty Ltd. (Narangba, QLD) and Enterra Pty Ltd. (Kingsgrove, NSW)	Base Catalysed Dechlorination or Base Catalysed Decomposition	Face to face, teleconference, written correspondence (The Department also wrote)	Yes – written responses were received and, where appropriate, changes were made to the SIA report
Tox Free – Waste Management Solutions	Thermal Desorption/destruction, High Temperature Incineration	Teleconference, written correspondence (The Department also wrote)	Yes – written responses were received and, where appropriate, changes were made to the SIA report
SRL Plasma	PLASCON waste destruction plants (using Plasma technology)	Teleconference (The Department also wrote)	Yes – written responses were received
Chemsal	Hazardous waste collection, disposal, resource, recovery, recycling, chemical treatment, chemical fixation and repackaging	Teleconference	Yes – written responses were received
Hydrodec Australia Pty Ltd	Hydrodec	Face to face, teleconference, written correspondence (The Department also wrote)	Yes – written responses were received and, where appropriate, changes were made to the SIA report
Zealmore Pty. Ltd	Plasma-electric Waste Converter (PWC)	Teleconference	No response
Bridle Consulting	HEAT (used to be Ecologic, GPCR)	Written correspondence	No response
ELI Eco Logic	GPCR	Written correspondence (The Department also wrote)	No response

Ausmelt	Ausmelt Process	Face to face meetings, teleconference, written correspondence (The Department also wrote)	Yes – written responses were received and, where appropriate, changes were made to the SIA report
Department of Environmental Protection (DEP) – WA	General knowledge of Kwinana operations and Ecologic	Teleconference	Yes – written responses were received
Queensland EPA	General knowledge of BCD and PLASCON	Face to face meetings	Yes – written responses were received
Orica	The waste generator	Face to face, teleconference, written correspondence	Yes – written responses were received and, where appropriate, changes were made to the SIA report

THE GAS PHASE CHEMICAL REDUCTION PROCESS (GPCR):

GPCR Technology in Australia:

Our most recent information is that the owner of the GPCR technology in Australia is ELI Eco Logic Australia Pty Ltd, based in Kwinana, Western Australia, however, there currently is no operational GPCR facility in Australia.

In mid-1995, a GPCR plant (Eco Logic) was commissioned in Kwinana, Western Australia. The majority of waste treatment activities using GPCR occurred at this plant, which began commissioning operations in 1995 and achieved commercial throughputs by 1998. The plant was closed in December 2000 due to declining waste availability in Australia.

Background to GPCR technology trials by ELI Eco Logic on Orica HCB waste

During the time that the GPCR Kwinana facility was in operation, Orica Australia Pty Ltd commissioned ELI Eco Logic to carry out trials on the destruction capability of the GPCR technology as applied to the Orica HCB waste. These trials were carried out by ELI Eco Logic in April 1999. The trials were observed by Orica and independent engineering specialists, Kvaerner Engineering.

In August 1999, Eco Logic of Ontario, Canada, prepared a commercial in confidence report for Orica on the HCB trials. Many of the GPCR findings in the SIA report refer to figures and results from this 1999 Eco Logic report.

It is important to note, therefore, that SIA relied upon data and test results produced by Eco Logic, not figures produced by Orica. This becomes very relevant when considering the claims made by Mr Trevor Bridle which have been incorporated in a letter by him to our Minister dated 26 February 2009 (**Attachment B1**) published on the Pro-Herten website and raised with the Danish EPA by the Danish Society for Nature Conservation.

These claims are seriously flawed and appear to be made by Mr Bridle in ignorance of the Eco Logic report of 1999. He claims in his letter that

> *"While I was contacted by SIA, I was not specifically asked to comment on the efficacy of the GPCR technology for the treatment of HCB waste. If I had been I would have been able to correct the misleading information published in the SIA report"*

This is difficult to reconcile with the fact that SIA wrote to him on 11 June 2008 providing him with a copy of the section of the SIA report dealing with the GPCR process and its capacity to deal with the HCB waste and specifically asked him:

> *"to review and comment on details prepared in the report to ensure that there are:*
> *1) no significant inaccuracies or errors of fact (based on information that you may or may not have provided) in the report;*
> *2) no other matters of concern in the document."*

SIA's letter to Mr Bridle is at **Attachment B2**.

SIA has confirmed to us that Mr Bridle never responded to this invitation.

SIA also wrote to Mr Craig McEwan (formerly with ELI Eco Logic) on 11 June 2008 asking for comment on the GPCR section of the SIA report and received no reply.

SIA has confirmed to us that Mr McEwan never responded to this invitation.

Involvement of Mr Trevor Bridle and Dr Doug Hallett:

We understand that Mr Trevor Bridle of Bridle Consulting represents Hallett Environmental And Technology group (HEAT) in Australia.

HEAT is a company run by the original developer of the GPCR technology, Dr Doug Hallett, and is based in Ontario, Canada.

The Department has been unable to determine the exact involvement of Mr Bridle in the ELI Eco Logic HCB trials conducted in 1999 or whether he has seen the detailed results of the commercial-in-confidence report provided by Eco Logic to Orica. In a letter to our Minister, published on the Pro Herten website on 26 February 2009 (**Attachment B1**), we note that Mr Bridle stated:

> *"in section 4.4.6 of the SIA report it is stated that the residues from the GPCR process, when processing Orica's HCB waste, contained more than 2 mg HCB/kg. I believe this is NOT correct but have been unable to source the reference material from Orica to confirm where this value comes from.*

This may suggest he has not seen the report, since the Eco Logic report quite clearly says that the concentrations of HCB in the residual mass from the drums processed were 3-5.6 *microg*/g (3-5.6 mg/Kg) (see **Attachment B** below).

This impression is strengthened when one reads all four comments sent to us by you and also mentioned in his letter. They all seem incompatible with the 1999 Eco Logic report. We also note that his paraphrasing of the SIA report often does not convey SIA's intent. Our responses to the four comments on the SIA report are given below, based on advice from SIA.

The trials, figures and other data referred to in our answers are taken from the 1999 Eco Logic report documenting the efforts to deal with the HCB waste with the GPCR process.

Responses to Questions on the GPCR Process

In this section we:

(i) respond to the questions raised by the National Toxics Network and the Danish Society for Nature Conservation;

(ii) provide the relevant section of Mr Bridle's letter which paraphrases the SIA report from which the question is taken;

(iii) provide the "actual" words from the SIA report; and

(iv) we provide technical responses to these questions.

We have explained above that SIA provided Mr Bridle with its draft report in June 2008, which should have provided him abundant opportunity to respond to these issues and to have his comments incorporated in the January 2009 final SIA report. We do not know why, but Mr Bridle did not respond to the SIA request.

We would like to emphasise that, in making our responses to the claims made by Mr Bridle we are not suggesting that the GPCR technology is not effective in dealing with a range of hazardous wastes.

The SIA report was looking specifically at the ability of existing technologies and facilities to deal in a realistic timeframe with the Orica HCB wastes which are unusually complex and difficult to handle, largely because of their heterogeneity.

As stated in the SIA report:

> *"It must be clearly noted that the assessment of these technologies (which are all proven technologies) is to determine their viability for treatment of the significant stockpile of high concentration HCB waste stored at Botany. This assessment does not apply to any other waste stream and should not reflect positively or negatively on whether the process is technically or commercially feasible in the treatment of other hazardous waste streams or even smaller and/or less concentrated volumes of Hexachlorobenzene (HCB) waste. The scale and concentration of the Orica HCB is unique and there are significant factors to consider in the safe and effective treatment of this stockpile as distinct from the treatment of other hazardous wastes.*
>
> *The scope of this assessment does not incorporate evaluation of these technologies for treatment of other waste streams and may well provide different outcomes and results in those cases."*

Similarly, we are not criticising Mr Bridle for defending the GPCR process, although we do not accept the correctness of his claims relating to the capacity to GPCR technology to deal with the Orica HCB waste. It is unfortunate that Mr Bridle's concerns were not raised and discussed with SIA earlier so that he better understood the basis for SIA's conclusions.

Question 1

In section 4.4.3 of the report SIA state that GPCR treated primarily "low concentration" OC wastes. This is not true, with most of the wastes treated being pure DDT and high-strength PCB wastes.

Mr Bridle's claim:

In section 4.4.3 of the report, SIA state that the GPCR process treated primarily "low concentration" OC wastes. This is not true; most of the WA wastes treated were pure DDT and high-strength PCB wastes. In fact, during its operational life, the GPCR facility in Kwinana treated much of Eastern Australia's high-strength Scheduled Wastes, after obtaining WA DEP approval to do so.

Actual wording in SIA report:

> "Eco Logic facilities to date have processed waste streams with low to medium hydrocarbon and organo-chlorine contamination levels, such as contaminated soils, and this is the continuing projected market for the technology. The Orica HCB waste stockpile has highly concentrated high chlorine content and is a high organics (hydrocarbon) content material.
>
> In total, the plant treated in excess of 2,000 tonnes of waste including PCBs, pesticides and other POP's, with up to 1,500 tonnes having been treated in the last two years of operation."

Response to Question 1

With respect to the scale of operation, SIA saw this as an area of concern because there is definitely no existing GPCR operation handling anything like the volume and chlorine content involved for the treatment of this particular HCB waste stream. This material is up to 100% HCB in most containers and HCB is 75% by weight chlorine of the complete stockpile.

Note that the SIA report in saying "<u>low to medium</u> hydrocarbon and organo-chlorine contamination levels" is doing so in relation to HCB.

The DDT and OC contaminated oil streams that were commercially destroyed in the Kwinana facility in Western Australia contained only a fraction of the chlorine content of this HCB waste.

HCB, C_6Cl_6 is 75% chlorine by weight.

DDT, $C_{14}H_9Cl_5$ is 50% chlorine by weight.

Commercial DDT is usually dissolved in a solvent such as toluene for direct use in solution form with normal concentrations of 5 to 10%. This equates to just 2.5 to 5% chlorine content. SIA have informed the Department that there are records of 30.3 % DDT being processed at the Kwinana GPCR facility but no quantities or rates are given. Even so, that is only 15% chlorine by content. Therefore, in direct comparison to the Orica HCB stockpile which is 75% chlorine by weight, it is clear that the GPCR facility treated lower concentration chlorine wastes.

PCB wastes are usually in the form of transformer and electric power condenser, switchgear insulation and coolant fluid. In commercial volumes, the concentrations are usually 20 – 40% chlorine by content. However, by the mid to late 1990s when the GPCR Kwinana plant was in operation, the majority of Australia's transformers had been flushed with fresh PCB free oil and concentrations were down to hundreds or a few thousand parts per million.

Please note that 1% is 10,000ppm meaning that the waste transformer oils being treated were well below the 1% level.

If the plant was still operating and if it could deal with the Orica HCB stockpiled waste, the decommissioned ELI Eco Logic plant in Kwinana could treat up to 0.66 tonnes per day (max) of the Orica HCB waste, requiring 100 plant years of operation to clear the HCB waste stream under consideration. To reduce this time frame a ten times scale up would be required as a minimum which introduces its own inherent engineering, technical and licensing issues.

Currently there are no GPCR facilities operating in Australia.

Question 2

In section 4.4.4 SIA report that the commercial HCB trial was not successful in that the process left an organic residue. This is not true as the residue in the SBV was the inorganics present in the mixed HCB waste. Again SIA incorrectly say that GPCR was used to treat predominately low strength wastes.

Mr Bridle's claim:

In section 4.4.4 of the SIA report it is stated that the commercial HCB trial was not successful in that the process left an organic residue. This is not true as the residue from the process was the inorganics present in the mixed HCB waste. In all the HCB trials the GPCR process achieved in excess of 99.99999% destruction of HCB and the inorganic residue from the process met regulatory requirements for landfill disposal. In this section SIA again say incorrectly say that GPCR was used to treat predominately low strength wastes.

Actual wording in SIA report:

> "The Eco Logic process was established with a hydrogen vaporization front end. Trials with Orica's HCB waste stockpile were disappointing and not all of the Chlorinated Hydrocarbons (CHCs) were volatilized. The residual material in the drums had transformed during the soaking process into a hard, not volatile char-like substance that would require a further treatment step. There were many other practical issues related to the use of hydrogen."

Response to Question 2

The factual analysis data on the residues from the Eco Logic 1999 report confirm that the residues contained HCB above the threshold level. They were not just inorganics:

Residues Mass:

0.4-2% (as % of the original HCB mass)

Chemical analysis:

I-TEQ	0.5-51 ng/g
Total Carbon	39-65 %
Chloride	2.3-3.1%
HCB	3-5.6 *micro*g/g (3-5.6 mg/kg)

The results indicate that the level of HCB in the residue after Thermal Reduction Batch Processing was in excess of the HCB Waste Management Plan specification that any solid residues will contain less than 2mg/kg of scheduled chemicals expressed as chlorine.

Possible solutions have been suggested that would require, as indicated in the SIA report, major re-engineering of waste pre-treatment equipment and extensive trials, resulting in lengthy delays in the development of a new facility to treat the Orica HCB waste stockpile.

Question 3

In section 4.4.5 SIA again do not state that the high dioxin emission result was generated when the processing rate exceeded the capacity of the scrubber to remove HCl, which when combusted, generated the dioxins. It appears that the GPCR information was obtained from Orica, with no attempt to verify the Orica statements by comment from Doug Hallett, who owns the technology.

Mr Bridle's claim:

In section 4.4.5 of the report, SIA do not state that the one high dioxin emission result occurred when, at the request of Orica, the processing rate exceeded the capacity of the scrubber to remove the HCl generated by the process. It was the presence of this HCl, which when combusted, that generated the dioxins. It appears that this GPCR information was obtained from Orica, with no independent attempt by SIA to verify these Orica statements, for example, with input from Dr Doug Hallett. Extensive independent testing and analysis has confirmed that dioxin emissions from the GPCR process are ***well*** *below international standards.*

Actual wording in SIA report:

> "The technology is not suitable in its present state for treating HCB waste, primarily due to the wide range of melting and boiling points of the compounds present in the waste.
>
> With further development, however, the technology could no doubt be suited to the destruction of the HCB waste. Some preliminary testing on the Orica HCB waste stockpile produced an off-gas with dioxin content 10 times the generally acceptable level. Further processing of the off-gases would have to be considered."

In addition from Section 4.4.6, SIA states:

> "The major concerns with Gas Phase Chemical Reduction (GPCR) were the demonstrated high dioxin level in stack emissions (0.85-1.59ng/m3) compared to the 0.1 ng level required, the resulting solid residues which did not meet landfill criteria (HCB> 2mg/Kg), and the production of "black tarry material" in the scrubbing system.
>
> Orica engaged trials for treatment of the HCB waste stockpile at the Kwinana facility and Kvaerner Engineering, who observed the trials, recommended major modifications to the plant – including additional scrubbers, column packing changes, and burner /combustion condition changes; and
>
> The plant at Kwinana did not meet the 0.1 ng (TEQ)/m3 limit for dioxins/furans during the HCB tests. Eco Logic questioned the accuracy of these results. Eco Logic suggested that more effective scrubbing, changes to gas reticulation rates and changes to auxiliary burner design would enable the process to meet emission criteria; and
>
> The main advantage of the Eco Logic process , in theory, is that it avoids the de novo synthesis of dioxins/furans. In practice, dioxin/furans were found in Eco Logic residuals and in the gaseous discharge."

Response to Question 3

The physical testing data relating to stack emissions from the three trials carried out indicate that emissions for dioxins/furans were in a range of 0.852 – 1.59 ng/m^3 I-TEQ. This does not meet the 0.1 ng/m^3 (TEQ) limit for dioxins/furans established for the HCB trials.

Note that these results are those provided by Eco Logic in their 1999 report to Orica, they are not figures produced by Orica as inferred by Mr Bridle.

The results of trials indicate that emissions scrubbing suffered badly due to carry over of tars from the treatment process. This was seen as a serious issue by SIA, estimated to require considerable process and equipment development, firstly to contend with the tar precipitation on scrubber internals and secondly to manage the tar and soot, solids residues extracted from the scrubbers, which would themselves be contaminated with organo-chlorine compounds.

SIA accurately states in its report that emissions could be reduced but only with major modifications to plant machinery.

Question 4

In section 4.4.6 SIA state that the residues contained more than 2 mg HCB/kg. We believe this is NOT correct, but will again re-confirm with Doug Hallett that *Only 2% of the input mass was present following treatment. This material was tested and found to be silicon and carbon residue. The HCB was destroyed in the reactor with a DE >99.9999% for all tests.*

Mr Bridle's claim:

In section 4.4.6 of the SIA report it is stated that the residues from the GPCR process, when processing Orica's HCB waste, contained more than 2 mg HCB/kg. I believe this is NOT correct but have been unable to source the reference material from Orica to confirm where this value comes from.

Actual wording in SIA report:

> "The major concerns with Gas Phase Chemical Reduction (GPCR) were the demonstrated high dioxin level in stack emissions (0.85-1.59ng/m3) compared to the 0.1 ng level required, the resulting solid residues which did not meet landfill criteria (HCB> 2mg/Kg), and the production of "black tarry material" in the scrubbing system.
>
> Orica engaged trials for treatment of the HCB waste stockpile at the Kwinana facility and Kvaerner Engineering, who observed the trials, recommended major modifications to the plant – including additional scrubbers, column packing changes, and burner /combustion condition changes.
>
> In addition, there were several residual streams which may be difficult to reprocess and would need further assessment and possible treatment before disposal. There are also the unresolved problems of dealing with the black tarry material formed in the dechlorination process."

Response to Question 4

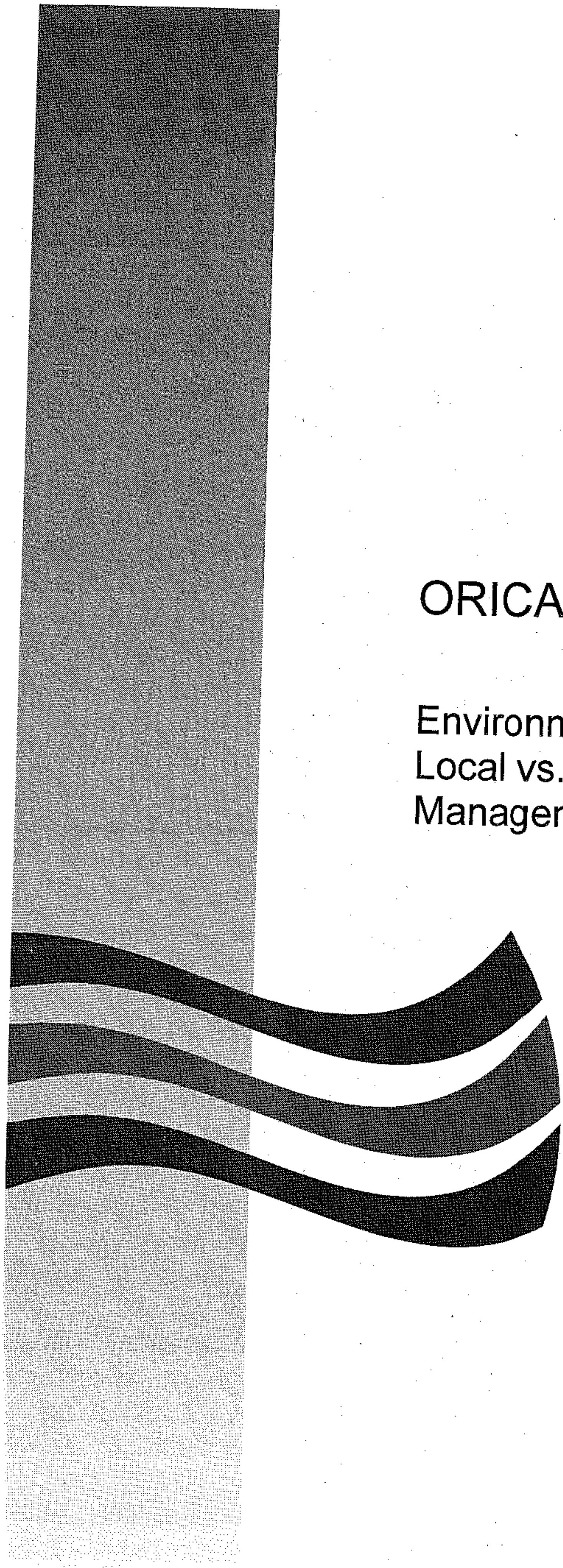
The level of destruction efficiency achieved is not in question. However, the 1999 Eco Logic test results clearly indicate that residual material was found in the drums after Thermal Batch Reduction Processing (TBRP). The concentrations of HCB in the residual mass from the drums processed were 3-5.6 *microg*/g (3-5.6 mg/kg) (see response to Question 2).

This exceeds the HCB Waste Management Plan specification that any solid residues will contain less than 2mg/kg of scheduled chemicals expressed as chlorine.

Again, these figures are the test results provided in the Eco Logic 1999 report.

The HCB drum pre treatment process therefore requires development of a separate process for handling and treating the solid residues still contaminated with the organo-chlorine compounds. The problem is the variety of compounds and physical forms of the Orica HCB waste, ranging from slurries to polymer gels and rubbers, requiring a wide range of evaporation temperatures and retention times.

SIA has indicated that this has been found to be a problem with any thermal desorption process and only the higher temperatures of incineration are capable of vaporizing or gasifying all the organic components of waste such as the Orica HCB material. Hence, the combination of thermal desorption (e.g. TBRP) and GPCR with high efficiency waste gas scrubbing, would require a second stage of thermal destruction (e.g. HTI) for the various solid residues arising from all three steps of the GPCR treatment process.



NolanITU

ORICA AUSTRALIA PTY LTD

Environmental Analysis of Local vs. Overseas HCB Waste Management Options

September 2005

Ref: 4128-06

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

EXECUTIVE SUMMARY

Project Background

From 1964 to 1991 Orica Australia Pty Limited (formerly ICI Australia) produced hexachlorobenzene (HCB) as a waste by-product from its manufacture of chlorinated solvents (carbon tetrachloride and perchlorethylene), at the Botany Industrial Park (Botany). As a result of these activities there are currently some 10,500 tonnes of high-level concentrated HCB waste and HCB-contaminated material, in addition to around 4,000 tonnes of low-level HCB contaminated material stored at Botany. Since 1991, no HCB waste has been produced by Orica.

HCB is a persistent organic pollutant (POP) with known human health and environmental impacts. It is included on the National Pollutant Inventory been classified as a 'scheduled waste' since 1993, being organic in nature; resistant to degradation by chemical, physical or biological means, and; toxic to humans, vegetation or aquatic life, and bio-accumulative in humans, flora and fauna, including likely carcinogenic and mutagenic properties.

Since 1976, a solution to the management of HCB waste at Orica's Botany site has been sought. In 2004, an Independent Review Panel, appointed by the NSW Government, found the GeoMelt technology, proposed by Orica for construction at Botany to destroy the HCB waste was fit for purpose but recommended that the destruction plant be located at a remote NSW site. While Orica has stated that it will be seeking to implement this and other recommendations of the Independent Review Panel, history has shown that the siting of such a facility introduces many additional challenges.

A review of available technologies for destruction of the HCB waste found export to a High Temperature Incinerator, operating to modern environmental standards, represented the next best option. As a contingency plan in the event that an appropriate site to destroy the HCB waste cannot be found, the option of exporting the waste under the *Hazardous Waste (Regulation of Exports and Imports) Act 1989* is concurrently being considered by Orica.

