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REPORT TO THE MINISTRY OF ENERGY WITH RESPECT TO STUDY TOUR OF WASTE INCINERATION FACILITIES

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In order to conserve energy and resources, this paper contains post-consumer fibre.

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ACKNOWLEDGEMENTS

As the following report should make clear, I found our study tour of refuse incineration and waste disposal extremely useful and informative. The opportunity to actually visit several facilities and meet those responsible for day to day operations offered an excellent format for gathering an array of complex environmental, technical and economic information about this approach to waste management.

I would like to introduce this report then, by thanking those who organized, supported and participated in our tour. It is appropriate to begin by acknowledging and thanking our many and very gracious hosts. From Sweden, through Denmark, Germany and the United States, we were very graciously received by a great many people whose hospitality, and efforts to provide us with an instructive and well-organized tour, were truly extraordinary. It was very apparent that a great deal of thought, planning and effort had gone into providing us with an informative and intensive opportunity to learn from their respective experiences. Being a neophyte of such excursions I was extremely impressed by the generosity and goodwill that greeted us everywhere.

Secondly, I should thank Alderman Richard Gilbert, who initiated and organized our tour. My personal interest notwithstanding, Alderman Gilbert's efforts to encourage and facilitate the participation of citizen and interest groups represents an innovative approach to such a study tour. His enthusiasm to secure the participation of those who not might share his views on energy from waste incinerators is a significant commitment to <u>informed</u> discussion, and debate about the merits of such undertakings. The approach recognizes, I believe, the

significant common ground among us, being a desire to identify and pursue environmentally viable and eocnomically sound strategies for dealing with the waste management and energy issues that EFW facilities encompass.

A similar note of appreciation should be sounded for the Ministry of Energy whose financial support made the study tour and my own participation possible. As an advocate of energy from waste, the Ministry may not embrace the recommendations that follow and it is to its considerable credit that it was willing to sponsor and support the participation of those who would no doubt offer some measure of criticism of the Ministry's own EFW program.

Next, let me express my appreciation of the collegial participation of my touring companions. The trip allowed a unique opportunity to discuss and debate the pros and cons of waste incineration from our particular perspectives, free from many of the tensions and influences that can inhibit candid and openminded discussion of this controversial issue.

Finally, let me thank Mr. Crawford Kitchen, who I have not yet had the pleasure of meeting, but to whom I understand I owe a considerable debt of gratitude for a well organized and instructive tour. Thank you.

EXECUTIVE SUMMARY

ENERGY FROM WASTE

An Overview

Our study tour of refuse incineration took us to four jurisdictions that share a very substantial commitment to energy from waste. In Sweden, Germany and Denmark, approximately 50% of municipal solid waste is incinerated and it appears that this percentage will rise over the next several years. The most important factor underlying this commitment appeared to be the absence of available waste management alternatives and in particular, landfill. Several of our hosts described the confrontations that have engulfed their efforts to licence new landfill facilities which by comparison make our own controversies in this regard seem mild and low-key. The other important motivation is the desire to exploit waste incineration as a renewable energy resource, particularly for those countries without indigenous oil or natural gas reserves.

Technology

A diverse array of waste incineration technologies exist that range in size from small, modular mass-burn units for single industrial establishments, to much larger plants designed to serve entire municipalities. Waste incineration technologies also vary signficantly in character and design and include mass burn systems with movable grates, pulse hearths and rotary kilns, to entirely different principles of incineration, including pyrolysis and fluidized bed combustion. Whatever the particular technological approach however, very substantial advances have been made in recent years to ensure complete, efficient and environmentally sound methods of waste incineration. It was apparent however, that future developments will similarly yield substantial technological and performance advances many of which have been detailed in an excellent Swedish report undertaken by the Association of Waste Incineration Corporations (DRV).

The trend in favour of increasingly stringent regulatory standards based upon the performance capabilities of the most sophisticated technologies available suggest that substantial benefits may accrue to those with the opportunity of postponing the substantial investments that waste incineration technologies presently require.

Environmental Impact

The enthusiasm with which EFW facilities are being embraced in Ontario suggests a "great expectation" that this approach to waste management will resolve many of the difficult environmental problems associated with other waste disposal options while providing a "renewable" source of energy in the bargain. Present economics of EFW however make it far more costly than landfill. The presumption appears then to be that the additional cost is justified because of the environmental benefits that waste incineration offers. Unfortunately, no detailed comparison of the environmental costs and benefits associated with EFW on the one hand, and landfill on the other, appears to have been carried out.

The environmental impacts associated with EFW are far from trivial however, and there are several reasons to doubt that EFW would win an environmental comparison with landfill.

Perhaps no more persuasive description of the impacts associated with waste incineration is available than is offered in the recent and excellent report of the National Environmental Protection Board and National Energy Administration of Sweden.