Giving regard to the governing legislative framework for environmental protection in NSW[1] and Australia[2], Orica has commissioned Nolan-ITU to review the overall environmental performance of alternative HCB waste treatment options. These options are:

1. Destruction of the HCB waste at a purpose built facility located in remote New South Wales (NSW) using GeoMelt technology; and
2. Exporting the waste to a hazardous waste treatment facility overseas using High Temperature Incineration (HTI) with energy and resource recovery.

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[1] The Protection of the Environment Operations Act 1997

[2] The Intergovernmental Agreement on the Environment 1989

These two options were arrived at based upon the findings and recommendations contained within the Independent Review Panel report, which was commissioned in January 2004 to examine the "capabilities of the proposed technology; alternative solutions".

The results of this assessment will be used to assist Orica to reach a decision as to its preferred management option for the waste. In seeking to identify the most appropriate option, Orica appreciates that this assessment is limited in scope. It specifically excludes hazard and risk assessment (as might arise during transportation of waste or from technology performance failure); and social or technical performance aspects of the different treatment options. The solution which is ultimately chosen will necessarily incorporate community values and build upon the advice of specialist appointed panels.

Project Approach

The internationally standardized method of Life Cycle Assessment (LCA) was used to compare the environmental performance of the two HCB waste management options.

The analysis is holistic in that all resource inputs and pollutant outputs associated with each aspect of the treatment system are incorporated in the analysis. This approach ensures that environmental impacts associated with plant construction, transport, treatment and residuals management, and resource recovery are given due regard.

In order to *interpret* the complex results of the LCA, two methods were used. The first method is the Australian-based, environmental-economic valuation method (Nolan-ITU, 2001; 2004). This method enables the results to be conveyed as a single monetised unit of measure. The method incorporates scientifically derived equivalence factors with environmental economic valuation techniques in order to make the results more meaningful to a wider audience.

The impact categories within the environmental-economic valuation method are:

- Global Warming Potential;
- Resource Savings;
- Air Pollution;
- Water Pollution;
- Solid Waste; and
- Water Use.

For the purposes of cross-checking results, the internationally used and commercially available Eco-Indicator (99) valuation method was also employed. This method represents one of the first internationally accepted methods to express environmental performance as a single indicator. The Eco-Indicator (99) method has been adapted to Australian conditions by RMIT University's Centre for Design, incorporating local life cycle inventory databases and weightings.

Findings

Figure A shows the relative environmental impacts of the two treatment options by process activity. The relative impact of the purpose built GeoMelt facility (in remote NSW) is shown along with export of the material to a European HTI rotary kiln. The environmental impact of the GeoMelt facility is substantially greater than that of the overseas HTI option across the sum of all impact categories. The dominant impact category associated with the actual "HCB Destruction" unit process is "Air Pollution" and while strict emission standards are assumed, the electricity demand of the GeoMelt facility contributes significantly to the poor performance of the technology.

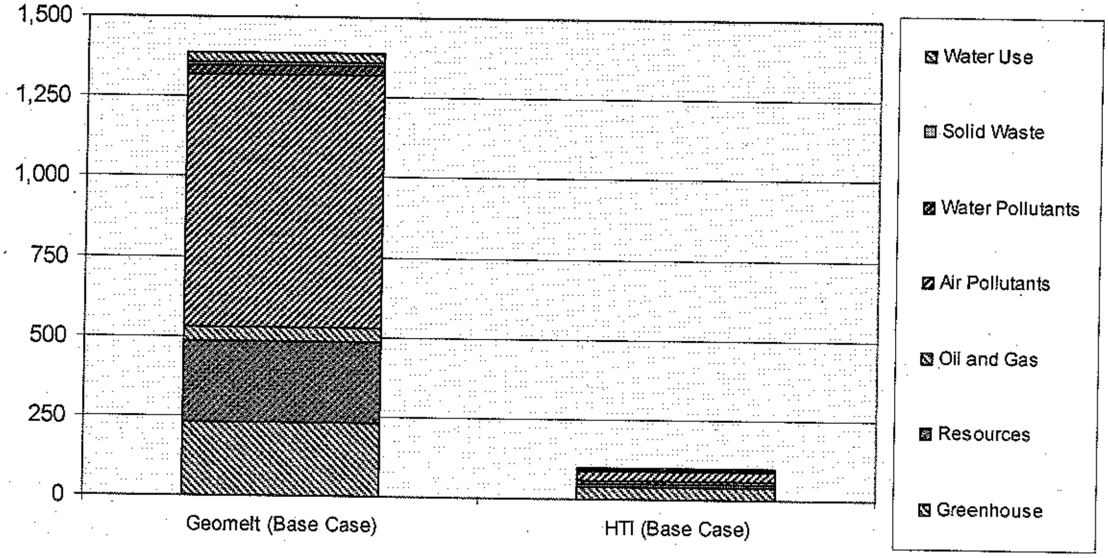

Figure A: Overall Environmental Impacts of HCB Management Options (Eco-$ per Tonne of HCB Waste)

Here, it should be noted that a peer review of the results and findings contained within this report has been conducted by RMIT University's Centre for Design.

Data Uncertainty

In addition to its lower (environmental) performance, relative to the overseas option (HTI rotary kiln), there is far greater uncertainty associated with the emissions data from the GeoMelt facility. By way of contrast, the HTI rotary kiln has many years of proven performance and reliable performance data from Europe. The influence of data uncertainty is captured in Figure B.

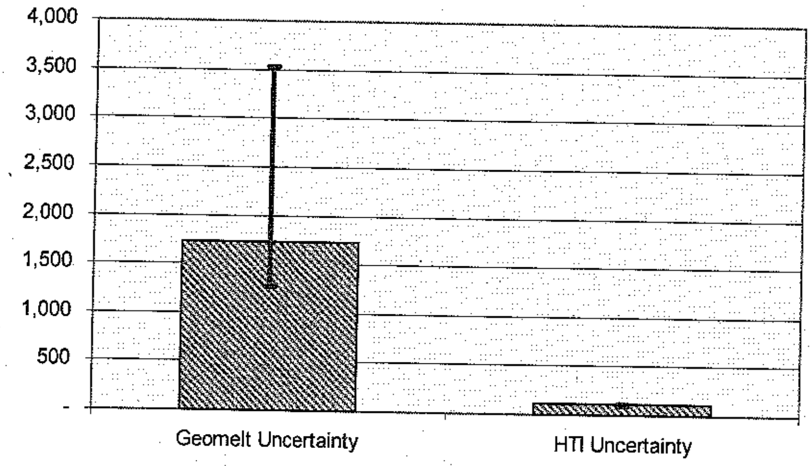

Figure B: Overall Relative Uncertainty Analysis Results for Both Treatment Options (Eco-$ per Tonne of HCB Waste)

Sensitivity Analysis

A number of sensitivity analyses were conducted to test the potential variation in environmental performance across the two options. These included:

1. GeoMelt and HTI facilities both performing in accordance with the strictest European Emissions standards;
2. Chlorine recovery from HTI rotary kiln as hydrochloric acid; and
3. Fly ash management costed at the maximum European rates, to account for the (uncosted) impact of fly ash disposal.
4. Substituting renewable electricity for conventional coal fired electricity within the GeoMelt process.

Figure C, D and E illustrate that the relative results remain largely unchanged even with the application of a significant waste disposal burden on the HTI rotary kiln process and varying energy sources. That is, the relative impact of the GeoMelt process still outweighs the HTI process by almost fivefold.

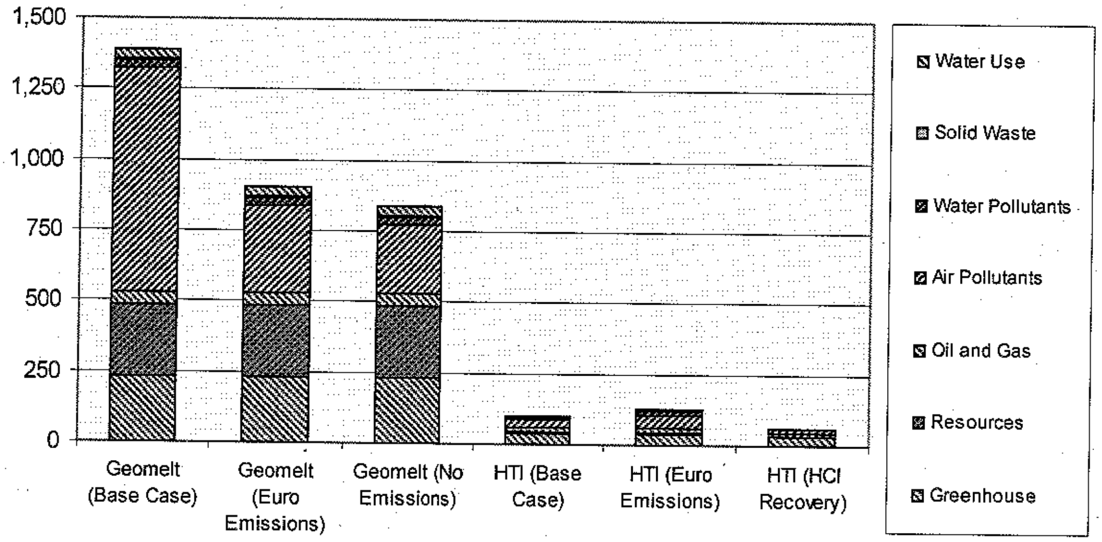

Figure C: Environmental Impacts Sensitivity Results (Eco-$ per Tonne of HCB Waste)

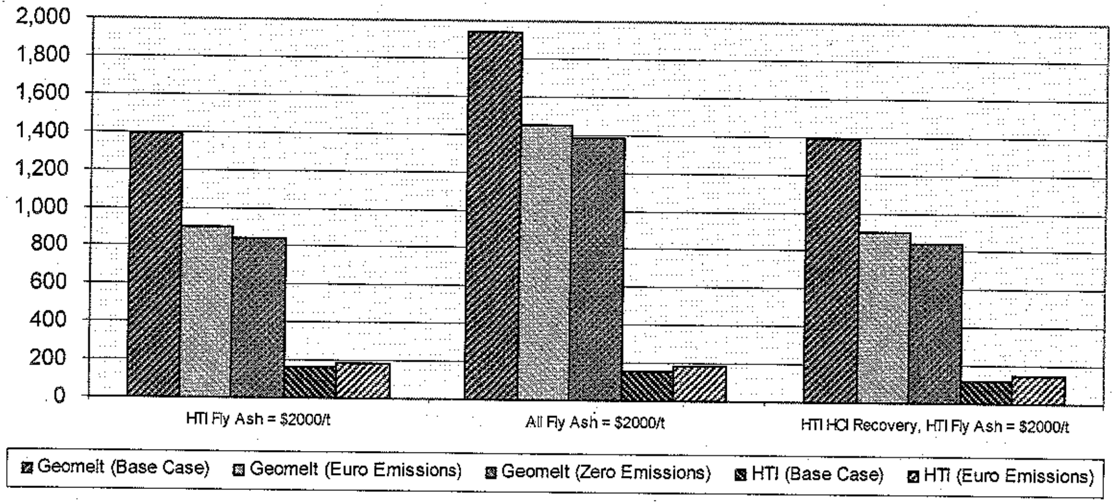

Figure D: Environmental Impacts Sensitivity Results (Eco-$ per Tonne of HCB Waste)

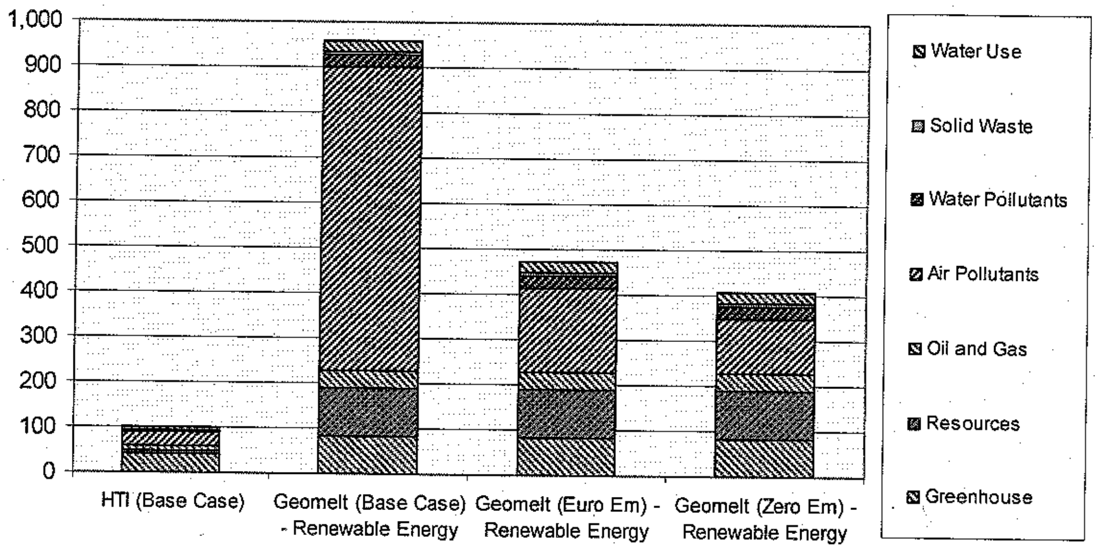

Figure E: Environmental Impacts Sensitivity Results – Renewable Electricity (Eco-$ per Tonne of HCB Waste)

Conclusions

The key conclusions from a life-cycle based analysis of the two options for managing HCB waste from Orica's Botany site are as follows:

- The establishment of a GeoMelt destruction facility in remote NSW carries a far greater overall environmental impact (not including risks) than exporting the HCB waste to Europe for destruction at an existing facility. That is, the principal differences in environmental impacts between the two options are technological rather than geographic.
- One of the major contributors to the relatively poor environmental performance of the GeoMelt process is the very high electricity demand to operate the process.
- Data uncertainty associated with the GeoMelt process is higher than with the HTI process as no *actual* emissions or effluent discharge data exists for the application of this treatment process to high level HCB waste.
- In contrast, the HTI rotary kiln process was assessed using actual measured data and shows a greater level of certainty, in addition to outperforming the GeoMelt process in all environmental impact categories.

Finally, Nolan-ITU believes that an environmental assessment of different management options for HCB waste at Botany is a highly critical consideration in the decision-making process. However, a range of other factors - such as social costs and benefits, hazards and risks, and stakeholder viewpoints about acceptable levels of risk, must also feature in the final solution chosen for managing Orica's HCB waste. It should be noted that the scope of this environmental assessment *did not include the above factors*.

1 INTRODUCTION

Nolan-ITU was engaged by Orica Australia Pty Limited (Orica) to undertake an independent comparison of two options for destroying hexachlorobenzene (HCB) waste and HCB-contaminated material[3] from its Botany Industrial Park (Botany), using Life Cycle Assessment (LCA). The two options currently being considered by Orica are:

- Option A – Destruction of the HCB and HCB-contaminated material at a purpose built facility located in remote New South Wales (NSW); and
- Option B – Exporting the waste to a hazardous waste treatment facility with potential resource recovery.

HCB is a persistent organic pollutant (POP) with known human health and environmental impacts. It is included on the National Pollutant Inventory which lists some 400 substances and assigns a ranking and total hazard score, based on health and environmental hazards and human and environmental exposure to the substance. Under this ranking system, HCB is ranked at 78 out of a possible 400, whereby a score of 1 represents the highest risk score of the substances considered.

Orica has previously proposed to build a waste destruction plant at Botany to destroy this HCB waste, and an Environmental Impact Statement (EIS) was prepared for the proposed plant and its operation. A subsequent Independent Review Panel appointed by the NSW Government recommended that such a HCB waste destruction facility – using GeoMelt Vitrification technology – be built at a remote site in NSW.

While Orica has stated that it will be seeking to implement this and other recommendations of the Independent Review Panel, it is clear that there is no Australian precedent for a private / commercial organization unilaterally and successfully developing a major-scale hazardous waste management facility that can treat HCB.

Indeed, even where there has been significant governmental involvement in and support for establishing a hazardous waste management facility, the outcome has been very difficult to realize, even where the primary waste in question is less contentious than HCB. This is due to a range of influencing factors including host community acceptance, perceived environmental justice and other concerns such as social equity and local amenity. Therefore, significant challenges are anticipated in identifying and procuring a site, and gaining planning permission for the establishment of Australia's largest ever HCB waste management facility, in the short-term future.

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[3] For simplicity purposes, the net material will be referred to as "HCB waste", although it is acknowledged that HCB waste material is known to contain other chemicals.

Orica, therefore, wishes to better understand the comparative environmental costs and benefits associated the option recommended by the Independent Review Panel (establishment of a destruction facility in – and transport of HCB waste to – remote NSW) and the alternative of exporting the HCB waste to Europe where facilities for treatment / destruction of the waste, as well as recovery of chlorine, currently exist and have the capacity to process the quantities currently stored on-site at Botany. (Presently, the latter option is conceptual. For the purposes of carrying out the comparison, an export approval under the *Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal 1992* by the Commonwealth Government has been presumed.) Such a theoretical comparison can assist the company and its stakeholders in further consideration of the Botany HCB issue.

Nolan-ITU is a sustainability and environmental engineering consultancy with particular experience and expertise in waste management. The conduct of Life Cycle Assessments (LCAs) – either as stand-alone projects or as components of "triple bottom line" assessments – is an integral part of Nolan-ITU's capability. Nolan-ITU has undertaken a number of LCAs, ranging from projects used for policy development by public agencies (e.g., for the Department of Environment & Conservation, EcoRecycle Victoria, SA Environment Protection Agency, and the Environment Protection & Heritage Council), as well as for private sector companies in process or product development.

Nolan-ITU believes that an environmental assessment of different management options for HCB waste at Botany is important for fulfilling legislated objectives relating to ecologically sustainable development including *The Protection of the Environment Operations Act 1997* and *The Intergovernmental Agreement on the Environment (1989).*

Clearly a range of other factors – such as social costs and benefits, human health risks, and stakeholder viewpoints about acceptable levels of risk are also required in decision-making.

It should be noted that this report does not include an assessment of risk and hazard which are the subject of a number of related reports.

2 BACKGROUND

2.1 HCB Waste at Botany Industrial Park

2.1.1 General

From 1964 to 1991 Orica Australia Pty Limited (formerly ICI Australia) produced HCB as a waste by-product from its manufacture of chlorinated solvents (carbon tetrachloride and perchlorethylene), at the Botany Industrial Park (Botany).

Carbon tetrachloride was used as a raw material in the further manufacture of chlorofluorocarbon (CFC) refrigerants and propellants and was listed as a 'controlled substance' in the *Montreal Protocol on Substances that Deplete the Ozone Layer 1987*. It has subsequently been phased out of use. Perchlorethylene was and continues to be used (amongst other applications) as a solvent in dry cleaning, fat and oil extraction, and as a vapour for metal degreasing. No HCB waste has been produced from Orica's Botany operations since 1991.

Since 1993, HCB has been known as a 'scheduled waste' in Australia, which is defined as: organic in nature; resistant to degradation by chemical, physical or biological means, and; toxic to humans, vegetation or aquatic life, and bio-accumulative in humans, flora and fauna, including likely carcinogenic and mutagenic properties.

In terms of the HCB waste stored at Botany, Orica advises that it consists of the following categories:

1. 10,500 tonnes of high-level (~70% Cl) concentrated HCB waste and/or HCB contaminated materials of which there are: 6,500 tonnes of HCB dry crystals; 3,000 tonnes of wet HCB, and; 1,000 tonnes of HCB polymer.
2. An additional 4,000 tonnes of low-level (~1% Cl) HCB contaminated materials including textiles and demolition rubble. Of this, 1,600 tonnes are steel drums and pallets, which are used to contain the 10,500 tonnes of high-level HCB waste.

In the late 1980's, a Commonwealth Government-led program (known as the Joint Task Force on Intractable Waste) sought to establish a national waste destruction facility in a remote area to handle intractable wastes from a variety of sources, including Orica. This process was abandoned in 1992 following strong community and environmental group opposition to the proposed site in central western NSW.

In the late 1990's, Orica commenced investigations into the development of a waste destruction facility to deal with the HCB waste stored on site. An EIS released in August 2001 sought to assess the potential environmental and human health impacts associated with an Orica proposal to establish a GeoMelt waste destruction facility at Botany. A Commission of Inquiry was established in December 2001 and recommended approval of the project, subject to certain conditions in November 2002. The New South Wales Minister for Infrastructure and Planning called an Independent Review Panel to consider the application.

Subsequently, the Independent Review Panel concluded that, while the GeoMelt technology "is fit for the intended purpose of treating HCB waste". However, it was also concluded that there was a degree of novelty associated with the GeoMelt process that could lead to operational upsets and incidents. Although these were unlikely to result in any serious environmental damage or health impacts, they could cause community alarm such that the project would be seriously delayed or even shut down. It would be preferable from risk management and community concern standpoints to undertake the waste destruction process at an alternative, remote site in rural NSW.

As the Panel noted in its report released in September 2004, the task of treating and disposing of 10,000 tonnes of HCB waste, along with storage containers, miscellaneous materials, and potentially some 20,000 tonnes of contaminated soil, substantially exceeds any hazardous waste management project ever undertaken in Australia. The Panel also recommended that the NSW Government take an active part in locating a suitable site for the waste destruction plant.

2.1.2 *Policy Framework*

a) Domestic

The current policy position has been arrived at following more than 15 years of government and stakeholder involvement in the Botany HCB issue. Since 1974, ICI investigated a number of options for destroying the waste before agreeing on a national approach to intractable waste with state and federal governments. In 1987, the Joint Taskforce on Intractable Waste was established by State and Commonwealth Governments to "examine and advise on the minimisation and management of intractable waste and the development of disposal facilities in south-eastern Australia".

Following the previously mentioned withdrawal of the proposal to develop a facility in central western NSW, the Independent Panel on Intractable Waste was established to review the findings of the Taskforce and make further recommendations. Final recommendations included:

- Long term storage is undesirable;
- Management guidelines for each intractable waste type are required;
- Transport should be minimised, and
- A number of small facilities should be established to treat the waste.

In 1992, further to these recommendations, the Australian New Zealand Environment and Conservation Council (ANZECC) established a National Advisory Body (NAB) to oversee the development of management plans for all scheduled wastes including HCBs.

In November 1996, ANZECC – the nation-wide body of Environmental Ministers considered and adopted the HCB Management Plan. Compliance is enforced by a condition in Orica's licence, under the *Environmentally Hazardous Chemicals Act 1985*. It was developed through an open and consultative process, and outlines a nationally agreed strategy for management procedures and technology deployment. The HCB waste at Botany is subject to the provisions of a variety of legislation and regulation, including:

- Commonwealth Hazardous Waste Act 1989;
- NSW Protection of the Environment Operation Act 1997;
- NSW Contaminated Land Management Act 1997, and;
- Environmentally Hazardous Chemicals Act 1985.

In the event that HCB waste is removed from Botany for destruction and/or treatment, the NSW Road & Rail Transport (Dangerous Goods) Regulations 1998 would apply. Any proposals to site and develop a facility in remote NSW would be subject to a broader range of planning instruments.

Beyond its regulatory and planning functions, the NSW Government also has a strategic policy role in terms of the HCB waste at Botany. Having established the process, the Government accepted the recommendation of the Independent Review Panel that waste destruction take place in remote NSW. In his media statement, the then Minister for Infrastructure, Planning, and Resources, the Hon. Craig Knowles MP, stated in relation to the report and the Panel:

> *"Given the significance of this finding, I have directed that the panel remain in place to facilitate, co-ordinate and direct the important task of identifying possible alternative locations for the waste destruction. I have also directed that my Department continue to coordinate whatever Government support the panel needs."*

Orica has been working cooperatively with the Independent Review Panel and NSW Agencies to locate a new site for the GeoMelt Process. Under Terms of Reverence issued to the Panel, a report on arrangements is required by July 2006.

b) International

The international movement of hazardous materials is largely governed by and subject to the *Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal 1992.*

Australia's obligations under the Basel Convention are implemented via the Hazardous Waste Act 1989 and its subsequent amendments. The Commonwealth Government has banned exports of hazardous waste for final disposal except where the circumstances are exceptional. Exceptional circumstances are considered to be (but not limited to) where "there will be significant risk of injury or damage to human beings or the environment if a permit were not granted."

As part of its administration of the Act, the Commonwealth Government supports the on-going deliberations of the multi-stakeholder Hazardous Waste Policy Reference Group and the expert-based Hazardous Waste Technical Group. As part of their role, the Technical Group provides advice to the Commonwealth in relation to any applications to export hazardous waste from Australia to other countries for the purposes of disposal and/or recovery.

From April 2004 to April 2005, there were 13 operating export permits for hazardous waste from Australia to overseas destinations for different forms of management. Recipient countries included Belgium, Italy, New Zealand, Germany, Thailand, the United Kingdom, and France. During that same time period, there were six further applications for export of hazardous waste from Australia to overseas destinations for different forms of management, including one application by Basell Australia to have 50 tonnes of non-halogenated solvents destroyed by AVR in Rotterdam, the Netherlands. One application – by Repco to export automotive gaskets containing asbestos to a reuse facility in New Zealand – was not approved.

2.1.3 Stakeholder & Community Expectations

A range of stakeholders is affected in different ways by the HCB contaminated waste at Botany and any moves to either keep it *in situ* or manage it off-site. These stakeholders include but are not limited to:

- Local residents in Botany, Banksmeadow, Hillsdale, Matraville, East Gardens, and other suburbs close to Botany;
- Community Participation and Review Committee (established in April 1997 as part of the HCB management plan) and its membership;
- Industrial neighbours of Botany;
- National and State-wide environmental advocacy non-government organisations;
- Locally-based and/or focussed environmental and civic advocacy non-government organisations;
- Commonwealth, NSW Government and local agencies, particularly the Department of Environment & Heritage (Commonwealth), the Department of Environment & Conservation (NSW), the Department of Infrastructure, Planning, and Natural Resources (DIPNR), and Botany Bay Council;
- Commonwealth and NSW elected officials, including local Members of Parliament and Botany Bay Councillors;
- Botany site employees;

- Local community in remote NSW where GeoMelt facility could be constructed;
- Local communities through which land transport would take place to GeoMelt facility in remote NSW;
- Local community near European hazardous waste treatment plant, and;
- Government agencies and officials in the country where the hazardous waste treatment facility is located.

3 LIFE CYCLE ASSESSMENT METHODOLOGY

3.1 Life Cycle Assessment Overview

The primary methodology of analysis for this study is life-cycle assessment (LCA). LCA is an internationally recognised method of assessing the overall environmental performance (cost/benefits) of products and services through a structured and consistent approach. Organisations such as the European Commission regularly use LCA combined with environmental-economic valuation to support policy making in waste management and other environmental fields (European Environment Agency, 2003; European Commission, 2003; COWI, 2000).

Life Cycle Assessment data and support models for waste management have been developed independently throughout the developed world. Models now available include: the USEPA decision support tool, *DST*; the UK Environment Agency model, *Wizard* and the private sector developed model by Proctor and Gamble, *IWM2* as well a number European models predominantly developed by academic institutes. A commercially available LCA modelling software package which is widely used both in Europe and here in Australia is SimaPro. Both Nolan-ITU and RMIT University's Centre for Design hold licences for this software which has been used in the conduct of this study.

The LCA modelling uses data that are compliant with international standards for LCA (ISO 14040; 41). The following overall structure, which is widely accepted and used, was utilised:

STEP 1: Goal and Scope Definition – the goal and scope of the LCA study are defined;

STEP 2: Inventory Analysis – the physical inputs and outputs within a defined system boundary are tallied in an inventory;

STEP 3: Impact Assessment – specific inventory items are aggregated into environmental impact categories and valued; and

STEP 4: Interpretation – the information provided by the inventory and the impact assessment is interpreted in relation to the goal of the study.

3.2 Life Cycle Impact Assessment

3.2.1 Environmental-Economic Valuation Method

The Australian-based, environmental-economic valuation method (Nolan-ITU, 2001; 2004) has been applied to measure the environmental performance of the two waste treatment options in terms of a single monetised unit of measure. The advantage of this approach is that a number of different and complex scientific measures are translated into one simplified and widely recognised unit.

Here, pollutant and resource loads have been assigned monetary values based on environmental economic valuations within published government reports. Where no suitable valuation data could be found, values have been calculated based on scientifically derived equivalence relationships. It is important to note that the final dollar valuation is note intended to represent financial transaction costs for environmental impacts but rather to indicate the relative significance of the different environmental loads and impacts. The main aim is to ensure the LCA results are more meaningful to more people.

This methodology was independently reviewed both internationally and locally as part of a national recycling study for the National Packaging Council (Nolan-ITU, 2001) and subsequently refined for use within a number of recent studies in Australia (e.g., *Triple Bottom Line Assessment of Alternative Domestic Waste and Recycling Systems*, for NSW Jurisdictional Recycling Group, and *National Benefits of Implementation of UR-3R Process - A Triple Bottom Line Assessment*).

Within the environmental-economic methodology, the following categories are used:

- ***Global Warming Potential*** i.e. climate change impact using internationally accepted equivalence factors (Intergovernmental Panel on Climate Change);
- ***Resource Savings*** – Mineral Resources i.e. environmental value of mineral resource extraction and depletion based on land use impacts and remaining years of mineral reserves;
- ***Resource Savings*** – Oil and Gas i.e. environmental value of oil and gas extraction and depletion based on land use impacts and remaining years of mineral reserves;
- ***Air Emissions*** i.e. air pollutants and the valuation of impacts associated with each pollutant;
- ***Water Emissions*** i.e. water pollutants and the valuation of impacts associated with each pollutant;
- ***Solid Waste*** i.e. the non-chemical impacts of landfilling (EPA NSW, 1997) and quantity of waste requiring disposal from the extraction of raw materials through the end-of-life management;
- ***Water Usage*** i.e. the quantity and value of water required for the delivery of the functional unit being studied.

3.2.2 *Eco-Indicator (99) Method*

For the purposes of cross-checking, the environmental life cycle performance was modelled using the Eco-Indicator (99) methodology. This method is based upon Eco-Indicator (95) which was originally developed under the Dutch NOH programme by PRé consultants under a joint project with Philips Consumer Electronics, NedCar, Océ Copiers, Schuurink, CML Leiden, TU-Delft, IVAM-ER (Amsterdam) and CE Delft, representing one of the first internationally accepted methods to express environmental performance as a single indicator.

Within the Eco-Indicator (99) method the substance definitions have been adapted to Australian conditions by RMIT University's Centre for Design, incorporating local life cycle inventory databases and weightings. As distinct from the Environmental-Economic Valuation Method used as the basis for this study, the method uses the impact categories of:

- Carcinogens;
- Minerals;
- Land Use;
- Acidification / Eutrophication;
- Ecotoxicity;
- Ozone Depletion;
- Radiation;
- Climate Change;
- Respiratory Inorganics;
- Respiratory Organics; and
- Carcinogens.

3.3 Peer Review of Methodology and Findings

In order to ensure that this assessment was carried out in a rigorous, robust and transparent manner, a peer review was conducted by Tim Grant from the RMIT University's Centre for Design. This included both a review of the:

- System models used to carry out the environmental assessment;
- Results the modelling; and
- Findings of this report.

4 LIFE CYCLE ASSESSMENT STUDY

4.1 Goal and Scope Definition

Life Cycle Assessment has been applied to determine the environmental performance of two options for managing the HCB waste at Orica's Port Botany site.

Option A - The construction and operation of an HCB destruction facility employing GeoMelt technology in remote NSW, and transport of the waste to this facility; and

Option B - Export of the waste to Europe for destruction and resource recovery at an existing High Temperature Incinerator (HTI).

These two options were arrived at based upon the findings and recommendations contained within the Independent Review Panel report, which was commissioned in January 2004 to examine the "capabilities of the proposed technology; alternative solutions".

The analysis is intended for decision support regarding the preferred treatment option. It compares the environmental performance of the systems associated with each option. The assumed technology performance is as detailed in the EIS for the GeoMelt facility and, in the case of export, as publicly reported by a European facility of the required configuration and performance standards. Further analysis of emissions, and emissions from end-of-life management of plant residuals are beyond the stated scope of the study. Uncertainty analysis has been used to provide information regarding the impact of data quality on the findings of the study. The analysis does not include risk or hazard assessment.

4.2 Overall System Characterisations

The scope of an LCA study must clearly specify the functions of the system being studied. A functional unit is a measure of the performance of the functional outputs of a system. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of the LCA results on a common basis. Within this study, the functional unit has been set as "the destruction of 1 tonne of HCB waste".

4.2.1 Option A – GeoMelt Facility in Remote NSW

The system characterisation for the destruction of 1 tonne of HCB waste using the GeoMelt process is given in Table 4-1 and presented graphically in Figure 4-1.

Table 4-1: GeoMelt System Characterisation

Parameter			4 Yr Total	Per Year	Per Tonne HCB
1	**Operational Life**		4 Years		
2	**Design Capacity**	100% Purpose built			
		Max Throughput	60,000 t	15,000 t/yr	
		- HCB	14,500 t		
		- Soil as additive	20,000 t		
3	**Products**	Vitrified blocks recycled as gravel	20,000 t	5,000 t/yr	1.38 t/t
4	**Location**	Remote NSW: distance from Sydney	650 km		
5	**Transport**	HCB Packing into 1m^3 HDPE containers			
		Rail freight	650 km		
		Trucking to facility	20 km		
6	**Construction**	Materials used (in house estimates based on industry data)	11,735 t		0.809 t/t
		Materials apportioned to 15ktpa capacity & 4 yr life			
7	**Operational**	Emissions as Per EIS			
		Consumables			
		- Water	328 ML	82 ML/yr	23 t/t
		- Sodium Hydroxide (NaOH)	10,000 t	2,500 t/yr	690 kg/t
		- Soda Ash (Na_2CO_3)	1,984 t	469 t/yr	137 kg/t
		- Calcium Carbonate ($CaCO_3$)	2,548 t	637 t/yr	176 kg/t
		- Sodium Bisulfate ($NaHSO_4$)	760 t	190 t/yr	52 kg/t
		- Graphite	320 t	80 t/yr	22 kg/t
		- Electricity	100,000 MWh	25,000 MWH/yr	6.9 MWh/t
		- Filter Cartridges	50 t	12.5 t/yr	3 kg/t
		- Carbon Electrodes	2,500 Units	625 Units/yr	0.2 Units/t
		- Refractory Sand	500t	125 t/yr	35 kg/t
		- Replacement Refractory	100 t	25 t/yr	6.9 t/t
		- Thermal Oxidiser Gas	220 TJ	55 TJ/yr	15 GJ/t
		By-products Incorporated into Melt			
		- Filter Particulates	480 t	120 t/yr	33 kg/t
		- Dirty PPE	50 t	12.5 t/yr	3 kg/t
		- Carbon from Filter Beds	5 t	1.25 t/yr	0.3 kg/t
8	**Decommissioning**	100% Purpose built w/ no maintenance events			
		80% of Construction materials recycled			

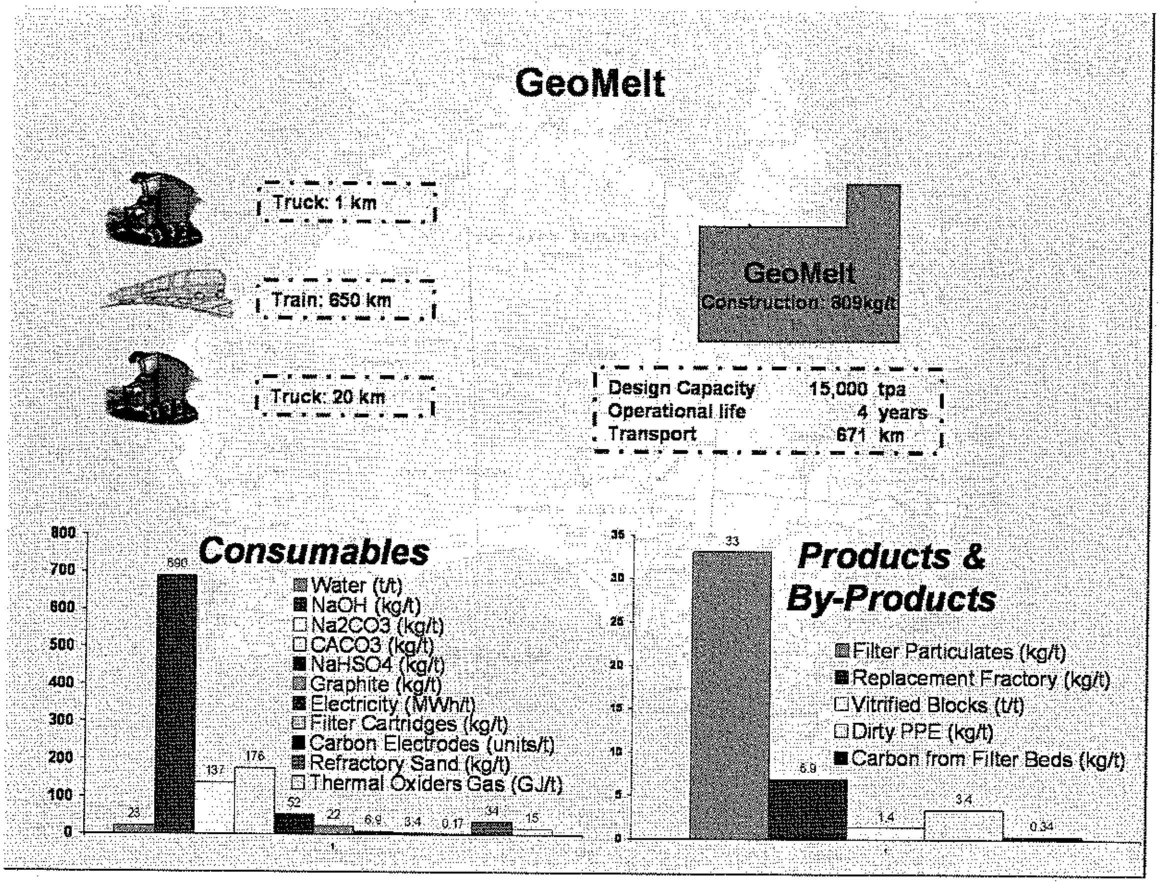

Figure 4-1: GeoMelt System Characterisation

4.2.2 Option B – Export to a European HTI Facility

The system characterisation for the destruction of 1 tonne of HCB waste using the HTI (rotary kiln) process is given in Table 4-2 and presented graphically in Figure 4-2. A typical rotary kiln configuration is also given in Appendix C.

Table 4-2: HTI System Characterisation

Parameter		20 Yr Total	Per Year	Per Tonne HCB
1 Operational Life		20 Years		
2 Design Capacity	Rotary kiln facility	1,774,280 t	88,714 t/yr	
3 Products	Input fuel recovered as electricity	20%		
4 Location	Antwerp or other European facility, distance from Sydney	11,600 km		
5 Transport	HCB packing in 120 L HDPE containers			
	Rail to port	1 km		
	Dedicated shipping	11,600 km		
	Trucking to facility	50 km		
6 Construction	Materials used (in house estimates based on industry data)	35,205 t		0.02t/t
	Materials apportioned to 88,714 tpa over 20 year life			
7 Operational	Emissions as per Indaver 2004 Sustainability Report			
	Consumables			
	- Water	11,735 ML	587 ML/yr	7 kg/t
	- Sodium Hydroxide (NaOH)	36,373 t	1,819 t/yr	21 kg/t
	- Quicklime (CaO)	51,632 t	2,582 t/yr	29 kg/t
	- Brown Coal	53 t	3 t/yr	30 g/t
	- Lime ($CaOH_3$)	21,824 t	1,091 t/yr	12 kg/t
	- Sodium Sulfate (Na_2SO_4)	1,242 t	62 t/yr	0.7 kg/t
	- Sodium Chlorate ($NaClO_3$)	307 t	15 t/yr	0.2 kg/t
	- Fuel and Waste Oil	100,069 t	5,003 t/yr	56 kg/t
	By-products			
	- Bottom Ash	386,793 t	19,340 t/yr	218 kg/t
	- Fly Ash	46,131 t	2,307 t/yr	26 kg/t
8 Decommissioning	3 Maintenance events at 5 yr intervals over 20 yr life	428 t		0.24 kg/t
	80% of Construction materials recycled			

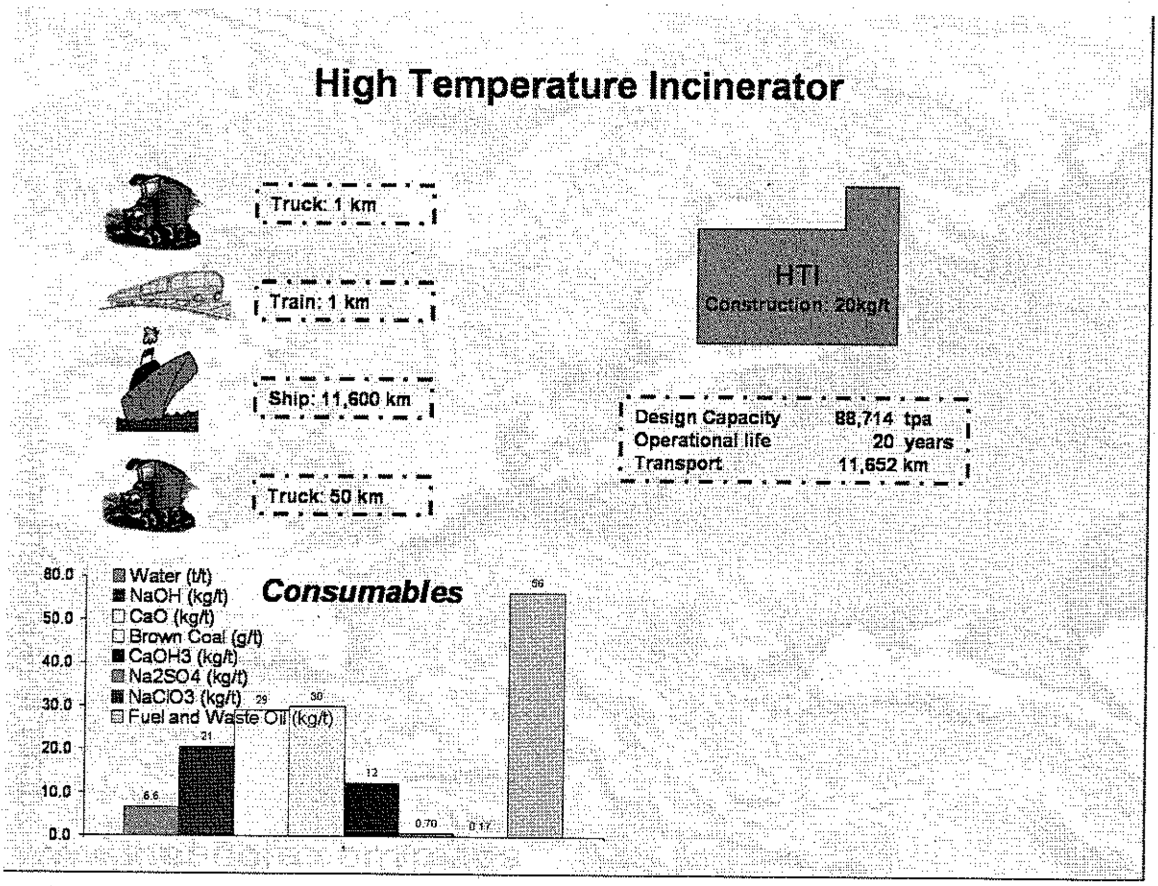

Figure 4-2: HTI System Characterisation

5 STAGE-BY-STAGE OUTCOMES

The following is a detailed description of the two Options (or scenarios) that were modelled and analysed using LCA. It should be noted that all results are based upon the functional unit of 1 tonne of HCB waste.

5.1 Re-Packing & Storage of HCB Waste Materials

5.1.1 Characterisation

The environmental impacts associated with presentation of material for off-site transport will be largely the same for both options. While 120L drums will be used for export and 1m^3 containers for transport to a local facility, the environmental impact of packing and re-drumming the HCB waste will be largely equivalent for both options.

The waste in its various forms and containments is modelled as being:

- retrieved on-site from 9 storage locations at the Orica Botany site and lifted using steel slates by forklift.
- transferred on-site by rigid trucks of about 7.5 tonne capacity.
- repacked at the Botany site in an enclosed, purpose built warehouse which is vented to a gas cleaning train as proposed in the EIS. (This assumption results in emission loads that are determined by stack emission limits and flow rates).
- repacked into UN approved 120L plastic containers for export or 1 m^3 plastic containers ("bricks") for the local treatment option.

Fugitive emissions from the warehouse are modelled with the equivalent data quality uncertainty as plant emission arising from the absence of monitored and verified data. Risks and hazards associated with this activity have not been assessed (and are not within the scope of study).

Additional material inputs to this activity include high density polyethylene (HDPE) for the repacking containers and wood pine for secondary packaging crates. The modelling assumes that 125kg of HDPE are required per tonne of HCB waste, based on a container wall thickness of 1 inch. In addition, the construction of a dedicated warehouse for the repacking and storage process has been allowed for within this activity.

5.1.2 Modelling Results

a) Enviro-Economic Valuation

The results of the Enviro-Economic Valuation of the repacking and storage process per functional unit (1 tonne of HCB waste) are given in Table 5-1.

Table 5-1: Enviro-Economic Valuation of HCB Repacking & Storage

Enviro-Economic Valuation (Eco-$/t HCB Waste)	GeoMelt (Base Case)	HTI (Base Case)
Packing of HCB Materials	35.6	35.6

Although it has been assumed that the repacking and storage process for both HCB treatment options is identical, from Figure 5-1 it may be seen that the majority of impacts relate to air pollutants, oil and gas and greenhouse. These impacts arise from the proportionately high use of materials used to repackage the HCB waste, in particular, the use of heavy duty 1 cubic metre or 120L high density polyethylene containers. Here, the impacts from Air Pollutants arise from the emission of oxides of nitrogen and non-methane volatile organic compounds, while Oil and Gas (depletion) are the result of natural gas utilisation for plastics production.

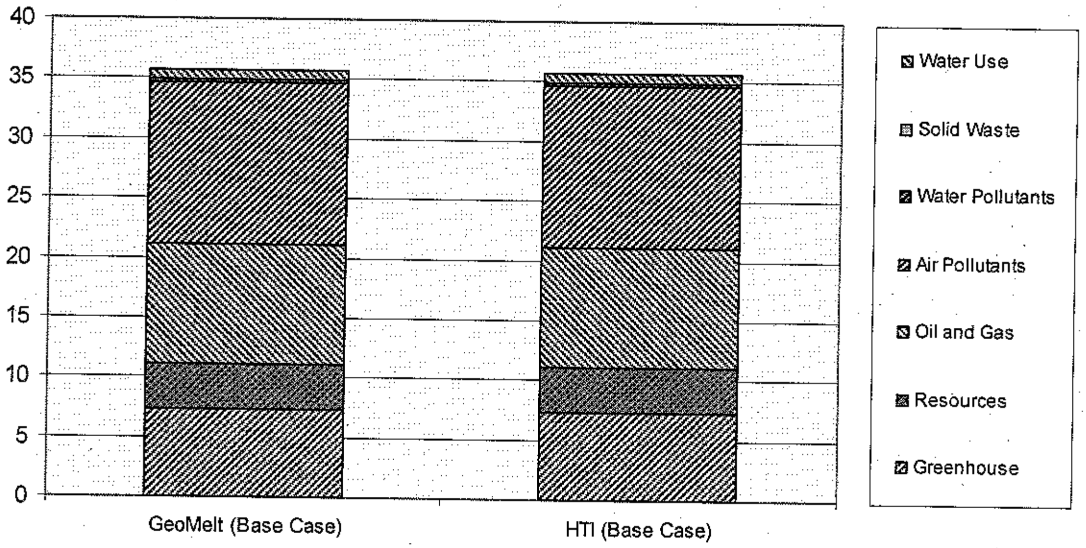

Figure 5-1: Environmental Impact of HCB Repacking & Storage (Eco-$ per Tonne of HCB Waste)

b) Eco-Indicator (99) Valuation

The results of the Eco-Indicator Valuation of the repacking and storage process per functional unit (1 tonne of HCB waste) are given in Table 5-1.

Table 5-2: Eco-Indicator Valuation of HCB Repacking & Storage

Eco-Indicator (99) Valuation (Eco-points/t HCB Waste)	GeoMelt (Base Case)	HTI (Base Case)
Packing of HCB Materials	43.7	43.7

Similar to the Enviro-Economic valuation, closer examination of the Eco-Indicator result reveals that the majority of impacts relate to fossil fuel (natural gas) consumption associated with the manufacture and use of high density polyethylene, and the emission of respiratory inorganics (nitrogen oxides and particulates).

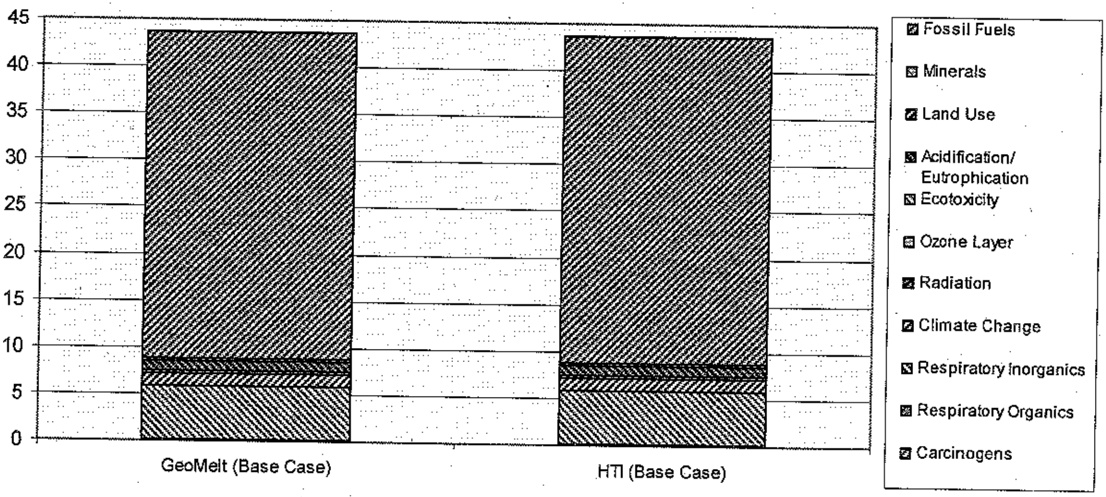

Figure 5-2: Environmental Impact of HCB Repacking & Storage (Eco-Indicator Points per Tonne of HCB Waste)

5.2 Outbound Transport of HCB Waste to Treatment Facility

5.2.1 Characterisation

a) Rail Haul and Road Transfer to GeoMelt Facility in Remote NSW

Transfer to a remote site in New South Wales assumes rail haul of 650 km plus transfer by truck 25km to the treatment facility. Loading and unloading assumes use of a forklift and steel slate.

This assumption is made on the basis of the findings of the Independent Review – HCB Waste Destruction (July 2004). The Independent Review Panel (IRP) noted that "There is compelling merit in treating the HCB waste in a location with more appropriate non-urban adjacent land uses, remote from human settlement and areas of ecological threat…. Sites such as abandoned, derelict mines, in remote parts of NSW could provide compatible land-use prospects, yet are close enough to towns to ensure viable servicing."

Further the preferred site, in accordance with the Draft HCB Waste Management Siting Framework (July, 2005), should be consistent with the community based "3C Site Selection Criteria". The distance of 25 km road haul from the rail spur has been selected in accordance with these criteria.

b) Freight Shipping and Road Transfer to HTI Facility in Europe

Transport to a European facility for High Temperature Incineration (HTI) assumes freight shipping a distance of 11,600 km to a European port and 50 km road transfer to a treatment facility. Loading and unloading assumes use of a forklift and steel slate with the additional use of a container crane at both ports.

5.2.2 Modelling Results

a) Enviro-Economic Valuation

A comparison of the impacts associated with transferring the HCB waste from Botany to the treatment facility per functional unit (1 tonne of HCB waste) is presented in Table 5-3. Using the Enviro-Economic valuation method, the impact of shipping and transferring the HCB waste to a European treatment facility is 6 times greater than rail hauling the material to a facility located in regional NSW. Here the three main impact categories are air pollutants emitted as a result of transportation, oil and gas depletion, and greenhouse emissions. In particular the air pollutants emitted are predominantly oxides of nitrogen and to a less extent, oxides of sulfur resulting from the combustion of fuel for transport.

The results by impact category are presented graphically in Figure 5-3.

Table 5-3: Enviro-Economic Valuation of HCB Transfer to Treatment Facility

Enviro-Economic Valuation (Eco-$/t HCB Waste)	GeoMelt (Base Case)	HTI (Base Case)
Transport & Transfer to Treatment Facility	1.4	8.7

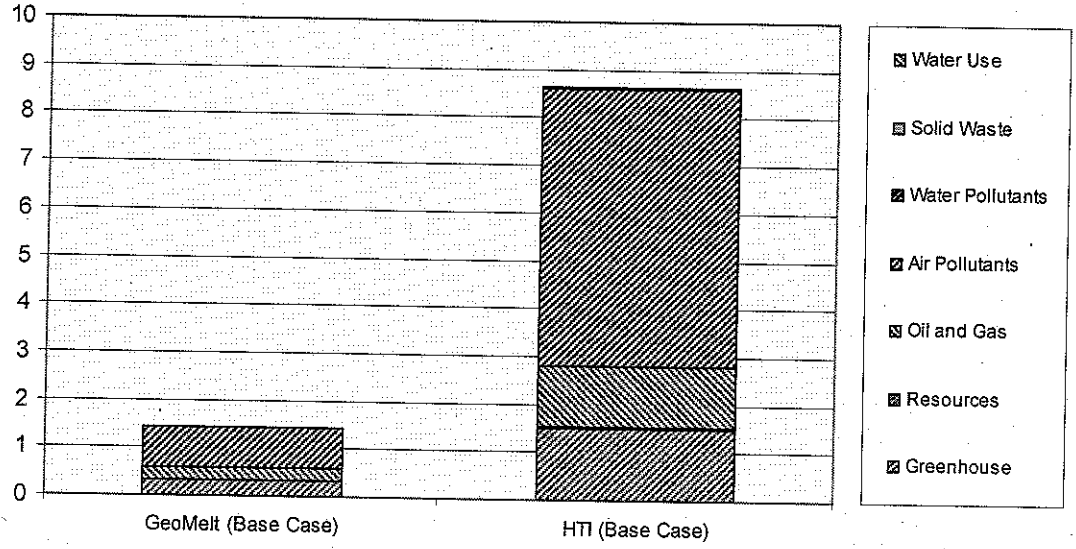

Figure 5-3: Environmental Impact of HCB Transfer to Treatment Facility (Eco-$ per Tonne of HCB Waste)

b) Eco-Indicator (99) Valuation

An alternative comparison of the impacts associated with transferring the HCB waste from Botany to the treatment facility per functional unit (1 tonne of HCB waste) is presented in Table 5-4. Using the Eco-Indicator (99) valuation method, the impact of shipping and transferring the HCB waste to a European treatment facility is 5.5 times greater than rail hauling the material to a facility located in regional NSW. As with the Enviro-Economic Valuation, these impacts primarily relate to the respiratory inorganics of nitrogen and sulfur oxides, in addition to crude oil consumption.

The results by impact category are presented graphically in Figure 5-4.

Table 5-4: Eco-Indicator Valuation of HCB Transfer to Treatment Facility

Eco-Indicator (99) Valuation (Eco-points/t HCB Waste)	GeoMelt (Base Case)	HTI (Base Case)
Transport & Transfer to Treatment Facility	1.5	6.9

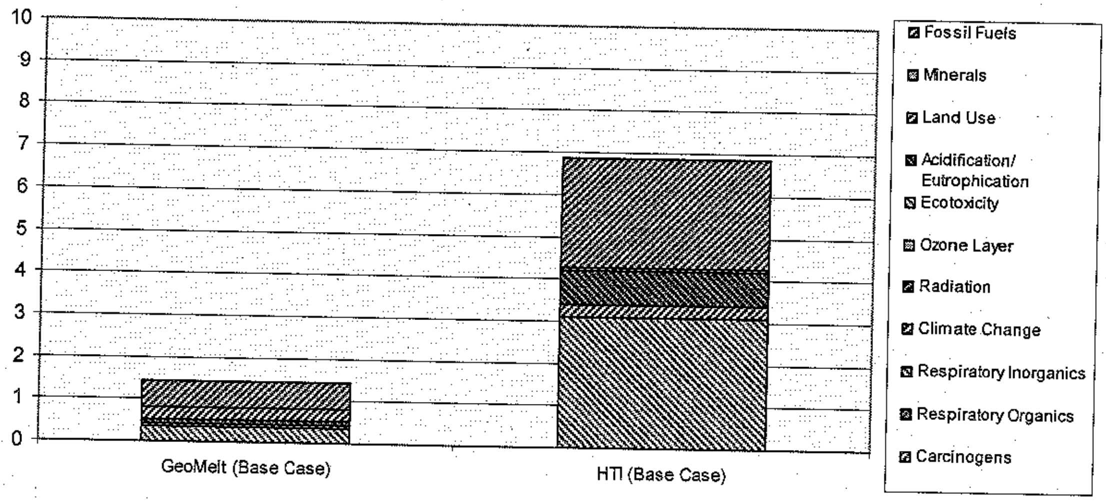

Figure 5-4: Environmental Impact of HCB Transfer to Treatment Facility (Eco-Indicator Points per Tonne of HCB Waste)

5.3 HCB Treatment Facility Construction

5.3.1 *Characterisation*

The impact of construction activities was modelled in order to determine the relative contribution of constructing a remote purpose-built facility for treating HCB waste, relative to the overall destruction process, and to allow for comparison with the option of sending the waste to an existing facility accepting a wider variety of hazardous wastes.

Construction impacts were modelled based on a life cycle approach and include raw material acquisition impacts, transport during the life cycle (including transport to the remote facility), plant maintenance impacts and decommissioning. In the absence of a detailed bill of materials for the GeoMelt facility, estimation was made based upon detailed information relating to a typical bill of materials for municipal waste incinerators including detailed component assemblies and comprehensive materials data for different incinerator configuration and capacity options.

Within this study, the construction of the alternative facilities have been modelled based on a life cycle approach and include raw material acquisition impacts, transport during the life cycle (including transport to the remote facility), plant maintenance impacts and decommissioning. Importantly, the environmental burdens of construction are allocated over 4 years for the GeoMelt technology and over a 20 year life for an HTI facility.

The construction allocation for the GeoMelt plant was finalised at 25% of a 400,000 tonne per annum MSW Incinerator. This allocation reflects the conclusions of a review of MSW construction impacts[4] that during construction "incinerator plant life is dominated by large quantities of bulk materials such as concrete and steel" and that "simplifications used in compiling the inventory data will therefore not greatly distort the overall findings. The report also concluded that "with larger or smaller incinerators, the effect of economies of scale is important. The smaller the capacity, the more the "burdens per tonne of waste will tend towards significance compared to operating burdens".

The construction allocation for the HTI facility has been finalised at 75% of a 400,000 tonne per annum MSW Incinerator. As a 20 year life has been assumed for this facility, it has been allocated 3 maintenance events over its life, at 5 year intervals. Maintenance impacts were modelled by apportioning the total quantity of materials used for this activity to the total quantity of material treated over the life of the facility.

In the case of both facilities, it has been assumed that 80% of the construction materials will be recycled, with the remaining waste being consigned to an inert landfill.

5.3.2 Modelling Results

a) Enviro-Economic Valuation

A comparison of the impacts associated with constructing an HCB treatment facility per functional unit (1 tonne of HCB waste) is presented in Table 5-5. Using the Enviro-Economic valuation method, the impact of constructing a purpose-built GeoMelt facility to treat the HCB waste is in excess of 40 times greater than that of constructing a HTI rotary kiln to treat a greater volume and variety of wastes. As would be expected, a range of categories contribute to the overall environmental impacts associated with the extraction, manufacture and final production of steel and concrete. These impacts predominantly include air emissions (oxides of nitrogen, particulates, benzene and polycyclic aromatic hydrocarbons), resource depletion (limestone, coal and sand), greenhouse gas generation (carbon dioxide) and solid waste generation.

The results by impact category are presented graphically in Figure 5-5.

Table 5-5: Enviro-Economic Valuation of HCB Treatment Facility Construction

Enviro-Economic Valuation (Eco-$/t HCB Waste)	GeoMelt (Base Case)	HTI (Base Case)
HCB Treatment Facility Construction	55.4	1.3

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[4] Environment Agency (2000), Life Cycle Inventory Development for Waste Management Operations: Incineration

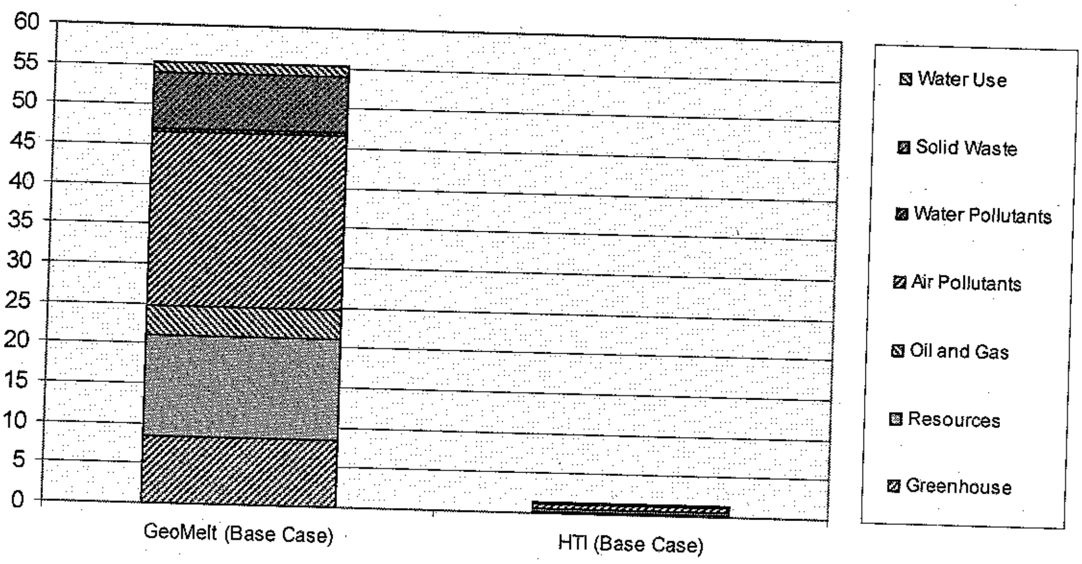

Figure 5-5: Environmental Impact of HCB Treatment Facility Construction (Eco-$ per Tonne of HCB Waste)

b) Eco-Indicator (99) Valuation

An alternative comparison of the impacts associated with constructing an HCB treatment facility per functional unit (1 tonne of HCB waste) is presented in Table 5-6. Similar to the Enviro-Economic valuation method, the Eco-Indicator (99) valuation method shows a purpose built GeoMelt facility to have an environmental impact 35 times greater than that of the HTI rotary kiln. Similar to the Enviro-Economic modelling, the respiratory inorganics relate primarily to particulates and oxides of nitrogen and sulfur. Fossil fuels depletion relates to the consumption of coal, crude oil and natural gas while mineral depletion is the result of copper, nickel, molybdenum and iron production and use.

The results by impact category are presented graphically in Figure 5-6.

Table 5-6: Eco-Indicator Valuation of HCB Treatment Facility Construction

Eco-Indicator (99) Valuation (Eco-points/t HCB Waste)	GeoMelt (Base Case)	HTI (Base Case)
HCB Treatment Facility Construction	45.3	1.1

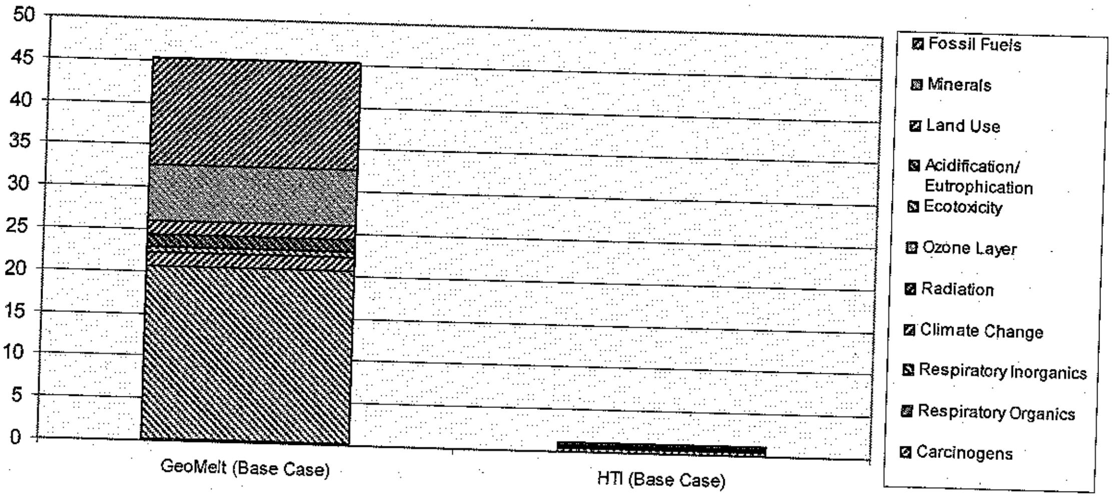

Figure 5-6: Environmental Impact of HCB Treatment Facility Construction (Eco-Indicator Points per Tonne of HCB Waste)

5.4 HCB Waste Destruction Process

5.4.1 Characterisation

a) GeoMelt Destruction of HCB

The GeoMelt destruction process has been modelled according to the system configuration as detailed within Orica's Environmental Impact Statement – Proposed HCB Waste Destruction Facility at Botany (2001) i.e. GeoMelt (Base Case). Here, it is important to note that the following parameters have been directly modelled from the EIS to establish a GeoMelt base case:

- Chemicals list (EIS Section 3.3.4);
- Proposed stack emission limits (EIS Section 6.1.2);
- Stack emission parameters (EIS Section 6.6);
- Energy requirements and greenhouse gas emissions (EIS Section 6.10);
- Effluent composition (EIS Section 9.5.2); and
- Secondary waste and proposed treatment (EIS Section 10.2).

Further details of the operational parameters for the GeoMelt facility is given in Section 4.2.

b) HTI Destruction of HCB

The HTI destruction process has been modelled according to 2004 operational data taken from the actual operation of Indaver's rotary kiln high temperature incinerator facility operating in Antwerp[5]. This information was also supplemented with inventory data contained within the Environment Agency's Life Cycle Inventory Development for Waste Management Operations: Incineration. Specifically, the following parameters have been adopted from the Indaver's rotary kiln operations:

- Additives to rotary kilns;
- Greenhouse emissions;
- Airborne emission quantities;
- Water requirements;
- Wastewater discharge pollutant quantities; and
- Wastes generated from rotary kilns.

Further details of the operational parameters for the HTI facility is given in Section 4.2.

5.4.2 Modelling Results

a) Enviro-Economic Valuation

A comparison of the impacts associated with the HCB destruction process per functional unit (1 tonne of HCB waste) is presented in Table 5-7. Using the Enviro-Economic valuation method, the impact destroying HCB waste using the GeoMelt process is in excess of 24 times greater than that of utilising a HTI rotary kiln process. While facility emissions for the two systems are broadly comparable, the GeoMelt process exhibits an extremely high electricity demand to vitrify waste whereas the HTI process utilises direct heat to destroy the HCB waste. As a result, much of the environmental impacts from the GeoMelt process are associated with the generation (and transmission) of electricity from the South-East Australian grid. In addition to this, European emission standards are somewhat more stringent than Australian standards, leading to lower emissions loads of a number of pollutants.

The main contributing categories are air pollutant emissions, greenhouse gas generation and resource depletion, in particular coal and limestone. It is noted that electricity generation is the predominant source of impacts across all categories. That is, the extremely high electricity demand, in addition to natural gas use for the thermal oxidiser, is the main cause of the high environmental impact associated with the GeoMelt option. Another cause of the high impact are the airborne emissions associated with the base case GeoMelt option, in particular mercury, oxides of nitrogen, benzene, arsenic and cadmium.

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[5] Indaver (2005), *Sustainability Report 2004*

The results by impact category are presented graphically in Figure 5-7.

Table 5-7: Enviro-Economic Valuation of HCB Destruction Process

Enviro-Economic Valuation (Eco-$/t HCB Waste)	GeoMelt (Base Case)	HTI (Base Case)
HCB Destruction	1,297.0	52.9

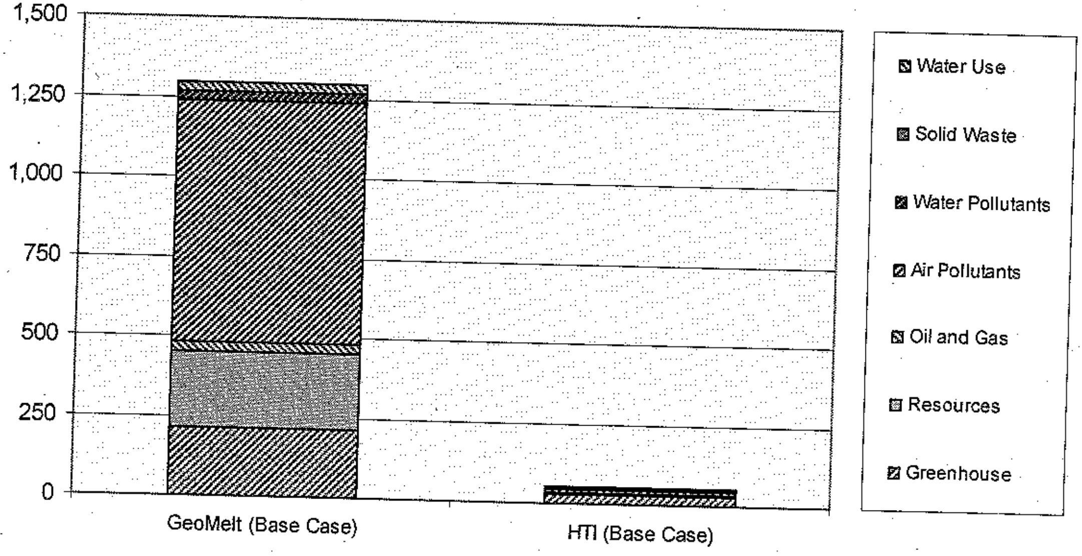

Figure 5-7: Environmental Impact of HCB Destruction Process (Eco-$ per Tonne of HCB Waste)

b) Eco-Indicator (99) Valuation

An alternative comparison of the impacts associated HCB waste destruction per functional unit (1 tonne of HCB waste) is presented in Table 5-8. Similar to the Enviro-Economic valuation method, the Eco-Indicator (99) valuation method shows a purpose built GeoMelt facility to have an environmental impact in excess of 30 times that of the HTI rotary kiln. As would be expected, fossil fuel depletion is associated with coal fired electricity generation and natural gas for the thermal oxidiser. Also associated with GeoMelt's electricity demand are oxides of nitrogen and sulfur, in addition to the generation of airborne particulates within the category of respiratory inorganics. It is also interesting to note that under the base case emissions assumptions for Geomelt, carcinogenic impacts are caused by the emission of cadmium and arsenic.

The results by impact category are presented graphically in Figure 5-8.

Table 5-8: Eco-Indicator Valuation of HCB Destruction Process

Eco-Indicator (99) Valuation (Eco-points/t HCB Waste)	GeoMelt (Base Case)	HTI (Base Case)
HCB Destruction	561.0	15.3

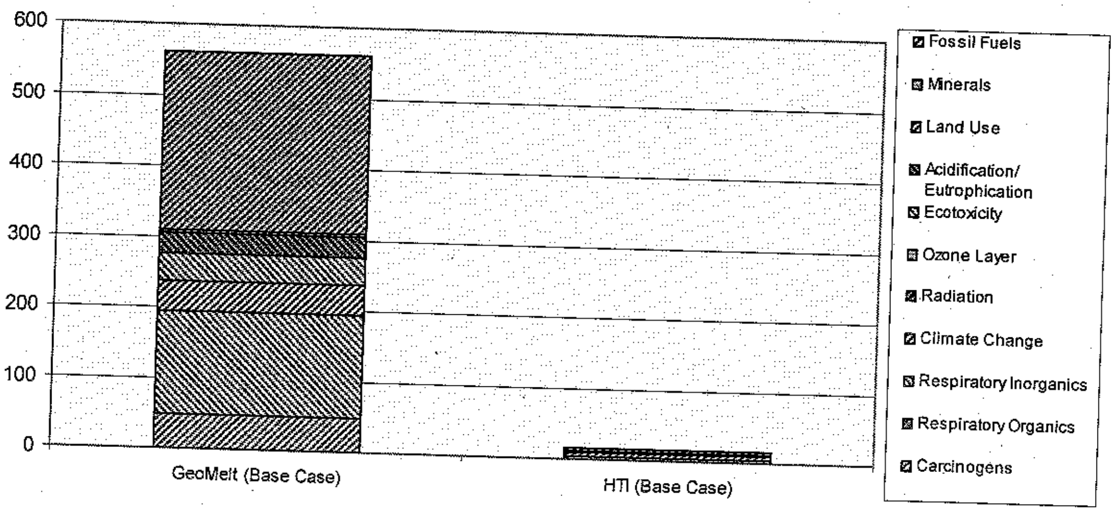

Figure 5-8: Environmental Impact of HCB Destruction Process (Eco-Indicator Points per Tonne of HCB Waste)

5.5 Materials Recovery

5.5.1 Characterisation

a) Materials Recovery from GeoMelt Process

As per the EIS, some 20,000 tonnes of "vitreous block" will be produced from the GeoMelt process. This material will be broken down and may be used for gravel, thereby replacing virgin material.

b) Materials Recovery from HTI Process

While it is possible to recover hydrochloric acid (HCl) from incineration facilities, the large scale recovery of HCl from hazardous waste incinerators is technically difficult. In addition, the recovered product is often of poor quality, thereby limiting its further use. Therefore, no hydrochloric acid recovery has been assumed for the operation of the HTI process for the "base case". This is supported by the Indaver (2004) data which documents the recovery of hydrochloric acid from its static kiln incinerators but not its rotary kilns.

6 NET OUTCOMES

The following two configurations have been taken as base cases for this study:

- Option A – GeoMelt (Base Case) modelled according to the system configuration as detailed within Orica's Environmental Impact Statement – Proposed HCB Waste Destruction Facility at Botany (2001); and
- Option B – HTI (Base Case) modelled according to 2004 operational data taken from the actual operation of a rotary kiln high temperature incinerator facility operating in Europe.

The analysis results for these two options are presented below.

6.1 Enviro-Economic Valuation

Using the Enviro-Economic valuation method, the impact associated with establishing and operating a GeoMelt facility to destroy HCB waste are 14 times higher than utilising an existing HTI rotary kiln facility located in Europe. While it is acknowledged that a European treatment option has a higher transport impact, this impact is only a relatively minor component of the overall life cycle.

As detailed in Section 5.4 the vast majority of impacts associated with the GeoMelt treatment option are related to the high electricity requirement associated with vitrifying the waste material plus the necessary sand additive. Contextually, the energy (electricity and gas) required to vitrify one tonne of HCB waste is around twice the total annual demand of an average Australian household. That is, over the 4 year life of the facility, the power consumed by the GeoMelt treatment process will be equivalent to the annual power consumption of around 28,000 households or 75,000 people. For a number of reasons, no energy can be recovered from the GeoMelt process.

The major impacts arising from the GeoMelt treatment process are from air emissions, namely mercury, oxides of nitrogen, benzene, arsenic and cadmium. While some of this impact is attributable to differences in emission standards between Australia and Europe, and therefore the process itself, the vast majority of emissions arise from coal fired power generation. In addition, this results in considerable greenhouse and resource depletion impacts.

The results for both of the overall processes per functional unit (1 tonne of HCB waste) are detailed in Table 6-1.

Table 6-1: Environmental Impact of HCB Management Options (Eco-$ per Tonne of HCB Waste)

	GeoMelt (Base Case)		HTI (Base Case)	
Repack and Store HCB	35.6	2.6%	35.6	36.1%
Transport HCB to Treatment Destination	1.2	0.1%	8.2	8.3%
HCB Road Transfer to Treatment Facility	0.2	0.01%	0.5	0.5%
HCB Destruction	1,297.0	93.3%	52.9	53.7%
Facility Construction	55.4	4.0%	1.3	1.3%
	1,389.4	100.0%	98.5	100.0%

Figure 6-1 shows the relative environmental impacts of the two treatment options by process stage. Here the relative impact of purpose building a GeoMelt facility may be seen, along with the long haul transport component for the HTI rotary kiln process.

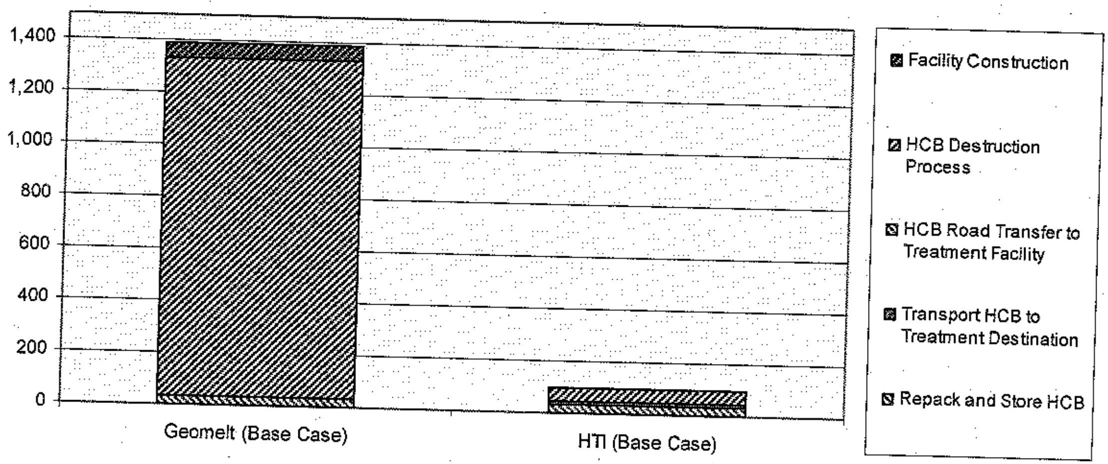

Figure 6-1: Overall Environmental Impact of HCB Management Options (Eco-$ per Tonne of HCB Waste)

The way both of the processing options have been modelled may be represented in the form of network diagrams, whereby each stage is represented by a "process box". The Enviro-Economic Valuation network diagrams representing the GeoMelt and HTI rotary kiln process options for 1 tonne of HCB waste are given in Appendix A. Lines of differing thickness connecting each of the process boxes are used to indicate the relative contribution of each stage to the overall environmental impact.

6.2 Eco-Indicator (99) Valuation

When applying the Eco-Indicator (99) Valuation model, the result shows an aggregate environmental impact 9 times greater than that of the HTI rotary kiln treatment option per functional unit (1 tonne of HCB waste). The vast majority of these impacts are associated with GeoMelt's electricity demand, with the major impacts arising from the categories of fossil fuel demand (coal and natural gas) and the emission of respiratory inorganics (oxides of nitrogen and sulfur, and airborne particulates).

Table 6-2: Environmental Impact of HCB Management Options (Eco-points per Tonne of HCB Waste)

	Geomelt (Base Case)		HTI (Base Case)	
Repack and Store HCB	43.7	6.7%	43.7	65.3%
Transport HCB to Treatment Destination	1.3	0.2%	6.5	9.7%
HCB Road Transfer to Treatment Facility	0.2	0.03%	0.4	0.6%
HCB Destruction	561.0	86.1%	15.3	22.9%
Facility Construction	45.3	7.0%	1.1	1.6%
	651.4	100.0%	67.0	100.0%

As detailed in Section 5.1, it is interesting to note the relative impact of repacking and storing the HCB waste relative to other process activities, particularly in the case of HTI rotary kiln destruction. Relative to the HTI destruction of HCB waste, the repacking has almost three time the environmental impact. This is because one of the main operating parameters of the HTI process is that of thermal loading whereby the waste materials are blended with other wastes or fuels to produce a feedstock within a predefined calorific range. Being exothermic, the result is a destruction process which is largely self sustaining in terms of energy, relative to other process activities.

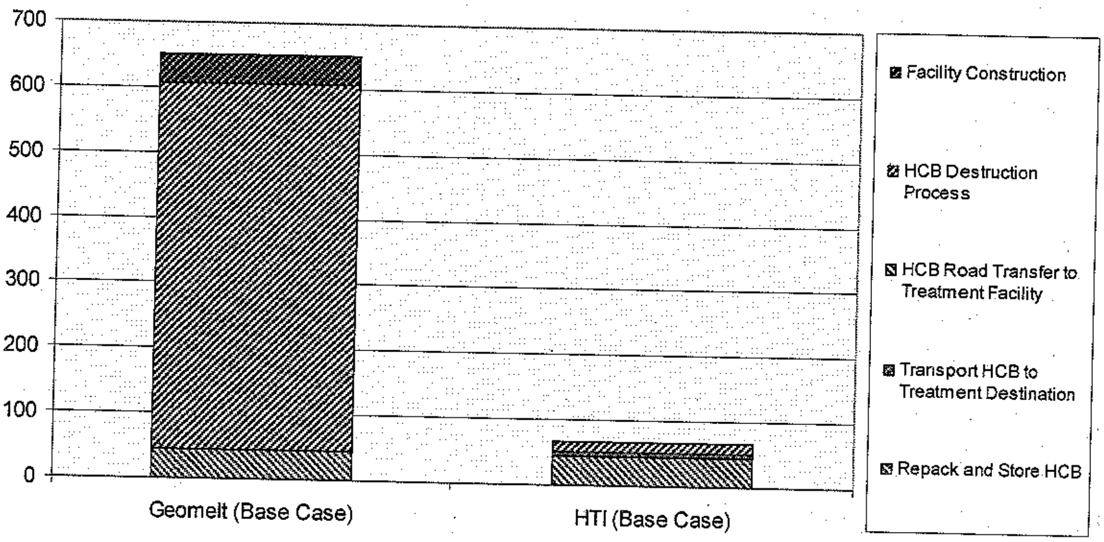

Figure 6-2: Overall Environmental Impact of HCB Management Options (Eco-Indicator Points per Tonne of HCB Waste)

Eco-Indicator (99) Valuation network diagrams representing the GeoMelt and HTI rotary kiln process options for 1 tonne of HCB waste are given in Appendix B.

7 SENSITIVITY AND UNCERTAINTY ANALYSIS

7.1 Sensitivity Analysis

7.1.1 Enviro-Economic Valuation

A total of 4 scenario sensitivity analyses were carried out to assess validity of assumptions and the effect of varying different parameters. The scenarios modelled were:

1. Setting the air emissions of the GeoMelt facility at contemporary European emission limits;
2. Modelling the GeoMelt operation to produce zero airborne emissions;
3. Setting the air emissions of the HTI facility at contemporary European emission limits (from the actual emissions data used);
4. The recovery of hydrochloric acid (HCl) from an HTI treatment process;

The results of the sensitivity modelling are presented in Table 7-1.

Table 7-1: Environmental Impact Sensitivity Results (Eco-$ per Tonne of HCB Waste)

	GeoMelt (Base Case)	GeoMelt (Euro Limits)	GeoMelt (Zero Emissions)	HTI (Base Case)	HTI (Euro Limits)	HTI (HCl Recovery)
Greenhouse	232.0	232.0	232.0	39.7	39.6	31.1
Resources	252.0	252.0	252.0	7.2	7.2	0.9
Oil and Gas	44.2	44.2	44.2	13.1	13.1	10.9
Air Pollutants	793.0	308.0	242.0	28.9	42.5	15.6
Water Pollutants	28.4	27.8	28.4	4.3	18.3	2.9
Solid Waste	7.5	7.5	7.5	0.3	0.3	0.3
Water Use	31.9	31.9	31.9	5.1	5.1	-5.5
	1,389.0	903.4	838.0	98.6	126.0	56.2

In order to test the relative importance of process emissions, the GeoMelt process was modelled as:

1. Meeting contemporary European emission limits; and
2. Having zero facility emissions.

Here it was found that result for the GeoMelt process varies by up to 40% but is still significantly higher that the actual result achieved for the HTI rotary kiln process. Furthermore as the GeoMelt facility will have some emissions but must operate below emission limits, the actual result will lie somewhere between the "Base Case" and "Zero Emissions" case. Notwithstanding this, the overall result remains unchanged.

In order to test the significance of emissions and resource recovery, the HTI rotary kiln process was modelled as:

1. Only meeting contemporary European emissions limits; and
2. Recovering hydrochloric acid (HCl).

Here the results were found to vary by up to 43%. However, due to the relative magnitude of the result, the overall findings remain unchanged as illustrated in Figure 7-1.

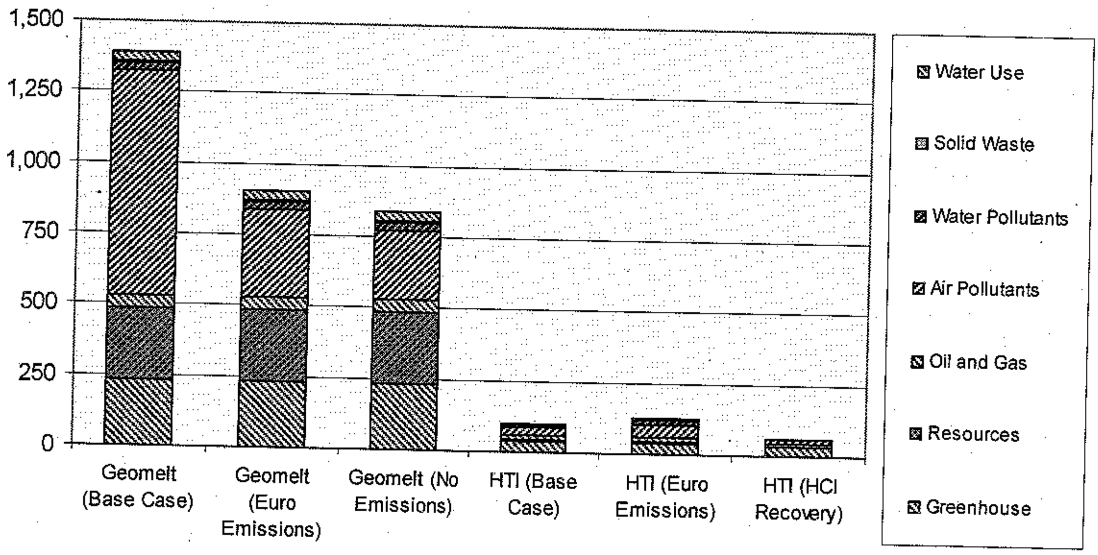

Figure 7-1: Environmental Impact Sensitivity Results (Eco-$ per Tonne of HCB Waste)

In addition, the environmental-economic valuation model was modified to include the following 3 sensitivity analyses:

1. Setting the environmental value for the disposal of fly ash from an HTI facility at $2000/t;
2. Setting the environmental value for the disposal of all fly ash (including electricity generation) at $2000/t;
3. The recovery of hydrochloric acid (HCl) from an HTI treatment process and Setting the environmental value for the disposal of fly ash from an HTI facility at $2000/t;

The purpose of these sensitivities was to test the degree to which process residues, in particular hazardous by-products requiring secure or special disposal, might affect the relative results. The results of the sensitivity modelling are presented in Table 7-2 and Figure 7-2.

Table 7-2: Environmental Impact Sensitivity Results
(Eco-$ per Tonne of HCB Waste)

	GeoMelt (Base Case)	GeoMelt (Euro Limits)	GeoMelt (Zero Emissions)	HTI (Base Case)	HTI (Euro Limits)
HTI Fly Ash = $2,000/t	1,389	903	837	160	188
All Fly Ash = $2,000/t	1,940	1,450	1380	159	187
HTI HCl Recovery, HTI Fly Ash = $2,000/t	1,389	903	837	118	145

As may be seen, relative results remain largely unchanged even with the application of a significant waste disposal burden on the HTI rotary kiln process. That is, because of its significant electricity demand, the relative magnitude of the GeoMelt process still outweighs the HTI process by almost fivefold.

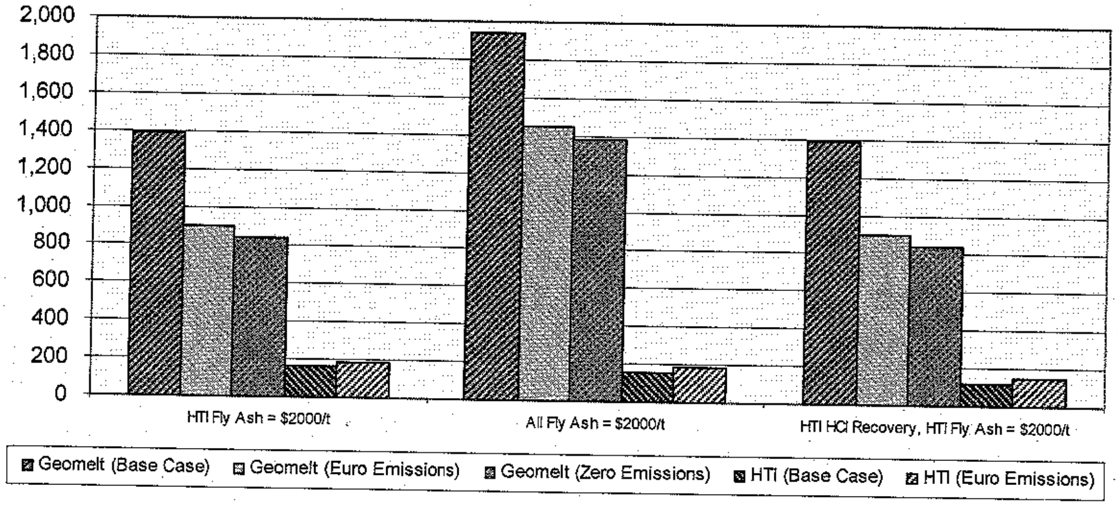

Figure 7-2: Environmental Impact Sensitivity Results (Eco-$ per Tonne of HCB Waste)

7.1.2 Eco-Indicator (99) Valuation

Using the Eco-Indicator (99) methodology, a total of 4 sensitivity analyses were carried out to assess validity of assumptions and the effect of varying different parameters. The scenarios modelled were:

1. Setting the air emissions of the GeoMelt facility at contemporary European emission limits;
2. Modelling the GeoMelt operation to produce zero airborne emissions; and
3. Setting the air emissions of the HTI facility at contemporary European emission limits.

The results of the sensitivity modelling are presented in Table 7-3 and Figure 7-3.

Table 7-3: Environmental Impact Sensitivity Results (Eco-Indicator Points per Tonne of HCB Waste)

	GeoMelt (Base Case)	GeoMelt (Euro Limits)	GeoMelt (Zero Emissions)	HTI (Base Case)	HTI (Euro Limits)	HTI (HCl Recovery)
Carcinogens	48.5	4.2	1.3	0.3	1.3	-0.3
Respiratory Organics	0.2	0.2	0.2	0.1	0.1	0.1
Respiratory Inorganics	172.0	156.0	144.0	12.6	18.2	10.8
Climate Change	46.1	46.0	46.0	7.9	10.5	8.2
Radiation	0.1	0.1	0.1	0.0	0.0	-0.3
Ozone Depletion	0.0020	0.0020	0.0020	0.0002	0.0002	-0.0173
Ecotoxicity	39.4	16.6	13.3	0.5	1.1	0.0
Acidification / Eutrophication	33.1	27.9	24.3	2.8	2.5	1.8
Land Use	4.9	4.9	4.9	0.3	0.3	-1.0
Minerals	7.8	7.8	7.8	0.2	0.2	0.1
Fossil Fuels	299.0	299.0	299.0	42.2	42.2	30.9
	651.1	562.7	541.0	66.9	76.4	50.3

As per the Enviro-Economic Valuation sensitivities, the Eco-Indicator sensitivity modelling confirmed that the relative results will remain unchanged even with varying facility emissions. Moreover, modelling the GeoMelt with zero emissions still yields a result which is seven times greater than a worst case scenario for the HTI rotary kiln.

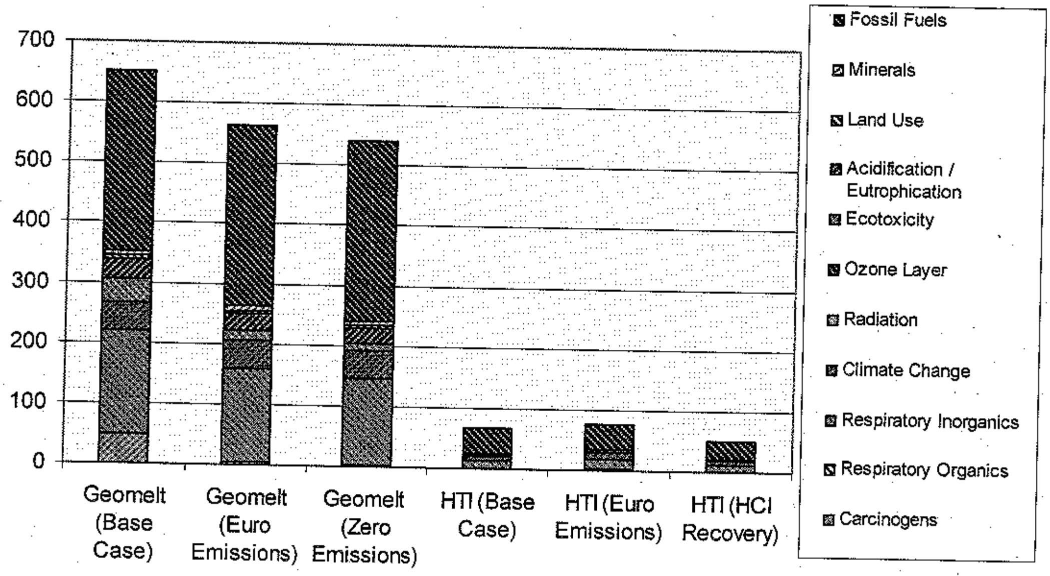

Figure 7-3: Environmental Impact Sensitivity Analyses Results (Eco-Indicator Points per Tonne of HCB Waste)

7.1.3 Renewable Electricity

Given that a large proportion of the environmental impacts associated with the GeoMelt base case arise from the production and supply of (predominantly coal fired) electricity, a sensitivity analysis was carried using a standard renewable electricity mix. Here it should be noted that with an annual demand of 25,000 MWh per year, the GeoMelt process would utilise only 0.03% of Australia's annual renewable electricity output[6]. The majority of this electricity would be from hydro-electricity with the other main sources being wind and biomass.

Table 7-4 details the renewable electricity mix and demand for destruction of one tonne of HCB using the GeoMelt process.

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[6] Australian Government (2005), *Australian Greenhouse Office - Renewable Energy Power Stations*, http://www.agso.gov.au/renewable/

Table 7-4: Renewable Electricity Mix and Demand for GeoMelt Process

Source	Proportion %	Demand MWh/t HCB
Solar	0.8%	0.056
Hydro	84.7%	5.839
Wind	7.0%	0.483
Biomass	7.5%	0.520
	100%	6.897

a) Enviro-Economic Valuation

Using the Enviro-Economic valuation method, a total of three scenarios were analysed, substituting renewable electricity in place of coal fired electricity from the south-east Australian grid network. These were:

1. GeoMelt (Base Case) processing;
2. Setting the air emissions of the GeoMelt facility at contemporary European emission limits; and
3. Modelling the GeoMelt operation to produce zero airborne emissions

The results of the sensitivity modelling are presented in Table 7-5 and Figure 7-4.

Table 7-5: Environmental Impact Sensitivity Results – Renewable Electricity (Eco-$ per Tonne of HCB Waste)

	HTI (Base Case)	GeoMelt w/ Renewable Energy (Base Case)	GeoMelt w/ Renewable Energy (Euro Emissions)	GeoMelt w/ Renewable Energy (Zero Emissions)
Greenhouse	39.7	84.0	84.0	84.0
Resources	7.2	104.0	104.0	104.0
Oil and Gas	13.1	39.8	39.8	39.8
Air Pollutants	28.9	672.0	187.0	121.0
Water Pollutants	4.3	26.9	26.3	26.9
Solid Waste	0.3	7.1	7.1	7.1
Water Use	5.1	25.3	25.3	25.3
	98.5	959.0	474.0	408.0

The results of this analysis show that even with renewable electricity, the GeoMelt process will have at least four times greater impact than that for the HTI process, predominantly arising from air pollutants (nitrogen oxides and airborne particulates), resource depletion (limestone for concrete) and greenhouse gases.

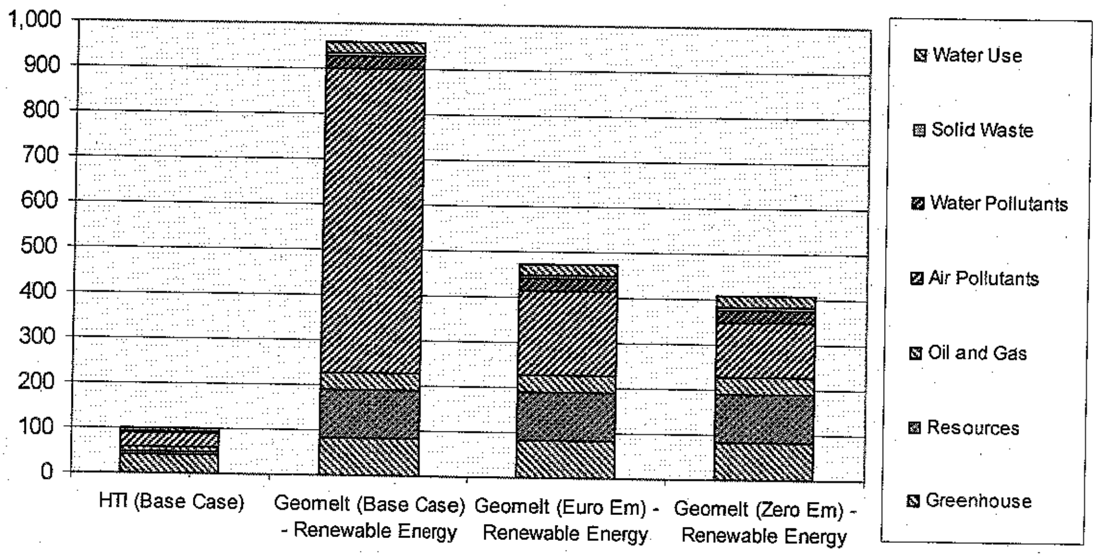

Figure 7-4: Environmental Impact Sensitivity Results – Renewable Electricity (Eco-$ per Tonne of HCB Waste)

b) Eco-Indicator (99) Valuation

In order to cross-check the effect of substituting coal fired electricity with renewable electricity, the same three scenarios were analysed using the Eco-Indicator (99) methodology, that is:

1. GeoMelt (Base Case) processing;
2. Setting the air emissions of the GeoMelt facility at contemporary European emission limits; and
3. Modelling the GeoMelt operation to produce zero airborne emissions

The results of the sensitivity modelling are presented in Table 7-6 and Figure 7-5.

Table 7-6: Environmental Impact Sensitivity Results – Renewable Electricity (Eco-Indicator Points per Tonne of HCB Waste)

	HTI (Base Case)	GeoMelt w/ Renewable Energy (Base Case)	GeoMelt w/ Renewable Energy (Euro Em)	GeoMelt w/ Renewable Energy (Zero Em)
Carcinogens	0.3	48.0	3.6	0.8
Respiratory Organics	0.1	0.1	0.1	0.1
Respiratory Inorganics	12.6	89.6	73.9	62.2
Climate Change	7.86	18.2	18.1	18.1
Radiation	0.002	0.089	0.089	0.089
Ozone Depletion	0.0002	0.0020	0.0020	0.0020
Ecotoxicity	0.5	27.9	5.2	1.9
Acidification / Eutrophication	2.8	19.8	14.6	11.0
Land Use	0.3	3.2	3.2	3.2
Minerals	0.2	7.8	7.8	7.8
Fossil Fuels	42.2	142.0	142.0	142.0
	66.9	357.0	269.0	248.0

As with the Enviro-Economic Valuation method, the Eco-Indicator (99) modelling shows the GeoMelt process to have and environmental impact at least four times greater than the HTI process. This is largely due the requirement for fossil fuels (natural gas) to operate the thermal oxidiser and the generation of respiratory inorganics (oxides of nitrogen and sulfur) in operating the thermal oxidiser. Therefore, even with the use of renewable electricity, the GeoMelt process has a greater environmental impact than the HTI process.

Here it should be noted that one of the most controversial environmental impacts associated with Hydro power supply relates to local habitat loss. However, neither of the two impact assessment methods incorporates site-specific impacts. This limitation is not considered to bias the study results as the conclusions regarding technology options would not change if it were included as the GeoMelt renewable energy option would have a still greater impact.

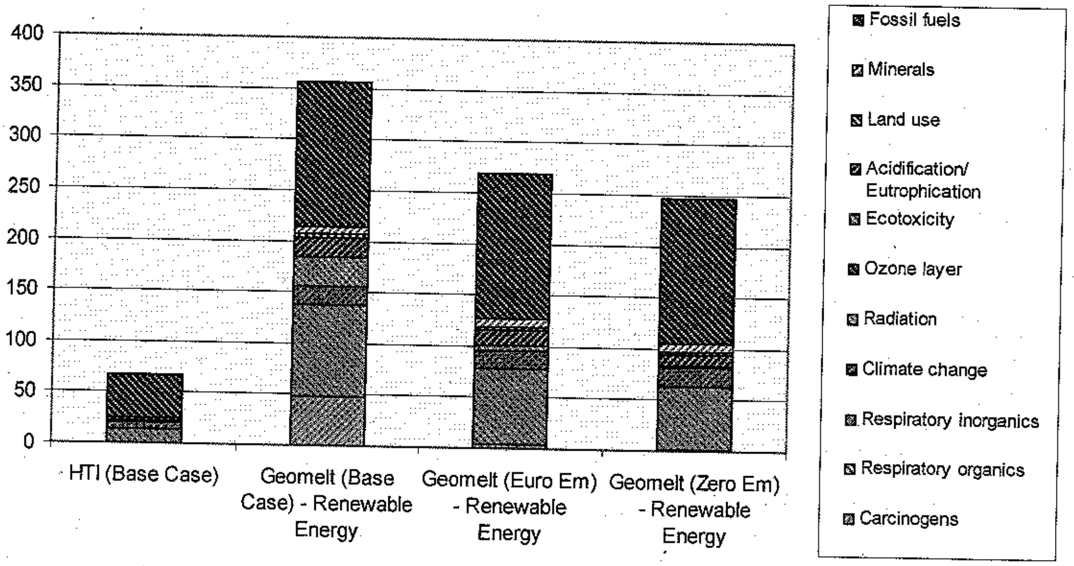

Figure 7-5: Environmental Impact Sensitivity Results – Renewable Electricity (Eco-Indicator Points per Tonne of HCB Waste)

7.2 Uncertainty Analysis

7.2.1 Data Sources, Quality and Uncertainty

Uncertainty analysis in LCA is designed to expose the audience of a study to the influence of data quality on the final results. Data quality requirements specify in general terms the characteristics of the data needed for the study[7]. Data quality requirements that are assessed in order to determine uncertainty include:

- Time-related coverage of data collection;
- Geographical coverage;
- Technological coverage;
- Precision, completeness and representativeness of the data; and
- Sources of the data and their representativeness.

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[7] AS/NZ 14 040: 1998 Environmental Management – Life Cycle Assessment – principles and framework. Standards Australia, Homebush.

In general, all scientific investigations benefit from an understanding of the uncertainties of results caused by uncertainties in the input data. This is particularly relevant to emissions data associated with the GeoMelt process which has yet to be commercially applied to the dedicated treatment of HCB waste. Consequently, within this study Monte Carlo uncertainty analysis calculations[8] have been carried out to determine the bearing of uncertainty associated with anticipated GeoMelt emissions.

All uncertainty estimates were based on lognormal distributions, which provide a value for the square of the geometric standard deviation (variance), which is then increase as data quality indicators deteriorated.

For the purposes of comparison, uncertainty analysis was also applied to the HTI rotary kiln process. However, in this case, emissions data was based on actual measurements resulting in lower lognormal uncertainty parameters. For ease of interpretation and comparison, the uncertainty associate with each process is displayed as graphical high-low ranges.

7.2.2 Environmental-Economic Valuation Method

a) GeoMelt – Base Case Uncertainty

Figure 7-6 presents the uncertainty associated with the GeoMelt assessment using the Enviro-Economic Valuation method. Here it may be seen that the greatest uncertainty lies with data associated with the impact category of air toxics. The reason for this is that the facility emissions are unknown as the GeoMelt process has not been previously applied to the destruction of high level HCB waste. As a consequence emissions limits have had to be relied upon as a proxy data source in the absence of quantitative data.

Whilst much lower, there is also significant uncertainty associated with the impact category of water toxics as this assessment has relied upon an expected effluent composition as set out under a 2001 draft agreement with Sydney Water, rather that actual effluent data. However, as the overall impact within this category is much lower, the uncertainty does little to affect the overall result.

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[8] Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. The random behavior in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a model. For each uncertain variable (one that has a range of possible values), the possible values are defined through a probability distribution. The type of distribution selected is based on the conditions surrounding that variable.

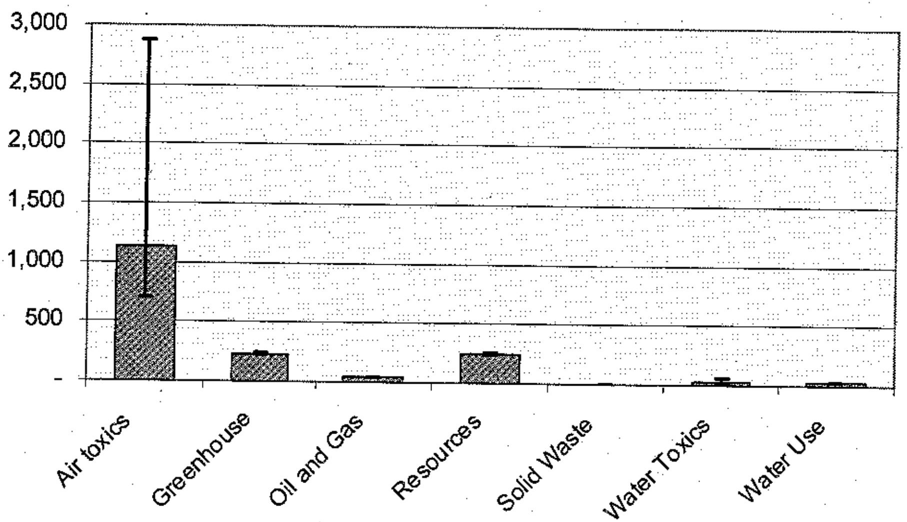

Figure 7-6: GeoMelt Uncertainty Analysis Results (Eco-$ per Tonne of HCB Waste)

b) HTI Rotary Kiln – Actual Uncertainty

Figure 7-7 shows the greatest uncertainty associated with the HTI rotary kiln assessment in the impact category of air toxics. However, because this assessment is based upon actual operating data, the uncertainty range is significantly less than that for the GeoMelt process. Similarly, as actual effluent measurements have been relied upon within this assessment, the uncertainty associated with the impact category of water toxics for the HTI rotary kiln process is much lower than that for the GeoMelt process.

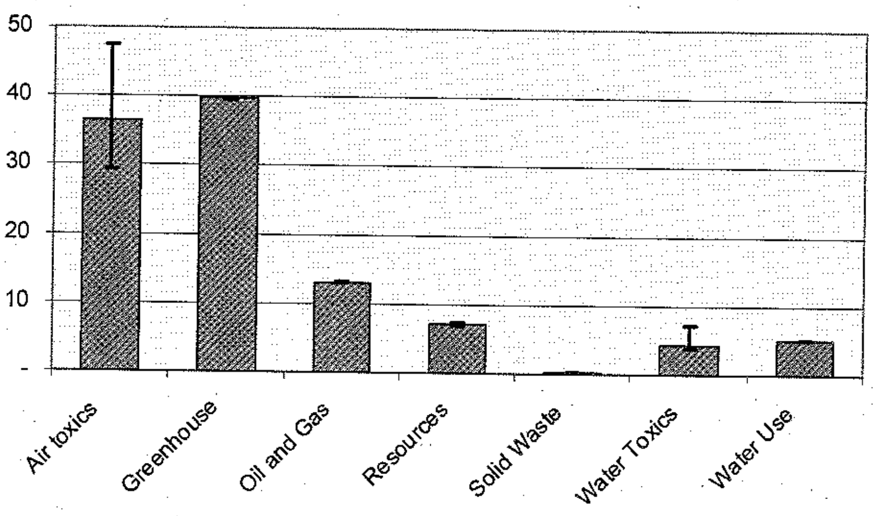

Figure 7-7: HTI Rotary Kiln Uncertainty Analysis Results (Eco-$ per Tonne of HCB Waste)

c) Overall Relative Uncertainty

Figure 7-8 shows the overall relative uncertainty between the GeoMelt and HTI rotary kiln processes using the Enviro-Economic Valuation model. Here it may be seen that while a high level of overall uncertainty exists with the emissions data associated with the GeoMelt process, the result relative to the HTI rotary kiln process is unchanged. That is even if the lower uncertainty range is taken for the GeoMelt process, the overall environmental impact is still more than 10 times greater than that for the HTI rotary kiln process for destroying 1 tonne of HCB waste.

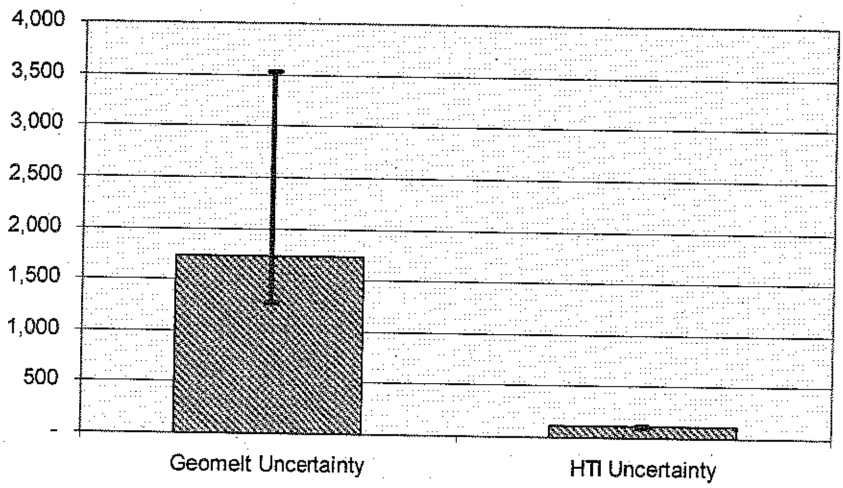

Figure 7-8: Overall Relative Uncertainty Analysis Results for Both Treatment Options (Eco-$ per Tonne of HCB Waste)

7.2.3 Eco-Indicator (99) Valuation Method

a) GeoMelt – Base Case Uncertainty

As shown in Figure 7-9, the impact category which carries the greatest uncertainty using the Eco-Indicator Valuation method is that of Human Health. As with the Environmental-Economic Valuation, this uncertainty is related to the absence of actual emissions data and the consequent use of emissions limits and effluent discharge agreement limits.

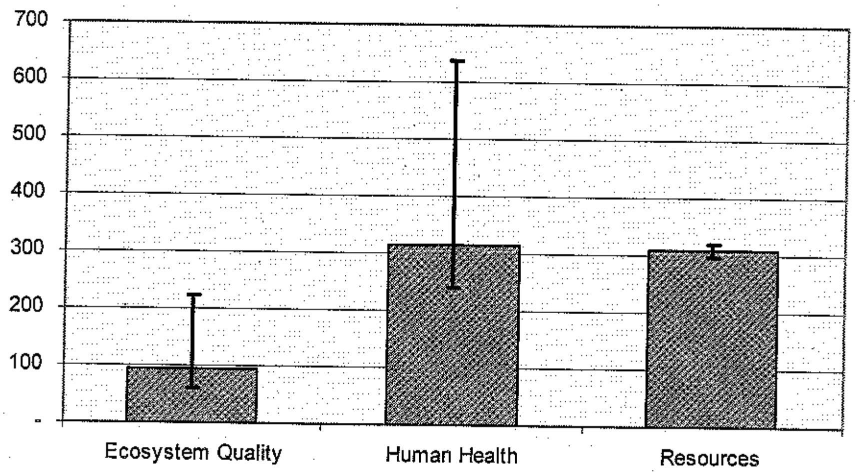

Figure 7-9: GeoMelt Uncertainty Analysis Results (Eco-Indicator Points per Tonne of HCB Waste)

b) HTI Rotary Kiln – Base Case Uncertainty

Similar to the results in Section 7.2.2b), the use of actual emissions data results in a much lower level of uncertainty within the assessment of the HTI rotary kiln process, using the Eco-Indicator (99) method. Similar to the above, the greatest area of uncertainty is the impact categories of Human Health and Ecosystem Quality.

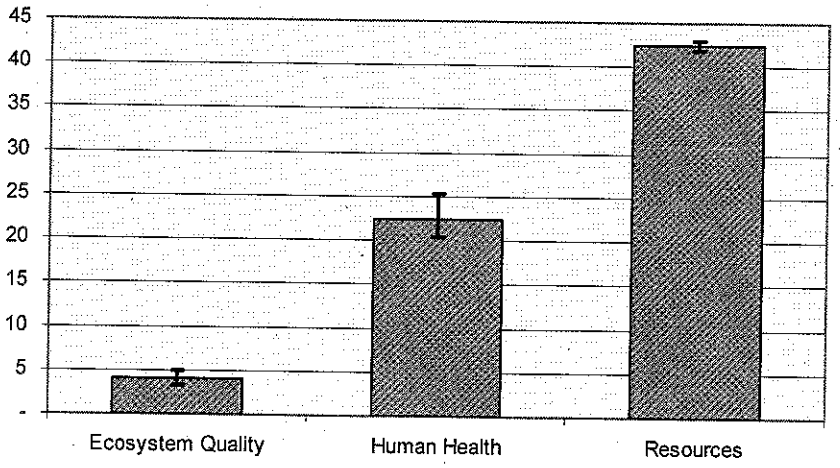

Figure 7-10: HTI Rotary Kiln Uncertainty Analysis Results (Eco-Indicator Points per Tonne of HCB Waste)

c) Overall Relative Uncertainty

Figure 7-11 shows the overall relative uncertainty between the GeoMelt and HTI rotary kiln processes using the Eco-Indicator Valuation model. As with Section 7.2.2c), it may be seen that while a high level of overall uncertainty exists with the emissions data associated with the GeoMelt process, the result relative to the HTI rotary kiln process is unchanged. That is even if the lower uncertainty range is taken for the GeoMelt process, the overall environmental impact is more than 8 times greater than that for the HTI rotary kiln process for destroying 1 tonne of HCB waste.

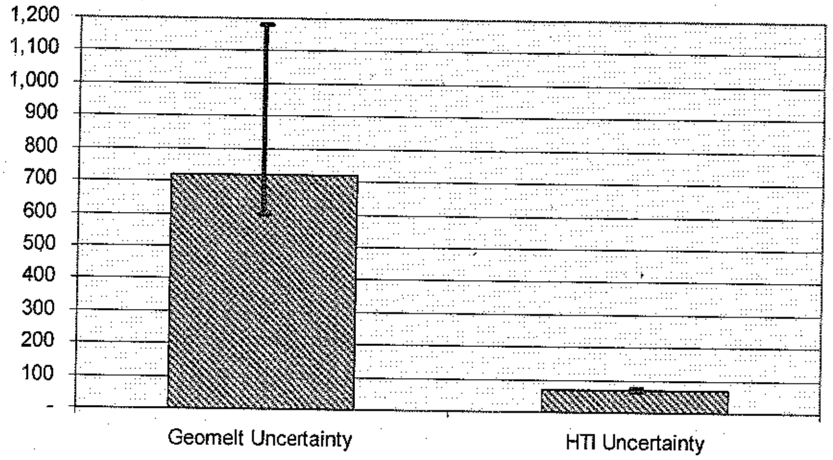

Figure 7-11: Overall Relative Uncertainty Analysis Results for Both Treatment Options (Eco-Indicator Points per Tonne of HCB Waste)

8 KEY FINDINGS & RELATED FACTORS

This study assessed two options of destruction of HCB wastes from Orica's Botany site:

Option A – GeoMelt modelled according to the system configuration as detailed within Orica's Environmental Impact Statement – Proposed HCB Waste Destruction Facility at Botany (2001); and

Option B – HTI modelled according to 2004 operational data taken from the actual operation of a rotary kiln high temperature hazardous waste incinerator facility operating in Europe.

Based upon the functional unit, the key findings from a life-assessment of the two options are as follows:

- The establishment of a GeoMelt destruction facility in remote NSW carries a far greater overall environmental impact (not including risk) than exporting the HCB waste to Europe for destruction at an existing facility. That is, the principal differences in environmental impacts between the two options are technological rather than geographic.
- One of the major contributors to the relatively poor environmental performance of the GeoMelt process is the very high electricity demand to operate the process.
- Whilst the pollutants for both processes are largely similar, the generation of electricity required for the GeoMelt process results in the generation of significant airborne pollutants.
- Data uncertainty associated with the GeoMelt process is higher than with the HTI process as no actual emissions or effluent discharge data exists for the application of this treatment process to high level HCB waste.
- In contrast, the HTI rotary kiln process (with a number of plants operating in Europe) was assessed using actual measured data and showed a greater level of certainty, in addition to outperforming the GeoMelt process in all environmental impact categories.

Finally, Nolan-ITU believes that an environmental assessment of different management options for HCB waste at Botany is a highly critical consideration in the decision-making process. However, a range of other factors - such as social costs and benefits, hazards and risks, and stakeholder viewpoints about acceptable levels of risk, must also feature in the final solution chosen for managing Orica's HCB waste. It should be noted that the scope of this environmental assessment *did not include the above factors.*

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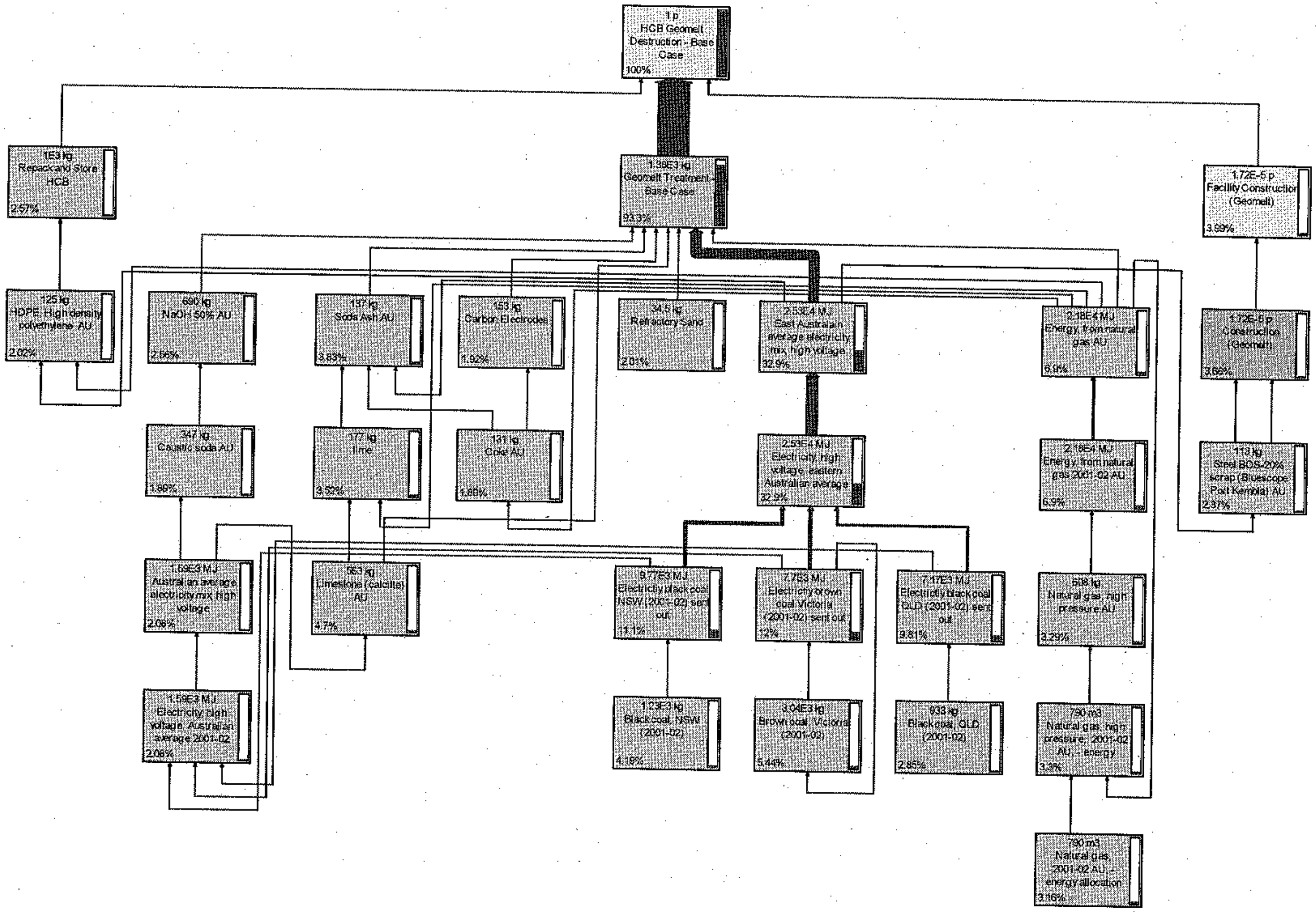
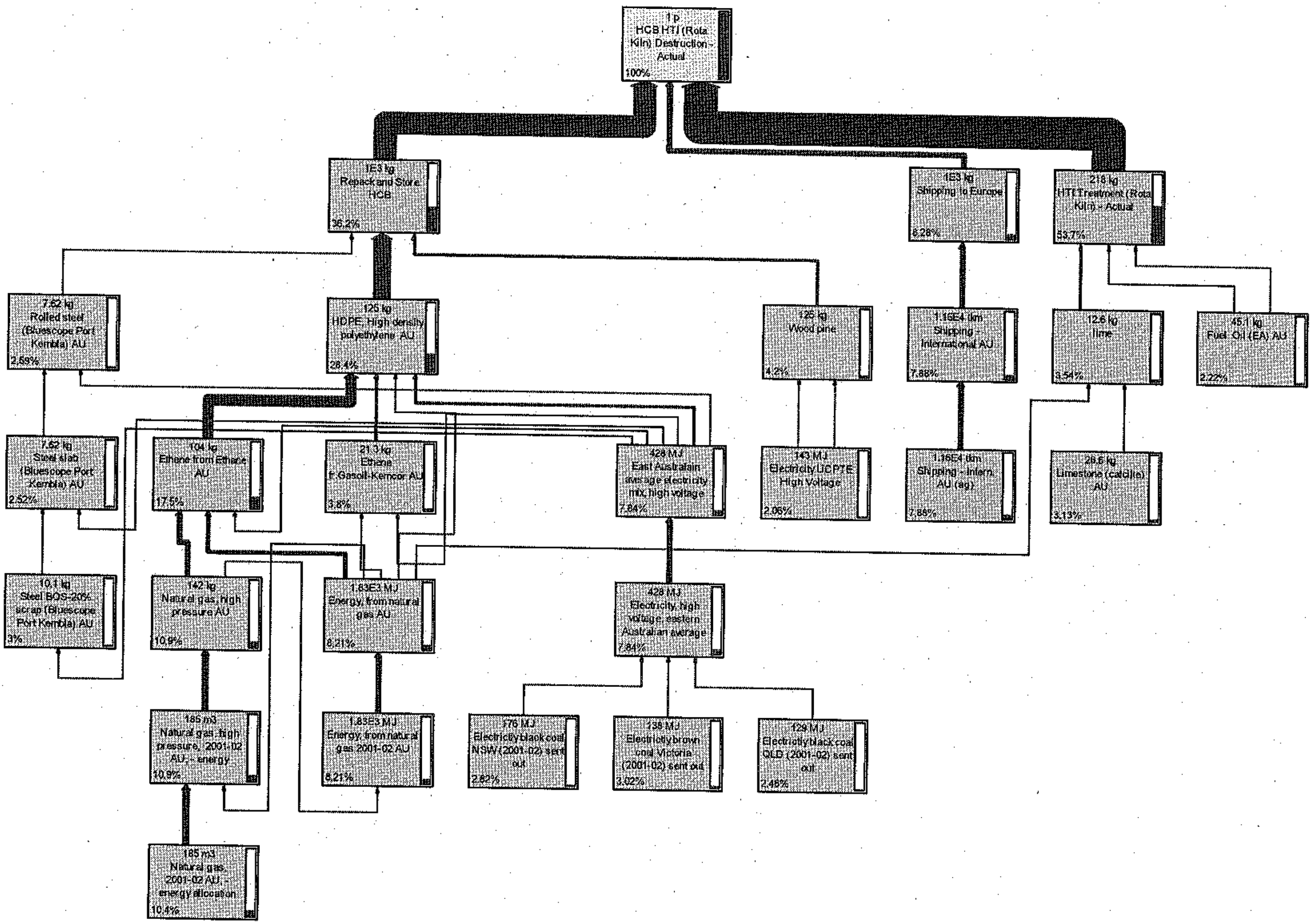
Appendix A

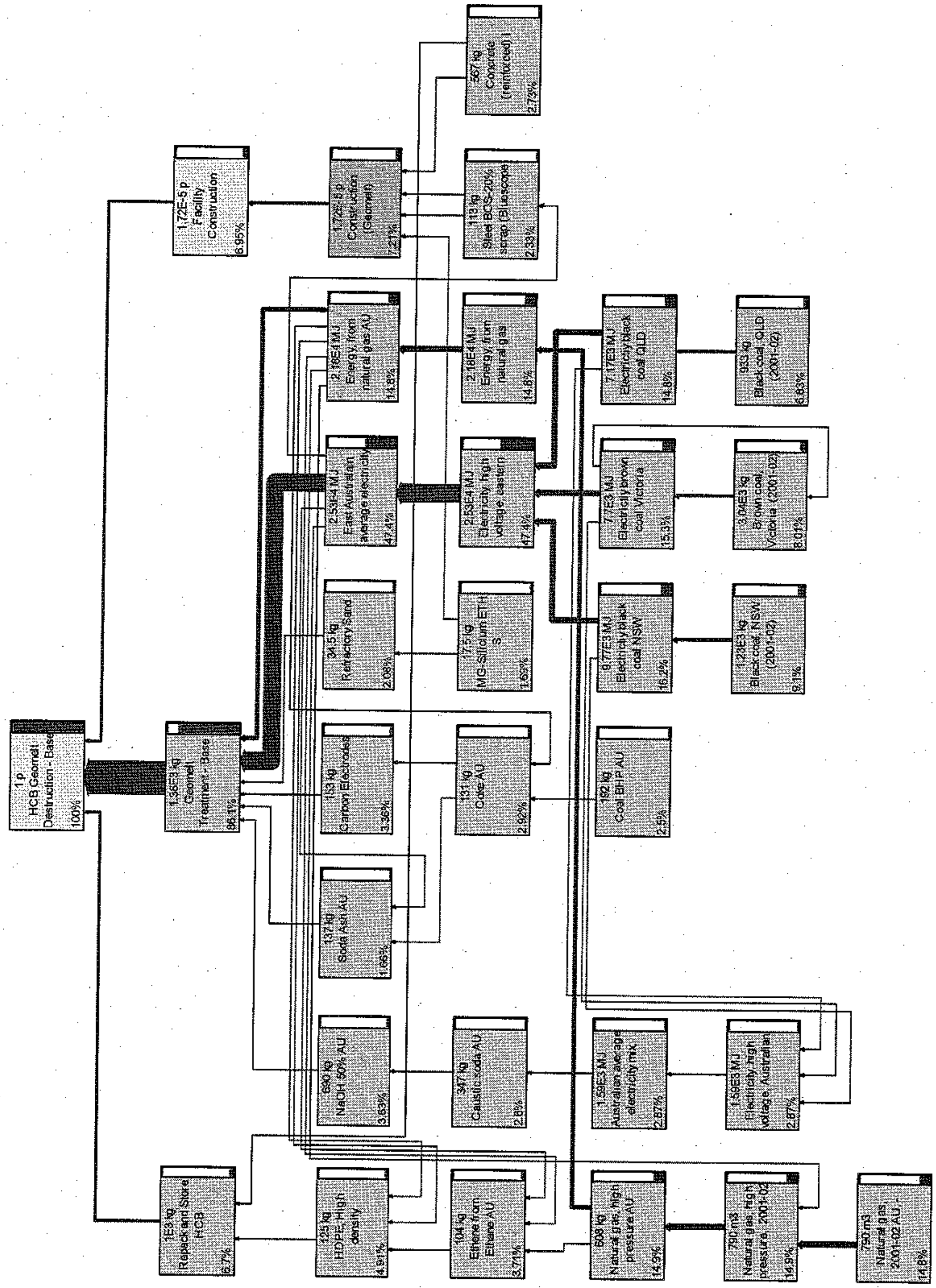
GeoMelt & HTI Network Diagrams (Environmental-Economic Valuation)

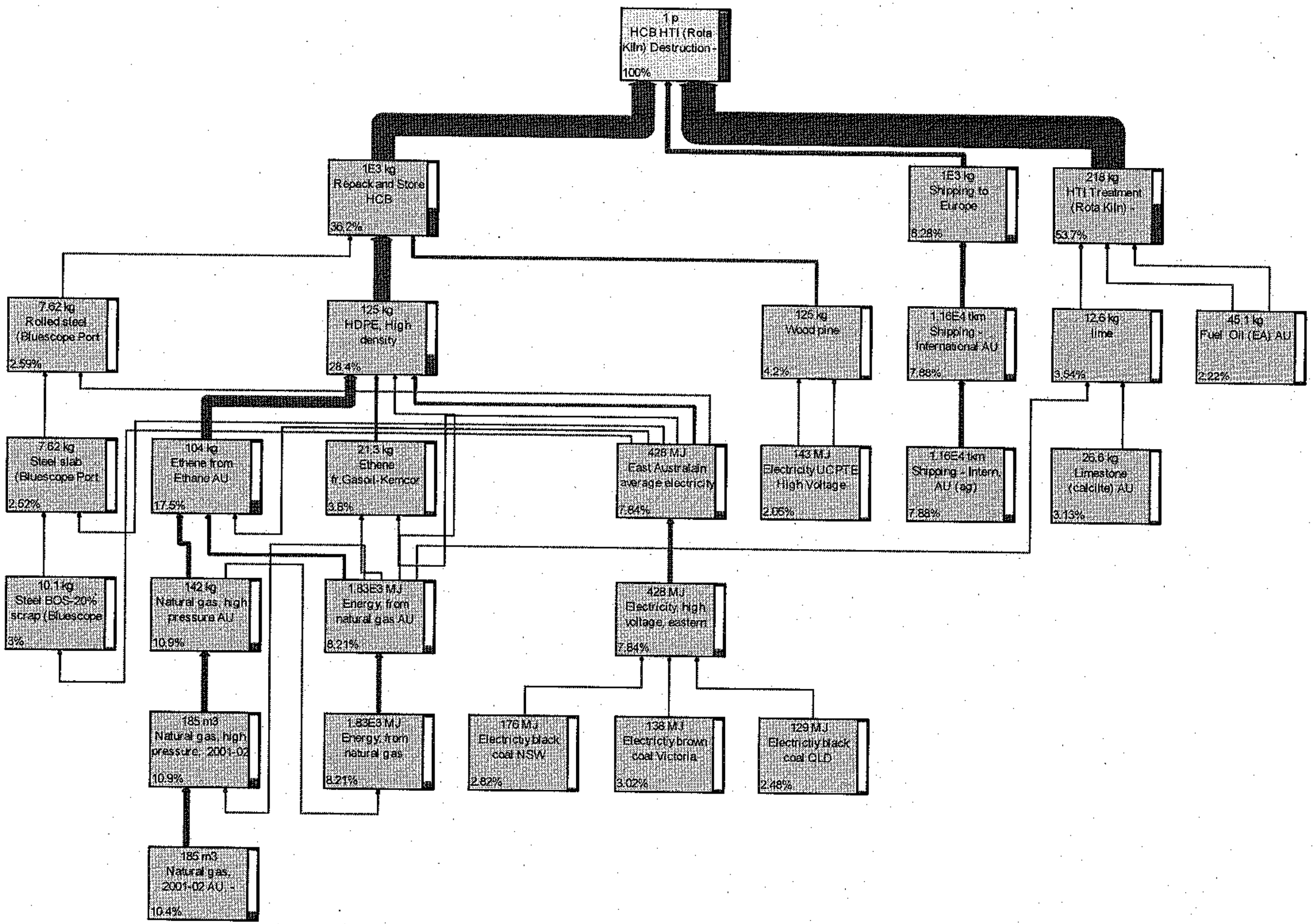

1 p
HCB Geomelt Destruction - Base Case
100%
1.39E3 kg
Geomelt Treatment - Base Case
93.3%
1E3 kg
Repack and Store HCB
2.57%
1.72E-5 p
Facility Construction (Geomelt)
3.99%
125 kg
HDPE, High density polyethylene AU
2.02%
690 kg
NaOH 50% AU
2.66%
137 kg
Soda Ash AU
3.83%
153 kg
Carbon Electrodes
1.92%
34.5 kg
Refractory Sand
2.01%
2.53E4 MJ
East Australain average electricity mix, high voltage
32.9%
2.18E4 MJ
Energy, from natural gas AU
6.9%
1.72E-5 p
Construction (Geomelt)
3.66%
347 kg
Caustic soda AU
1.89%
177 kg
lime
3.52%
131 kg
Coke AU
1.89%
2.53E4 MJ
Electricity, high voltage, eastern Australian average
32.9%
2.18E4 MJ
Energy, from natural gas 2001-02 AU
6.9%
113 kg
Steel BOS-20% scrap (Bluescope Port Kembla) AU
2.37%
1.59E3 MJ
Australian average electricity mix, high voltage
2.06%
563 kg
Limestone (calcite) AU
4.7%
9.77E3 MJ
Electrictiy black coal NSW (2001-02) sent out
11.1%
7.7E3 MJ
Electrictiy brown coal Victoria (2001-02) sent out
12%
7.17E3 MJ
Electrictiy black coal QLD (2001-02) sent out
9.81%
608 kg
Natural gas, high pressure AU
3.29%
1.59E3 MJ
Electricity, high voltage, Australian average 2001-02
2.06%
1.23E3 kg
Black coal, NSW (2001-02)
4.19%
3.04E3 kg
Brown coal, Victoria (2001-02)
5.44%
933 kg
Black coal, QLD (2001-02)
2.85%
790 m3
Natural gas, high pressure, 2001-02 AU, - energy
3.3%
790 m3
Natural gas, 2001-02 AU, - energy allocation
3.16%


1 p
HCB HTI (Rota Kiln) Destruction - Actual
100%
1E3 kg
Repack and Store HCB
36.2%
1E3 kg
Shipping to Europe
8.28%
218 kg
HTI Treatment (Rota Kiln) - Actual
53.7%
7.62 kg
Rolled steel (Bluescope Port Kembla) AU
2.59%
125 kg
HDPE, High density polyethylene AU
28.4%
125 kg
Wood pine
4.2%
1.16E4 tkm
Shipping - International AU
7.88%
12.6 kg
lime
3.54%
45.1 kg
Fuel Oil (EA) AU
2.22%
7.62 kg
Steel slab (Bluescope Port Kembla) AU
2.52%
104 kg
Ethene from Ethane AU
17.5%
21.3 kg
Ethene fr.Gasoil-Kemcor AU
3.8%
428 MJ
East Australain average electricity mix, high voltage
7.84%
143 MJ
Electricity UCPTE High Voltage
2.06%
1.16E4 tkm
Shipping - Intern. AU (ag)
7.88%
28.6 kg
Limestone (calcite) AU
3.13%
10.1 kg
Steel BOS-20% scrap (Bluescope Port Kembla) AU
3%
142 kg
Natural gas, high pressure AU
10.9%
1.83E3 MJ
Energy, from natural gas AU
8.21%
428 MJ
Electricity, high voltage, eastern Australian average
7.84%
185 m3
Natural gas, high pressure, 2001-02 AU, - energy
10.9%
1.83E3 MJ
Energy, from natural gas 2001-02 AU
8.21%
176 MJ
Electricity black coal NSW (2001-02) sent out
2.82%
138 MJ
Electricity brown coal Victoria (2001-02) sent out
3.02%
129 MJ
Electricity black coal QLD (2001-02) sent out
2.48%
185 m3
Natural gas, 2001-02 AU, - energy allocation
10.4%

Appendix B

GeoMelt & HTI Network Diagrams (Eco-Indicator (99) Valuation)


1 p
HCB Geomelt Destruction - Base
100%
1.36E3 kg
Geomelt Treatment - Base
96.1%
1.72E-5 p
Facility Construction
6.95%
1.72E-5 p
Construction (Geomelt)
7.21%
567 kg
Concrete (reinforced) I
2.73%
113 kg
Steel BOS-20% scrap (Bluescope
2.33%
2.18E4 MJ
Energy, from natural gas AU
14.8%
2.18E4 MJ
Energy, from natural gas
14.8%
7.17E3 MJ
Electricity black coal QLD
14.8%
933 kg
Black coal, QLD (2001-02)
6.83%
2.53E4 MJ
East Australian average electricity
47.4%
2.53E4 MJ
Electricity, high voltage, eastern
47.4%
7.7E3 MJ
Electricity brown coal Victoria
15.3%
3.04E3 kg
Brown coal, Victoria (2001-02)
8.01%
34.5 kg
Refractory Sand
2.08%
17.5 kg
MG-Silicium ETH S
1.69%
9.77E3 MJ
Electricity black coal NSW
16.2%
1.23E3 kg
Black coal, NSW (2001-02)
9.1%
153 kg
Carbon Electrodes
3.36%
131 kg
Coke AU
2.92%
192 kg
Coal BHP AU
2.5%
137 kg
Soda Ash AU
1.66%
690 kg
NaOH 50% AU
3.63%
347 kg
Caustic soda AU
2.8%
1.59E3 MJ
Australian average electricity mix
2.87%
1.59E3 MJ
Electricity, high voltage, Australian
2.87%
1E3 kg
Repack and Store HCB
6.7%
125 kg
HDPE, High density
4.91%
104 kg
Ethene from Ethane AU
3.71%
608 kg
Natural gas, high pressure AU
14.9%
790 m3
Natural gas, high pressure, 2001-02
14.9%
790 m3
Natural gas, 2001-02 AU, -
14.8%


1 p HCB HTI (Rota Kiln) Destruction - 100%
1E3 kg Repack and Store HCB 36.2%
1E3 kg Shipping to Europe 8.28%
218 kg HTI Treatment (Rota Kiln) - 53.7%
7.62 kg Rolled steel (Bluescope Port 2.59%
125 kg HDPE, High density 28.4%
125 kg Wood pine 4.2%
1.16E4 tkm Shipping - International AU 7.88%
12.6 kg lime 3.54%
45.1 kg Fuel Oil (EA) AU 2.22%
7.62 kg Steel slab (Bluescope Port 2.52%
104 kg Ethene from Ethane AU 17.5%
21.3 kg Ethene fr.Gasoil-Kemcor 3.8%
428 MJ East Australaian average electricity 7.84%
143 MJ Electricity UCPTE High Voltage 2.05%
1.16E4 tkm Shipping - Intern. AU (ag) 7.88%
26.6 kg Limestone (calcite) AU 3.13%
10.1 kg Steel BOS-20% scrap (Bluescope 3%
142 kg Natural gas, high pressure AU 10.9%
1.83E3 MJ Energy, from natural gas AU 8.21%
428 MJ Electricity, High voltage, eastern 7.84%
185 m3 Natural gas, high pressure, 2001-02 10.9%
1.83E3 MJ Energy, from natural gas 8.21%
176 MJ Electricity black coal NSW 2.82%
138 MJ Electricity brown coal Victoria 3.02%
129 MJ Electricity black coal QLD 2.48%
185 m3 Natural gas, 2001-02 AU - 10.4%

Appendix C

Enviro-Economic Pollutant Load Assessments – GeoMelt & HTI

Title: Comparing 1 p life cycle 'HCB HTI (Rota Kiln) Destruction - Base Case' with 1 p life cycle 'HCB Geomelt Destruction - Base Case'
Method: Nolan-ITU EE Method 24/03/05 / Austrlaia HHweek
Indicator: Characterisation
Category: Air toxics
Cut-off: 0.10%

No	Substance	Compartm	Sub-compa	Unit	HCB HTI (Rota Kiln) Destruction - Base Case	HCB Geomelt Destruction - Base Case
	Total of all compartments			$	28.9	793
	Remaining substances			$	0.761	4.43
1	Mercury	Air		$	0.212	227
2	Nitrogen oxides	Air		$	12.7	188
3	Benzene	Air		$	0.58	140
4	Arsenic	Air		$	1.02	62.6
5	Cadmium	Air		$	0.212	56.1
6	Hydrogen chloride	Air		$	0.466	23
7	Particulates	Air		$	0.921	19.7
8	Sulfur oxides	Air		$	0.739	19.3
9	Particulates, < 10 um	Air		$	0.272	14.4
10	Methane	Air		$	0.973	10.2
11	Nickel	Air		$	0.133	6.6
12	Chromium VI	Air		$	0.127	6.34
13	NMVOC, non-methane volati	Air		$	3.94	5.25
14	Sulfur dioxide	Air		$	0.258	3.51
15	PAH, polycyclic aromatic hyd	Air		$	0.321	2.15
16	Nitrogen oxides	Air	low. pop.	$	5.14	2.11
17	Fluoride	Air		$	0.0264	1.42
18	Ammonia	Air		$	0.059	1.08

Title: Comparing 1 p life cycle 'HCB HTI (Rota Kiln) Destruction - Base Case' with 1 p life cycle 'HCB Geomelt Destruction - Base Case'
Method: Nolan-ITU EE Method 24/03/05 / Austrlaia HHweek
Indicator: Characterisation
Category: Resources
Cut-off: 0.10%

No	Substance	Compartm	Sub-compa	Unit	HCB HTI (Rota Kiln) Destruction - Base Case	HCB Geomelt Destruction - Base Case
	Total of all compartments			$	7.17	252
	Remaining substances			$	0.0521	0.609
1	Coal, brown, 8.1 MJ per kg, i	Raw	in ground	$	1.3	72.3
2	Limestone, in ground	Raw	in ground	$	2.86	59.1
3	Coal, 21.5 MJ per kg, in grou	Raw	in ground	$	0.907	50.4
4	Coal, 20.5 MJ per kg, in grou	Raw	in ground	$	0.653	36.4
5	Coal, 24.0 MJ per kg, in grou	Raw	in ground	$	0.328	12.7
6	Bauxite, in ground	Raw	in ground	$	0.0113	5.92
7	Coal, 13.3 MJ per kg, in grou	Raw	in ground	$	0.0652	3.64
8	Coal, 18 MJ per kg, in groun	Raw	in ground	$	0.363	3.16
9	Sand, unspecified, in ground	Raw	in ground	$	0.211	2.46
10	Coal, 29.3 MJ per kg, in grou	Raw	in ground	$	0.0941	1.94
11	Coal, brown, 8 MJ per kg, in	Raw	in ground	$	0.168	1.19
12	Dolomite, in ground	Raw	in ground	$	0.11	1.06
13	Gypsum, in ground	Raw	in ground	$	0.0398	0.406
14	Coal, 18.5 MJ per kg, in grou	Raw	in ground	$	0.0142	0.394

Title: Comparing 1 p life cycle 'HCB HTI (Rota Kiln) Destruction - Base Case' with 1 p life cycle 'HCB Geomelt Destruction - Base Case'
Method: Nolan-ITU EE Method 24/03/05 / Austrlaia HHweek
Indicator: Characterisation
Category: Greenhouse
Cut-off: 0.10%

No	Substance	Compartm	Sub-compa	Unit	HCB HTI (Rota Kiln) Destruction - Base Case	HCB Geomelt Destruction - Base Case
	Total of all compartments			$	39.7	232
	Remaining substances			$	0.137	0.152
1	Carbon dioxide, fossil	Air		$	2.83	157
2	Carbon dioxide	Air		$	36.2	69.2
3	Methane	Air		$	0.438	4.58
4	Dinitrogen monoxide	Air		$	0.0505	0.667

Appendix D

Eco-Indicator Pollutant Load Assessments – GeoMelt & HTI

Title:	Comparing 1 p life cycle 'HCB HTI (Rota Kiln) Destruction - Base Case' with 1 p life cycle 'HCB Geomelt Destruction - Base Case'
Method:	Eco-indicator 99 (E) V2.1 Australian substances / Europe EI 99 E/E
Indicator:	Characterisation
Category:	Fossil fuels
Cut-off:	0.10%

No	Substance	Compartm	Sub-comp	Unit	HCB HTI (Rota Kiln) Destruction - Base Case	HCB Geomelt Destruction - Base Case
	Total of all compartments			MJ surplus	1.25E+03	8.91E+03
	Remaining substances			MJ surplus	1.56	18
1	Gas, natural, 35.9 MJ per m3, in ground	Raw	in ground	MJ surplus	666	2.84E+03
2	Coal, 21.5 MJ per kg, in ground	Raw	in ground	MJ surplus	31	1.72E+03
3	Coal, brown, 8.1 MJ per kg, in ground	Raw	in ground	MJ surplus	26.9	1.50E+03
4	Coal, 20.5 MJ per kg, in ground	Raw	in ground	MJ surplus	23.3	1.30E+03
5	Coal, 24.0 MJ per kg, in ground	Raw	in ground	MJ surplus	11.5	448
6	Oil, crude, 42.0 MJ per kg, in ground	Raw	in ground	MJ surplus	53.6	191
7	Oil, crude, 41 MJ per kg, in ground	Raw	in ground	MJ surplus	187	188
8	Coal, 13.3 MJ per kg, in ground	Raw	in ground	MJ surplus	2.74	153
9	Oil, crude, 43.4 MJ per kg, in ground	Raw	in ground	MJ surplus	34	121
10	Coal, 18 MJ per kg, in ground	Raw	in ground	MJ surplus	12.8	111
11	Coal, 29.3 MJ per kg, in ground	Raw	in ground	MJ surplus	4.03	83.1
12	Oil, crude, 41.0 MJ per kg, in ground	Raw	in ground	MJ surplus	155	71.1
13	Oil, crude, 42.6 MJ per kg, in ground	Raw	in ground	MJ surplus	19	67.2
14	Gas, natural, 50.3 MJ per kg, in ground	Raw	in ground	MJ surplus	12	35.8
15	Coal, brown, 8 MJ per kg, in ground	Raw	in ground	MJ surplus	3.23	22.9
16	Gas, natural, 35 MJ per m3, in ground	Raw	in ground	MJ surplus	9.45	22.5
17	Coal, 18.5 MJ per kg, in ground	Raw	in ground	MJ surplus	0.502	13.9
18	Gas, natural, 36.6 MJ per m3, in ground	Raw	in ground	MJ surplus	1.14	9.57

Title:	Comparing 1 p life cycle 'HCB HTI (Rota Kiln) Destruction - Base Case' with 1 p life cycle 'HCB Geomelt Destruction - Base Case'
Method:	Eco-indicator 99 (E) V2.1 Australian substances / Europe EI 99 E/E
Indicator:	Characterisation
Category:	Respiratory inorganics
Cut-off:	0.10%

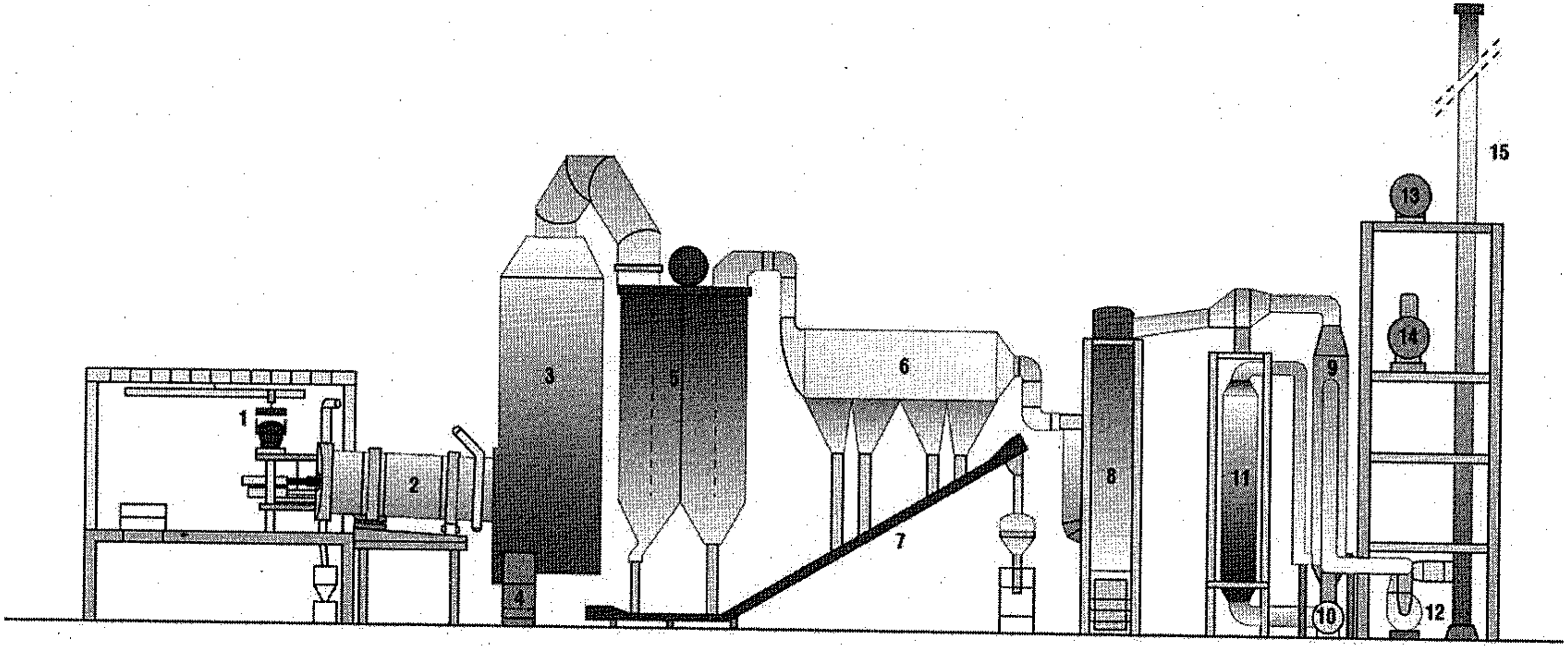
No	Substance	Compartm	Sub-comp	Unit	HCB HTI (Rota Kiln) Destruction - Base Case	HCB Geomelt Destruction - Base Case
	Total of all compartments			DALY	0.000648	0.00885
	Remaining substances			DALY	2.76E-06	1.87E-05
1	Nitrogen oxides	Air		DALY	0.000296	0.00437
2	Sulfur oxides	Air		DALY	9.18E-05	0.00239
3	Particulates, SPM	Air		DALY	8.11E-05	0.000725
4	Particulates, < 10 um	Air		DALY	1.09E-05	0.000574
5	Sulfur dioxide	Air		DALY	3.20E-05	0.000435
6	Particulates	Air		DALY	1.08E-05	0.000231
7	Nitrogen oxides	Air	low. pop.	DALY	0.00012	4.91E-05
8	Carbon monoxide	Air		DALY	1.12E-06	1.92E-05
9	Nitrogen dioxide	Air		DALY	1.04E-06	1.77E-05
10	Particulates, < 10 um (stationary)	Air		DALY	7.52E-07	1.67E-05

Title:	Comparing 1 p life cycle 'HCB HTI (Rota Kiln) Destruction - Base Case' with 1 p life cycle 'HCB Geomelt Destruction - Base Case'
Method:	Eco-indicator 99 (E) V2.1 Australian substances / Europe EI 99 E/E
Indicator:	Characterisation
Category:	Carcinogens
Cut-off:	0.10%

No	Substance	Compartm	Sub-comp	Unit	HCB HTI (Rota Kiln) Destruction - Base Case	HCB Geomelt Destruction - Base Case
	Total of all compartments			DALY	1.40E-05	0.0025
	Remaining substances			DALY	1.39E-07	5.88E-06
1	Cadmium	Air		DALY	8.07E-06	0.00213
2	Arsenic	Air		DALY	2.95E-06	0.000181
3	Benzene, hexachloro-	Air		DALY	3.46E-13	0.00013
4	Arsenic	Soil		DALY	4.02E-07	2.24E-05
5	Arsenic, ion	Water		DALY	2.25E-06	2.01E-05
6	Benzo(a)pyrene	Water		DALY	1.19E-13	5.50E-06
7	Cadmium, ion	Water		DALY	1.49E-07	3.28E-06

Appendix E

HTI Rotary Kiln (Typical Configuration)



1 Feed System Tank
2 Rotary Kiln Tank
3 Secondary Combustion Chamber
4 Slag Quench Tank
5 Heat Recovery Boiler
6 Electrostatic Precipitator
5 Ash Handling System
8 Wet Scrubber
9 Heat Exchanger
10 Reheat burner
11 Catalyst
12 Induced Draft Fan
13 Emergency Water
14 Boiler Feed Water
15 Stack

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Mr. Trevor Bridle- Technical Director
Environmental Solutions International Ltd.
PO Box 116
Burswood
Western Australia 6100
Australia

11th June 2008

Dear Mr. Bridle,

We would like to thank you for providing information to Sustainable Infrastructure Australia (SIA) to assist in our review of waste treatment technologies being undertaken for the Australian Government's Department of the Environment, Water, Heritage and the Arts (DEWHA).

Although we have received quality information from Environmental Solutions International Ltd. through the stakeholder consultation process, the Department has requested that we provide Environmental Solutions International Ltd. the opportunity to review and comment on details prepared in the report to ensure that there are:

1) no significant inaccuracies or errors of fact (based on information that you may or may not have provided) in the report;

2) no other matters of concern in the document.

The document is intended to be used by the Department for briefing the Minister and possibly other government authorities within Australia and overseas. It remains possible, however, that the document may become publicly available through statutory or other processes.

If you would like to make any comments on the issues outlined above, we would appreciate if you could provide a response in confidence prior to close of business Tuesday 17th June 2008. If there is any important information you believe you need to submit and will have trouble providing this before the deadline please contact Damien Hall - Head of the Hazardous Waste Management Section on 02 6274 1411 to discuss the matter further.

Please direct all correspondence and responses to Stephen Thompson either electronically to sthompson@siaustralia.com or in paper format to Level 2, 231 Miller Street, North Sydney NSW 2060 by close of business Tuesday 17th June 2008.

With Regards,

Stephen Thompson
Director

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Gas-Phase Chemical Reduction (GPCR)

This hazardous organic waste treatment technology was developed by Doug Hallett and patented and implemented together with Eco Logic of Rockwood, Ontario, Canada. Internationally accepted and tested, GPCR has been used to treat thousands of tons of polychlorinated biphenyls (PCBs), dioxins and furans, Hexachlorobenzene (HCB), organochlorine pesticides (OCP's) and other Persistent Organic Pollutants (POPs). The process involves the gas-phase chemical reduction of organic compounds by hydrogen at temperatures of approximately 875°C. Chlorinated organic compounds are ultimately reduced to methane, hydrogen chloride, and minor amounts of low molecular weight hydrocarbons (benzene and ethylene). The hydrochloric acid is neutralized by addition of caustic soda during initial cooling of the process gas.

Four waste preparation and feed systems have been proposed to allow the treatment of a variety of waste materials including organic liquid waste streams, contaminated watery wastes, solid wastes such as soil or sediment, and gases, including product gas produced in the process. Product gas may contain products of incomplete destruction and these may be recycled through the system to ensure the final product gas meets licensed emission limits.

The mixture of gases and vaporized liquids are passed over electric heating elements situated around the central ceramic-coated steel tube of the reactor. Treated gases pass through a scrubber where water, heat, acid and carbon dioxide are removed. A caustic scrubbing agent is added to neutralize acids.

The process uses hydrogen gas under pressure and care must be taken to operate the system to ensure that explosive air-hydrogen mixtures do not form. For most of the wastes treated, the product gas generated provides much of the process fuel needs. Chlorinated organics may be converted into fuel, and the chlorine is converted into a salt solution which will require disposal to a sewer (some arsenic may also be expected in the scrubber water). Desorbed solid waste can be disposed of to a landfill if other waste constituents such as heavy metals are at acceptable levels.

Proven Nature of Technology

The GPCR process is a proven technology. In mid-1995, a GPCR plant (Eco Logic) was commissioned in Kwinana, Western Australia. The majority of waste treatment activities using GPCR occurred at this plant, which began commissioning operations in 1995 and achieved commercial throughputs by 1998. The plant was closed in December 2000 due to declining waste availability in Australia. In total, the plant treated in excess of 2,000 tonnes of waste including PCBs, pesticides and other POP's, with up to 1,500 tonnes having been treated in the last two years of operation.

Another large-scale operation was conducted at General Motors of Canada Limited (GMCL) in St. Catharines, Ontario. This demonstration project, which began in February 1996 and concluded in September 1997, saw the destruction of approximately 1,000 tonnes of PCB-contaminated electrical equipment (transformers, capacitors, ballasts), concrete, oil, soil and miscellaneous other solids and liquids.

There are currently three GPCR plants in existence worldwide. A demonstration-scale plant is currently housed at Eco Logic's head office in Rockwood, Ontario, Canada, where it is being used for treatability testing and engineering development. This unit had been previously housed at a US Army facility where it underwent extensive testing for chemical munitions treatment. A second demonstration-scale plant is located in Japan, where it has been used for regulatory testing for PCB and dioxin waste treatment. Eco Logic's Japanese partners have recently completed construction of a semi-mobile GPCR plant, which will be used for commercial treatment of PCB wastes throughout Japan.

This technology has been accepted as environmentally sound under the Basel Convention's General Technical Guidelines for destroying Persistent Organic Pollutants.

Scale and Time to Treat Stockpile

Eco Logic facilities to date have processed waste stream with low to medium organo-chlorine contamination levels and this is the continuing projected market for the technology. The Orica HCB waste stockpile has highly concentrated high chlorine content and is a high organic content material.

Plant capacity or size can perhaps best be visualized in terms of the process hydrogen requirement. Hydrogen is consumed not only in the formation of hydrogen chloride but in the addition of 4 atoms of hydrogen to every atom of carbon to produce methane. For a plant processing 10 tonnes per day of the Orica HCB waste stockpile, this amounts to approximately 1.1 tonnes per day of hydrogen. An electrolytic hydrogen plant with this capacity consumes about 2.75MW of electricity, or 66,000 kWh of power per day.

This is a large plant. Present Eco Logic operating facilities have hydrogen consumption 300 times smaller so we are looking at a scale-up of about 300% to achieve a practicable treatment rate of 10 tonnes per day, requiring approximately 5 years to process the Orica HCB waste stockpile. This size of plant may be feasible, probably in multiple units, but there is certainly no such plant in existence.

Pre Treatment and Front End Waste Handling

The Eco Logic process was established with a hydrogen vaporization front end. Trials with Orica's HCB waste stockpile were disappointing and not all of the Chlorinated Hydrocarbons (CHC's) were volatilized. The residual material in the drums had transformed during the soaking process into a hard, not volatile char-like substance that would require a further treatment step. There were many other practical issues related to the use of hydrogen.

A cost effective hydrogen source would need to be identified to make front end treatment feasible and the hydrogen plant constructed nearby. The pretreatment process would need to produce a uniform vapor gas stream of CHC's in hydrogen gas (from a waste that is a mix of polymerized materials, tars, and water-based sludge's), all of which would make pre-treatment of the Orica HCB waste stockpile a very complex process without any certainty that no difficult-to-manage residues would remain.

Safety aspects and the environmental risks associated with heating a large container of explosive and toxic materials at high concentrations in the solid, liquid and gaseous states results in a complex and difficult development design that is likely to encounter significant issues with the permitting process.

The presence of water and other oxygen containing compounds would demand another stage of treatment to prepare the gaseous stream for the subsequent dechlorination step, assuming it would not be practicable or acceptable to pre-dry the waste.

The dechlorination process has so far been applied only to wastes with low concentrations of organo-chlorine contaminants and the vaporizing processes used to date would not be applicable to the Orica HCB waste stockpile. Puncturing drums and distributing waste so that vaporization can proceed at a satisfactory pace and without pyrolysis and charring by overheating are aspects yet to be addressed.

From experience, this whole development process would take considerable resources and time, at least 3 years of development work and many uncertain years for the permitting process.

Process Capability to Treat HCB

The technology is not suitable in its present state for treating HCB waste, primarily due to the wide range of melting and boiling points of the compounds present in the waste.

With further development, however, the technology could no doubt be suited to the destruction of the HCB waste. Some preliminary testing on the Orica HCB waste stockpile produced an off-gas with dioxin content 10 times the generally acceptable level. Further processing of the off-gases would have to be considered.
A batch of some 27 drums of Orica's HCB waste stockpile was treated in a trial operation at the former Kwinana plant. The test work showed that significant levels of black tarry material were produced which would cause difficulties within the gas scrubbing system and which showed incomplete destruction of the waste.

Operational process issues which may be encountered in the application of GPCR technology to the treatment of Orica's HCB waste stockpile include:

- Problems in fully vaporizing the waste material prior to dechlorination (98% on test) thus leaving residues requiring further destruction by some other means.
- Severe corrosion potential arising from high temperatures and the presence of HCl gas, as for Geomelt process, but possibly exacerbated by the reducing conditions
- Other potential difficulties with materials of construction such as possible hydrogen – related embrittlement of metals

- Considerable development work required to scale up to the size of plant required for the Orica's HCB waste stockpile.

Emissions and Residues from the Process

The major concerns with Gas Phase Chemical Reduction (GPCR) were the demonstrated high dioxin level in stack emissions (0.85-1.59ng/m^3) compared to the 0.1 ng level required, the resulting solid residues which did not meet landfill criteria (HCB> 2mg/Kg), and the production of "black tarry material" in the scrubbing system.

Orica engaged trials for treatment of the HCB waste stockpile at the Kwinana facility and Kvaerner Engineering, who observed the trials, recommended major modifications to the plant – including additional scrubbers, column packing changes, and burner /combustion condition changes.

In addition, there were several residual streams which may be difficult to reprocess and would need further assessment and possible treatment before disposal. There are also the unresolved problems of dealing with the black tarry material formed in the dechlorination process.

The plant at Kwinana did not meet the 0.1 ng (TEQ)/m^3 limit for dioxins/furans during the HCB tests. Eco Logic questioned the accuracy of these results. Eco Logic suggested that more effective scrubbing, changes to gas reticulation rates and changes to auxiliary burner design would enable the process to meet emission criteria.

The main advantage of the Eco Logic process is the recovery of organic materials and the absence of oxygen in the process, thereby precluding, in theory, the de novo synthesis of dioxins/furans. In practice, dioxin/furans were apparently found in Eco Logic residuals and the gaseous discharge, although Eco Logic raised doubts about the results of the dioxin testing in the Kwinana trials.

Ability to Permit or License Facility

Feedback from the Western Australian Department of Environmental Protection (Kwinana Branch) has been positive with respect to the technology. They were heavily involved in the permitting process for the original plant. They would be supportive of any other application to permit another Eco Logic plant but would likely take at least 12 months.

However, it appears unlikely that a new plant would bear very much similarity to the original plant, and that there would be considerable work required to secure a permit and to license such a facility.