> "Current emissions of pollutants into the atmosphere from waste incineration plants are far too high. This applies, in particular, to certain heavy metals such as mercury and cadmium, to such acidic substances as hydrogen chloride, and to dioxins and other organic pollutants. The emissions must therefore be reduced to levels that are acceptable from the point of view of health and the environment.
>
> The limited information available today from various sources in Sweden indicates that waste incineration may be the largest source of dioxin emissions. The emissions must therefore be reduced radically.
>
> Waste incineration is also the largest source of uncontrolled release of mercury."

The study from which these quotations are taken was initiated in 1985 as an outgrowth of a report revealing high dioxin levels in fish and mothers' milk, which were so disturbing to the Swedish government that it declared a moratorium on the construction of new waste incineration plants. A comparison of the levels of dioxin emissions from waste incineration with those from Ontario reveals that we have a problem significantly more severe than that identified by the Swedes in 1985. The swift and effective response of the Swedish government stands in sharp contrast to our own.

In addition to the emission of toxic air contaminants, waste incineration also leaves a residue of slag and fly ash that represents 25% by weight of the initial waste stream. Because these residues concentrate many of the toxins in the waste stream, special engineered landfill facilities are then required for their disposal.

The description offered by this report of the environmental imapcts associated with waste incineration is obviously annecdotal and incomplete. However it is quite apparent that significant environmental impacts are associated with EFW and that several fundamental questions remain unanswered. Any conclusion that waste incineration is preferable to landfill at this time is simply not supported on the evidence available.

Pollution Control

Technological advances that have been made during the last several years to provide more effective incineration flue gas cleaning are truly impressive. Perhaps the best assessment of the capabilities of this new generation of gas cleaning equipment is offered by the National Incineration Testing Program of Environment Canada. While the performance of sophisticated pollution abatement equipment is impressive however, it is important to note that even at the levels of efficiency observed during the NITEP program at Quebec City, levels of emissions are still significant and on occasion in excess of the new standards promulgated in Sweden. It is not surprising then that proponents of the industry in Sweden anticipate substantial developments aimed at improving the environmental performance of waste incinerators.

Operations

The point that was most often stressed by those in charge of EFW plant operations was the need for adequate personnel training. We were repeatedly told that poor operation would easily defeat the most advanced pollution abatement systems. Not only must plant managers be highly skilled but so must other plant employees to ensure a well moderated combustion process necessary to environmentally sound operations. For this reason the Swedes have recently established an operator training school specifically designed to train EFW personnel.

While the plants we visited were all equipped with several process and flue gas monitoring systems, all agreed that no tamper-proof monitoring exists. Neither of course is there any way to continuously monitor stack gases for many of the pollutants of greatest concern. While periodic sampling may be carried out for such substances as dioxins and mercury, tests are very expensive and elaborate and may provide little indication of actual day to day performance.

Another matter that was stressed by several of the plant operators with whom we met was the need to allow adequate maintenance time. This is particularly true for plants of new design, configuration or application which invariably present unanticipated problems. Representative of the industry candidly described the various and sometimes severe problems that have been encountered by proponents of EFW projects which have on occasion resulted in complete project failure.

Economics

In addition to capital and operating costs, the two additional factors that will determine profitability of EFW are the market potential for energy sales and the cost and availability of other waste management options. While we were presented with a diverse array of facts and figures associated with the economics of waste incineration, some general impressions did emerge.

On present estimates, it would cost somewhere in the vicinity of $170 million dollars to build a facility in Ontario that would burn 400,000 tons of waste each year. Together with operating costs, there is a general consensus that this would require a tipping fee in excess of $40.00 assuming energy sales in today's market. This compares with an $18.00 - $22.00 fee presently charged for tipping wastes at landfill sites operated by Metropolitan Toronto. When the costs associated with slag and fly ash disposal are factored in, energy from waste may represent an option 2 - 3 times as expensive as landfill. These additional costs may indeed be justified if environmental benefits are to be derived from this waste management approach. However with no assessment of whether this would indeed be the case, it is hard to regard present and substantial commitments, to EFW, as responsible.

Refuse Derived Fuel

RDF plants involve a variety of processes intended to remove non-combustible fractions from the waste stream, leaving a "fuel" particularly well-suited to waste incineration. The notion of taking MSW and sorting it into various components that can then be reused, recycled and even incinerated has considerable appeal. Unfortunately experience to date suggests that a great deal of the promise of resource recovery has not been realized. Compost derived from the organic fraction of the waste stream has proven too contaminated by heavy metals and plastics to be usable as an agricultural fertilizer. Markets for other materials such as glass, paper and ferrous metals are not always available and prices are invariably low. In addition RDF plants require a great deal of maintanence and pose particular problems associated with the waste shredding devices these plants employ. It seems clear that without full utilization of the waste fractions recovered, RDF plants make little sense.

RECYCLING REDUCTION AND REUSE

It is difficult to find a waste management plan, study or report that does not begin with an emphasis upon the need to reduce, recycle and reuse waste as the first priority of any waste management endeavour. Harder to find however, are the legislative initiatives, programs and other resources necessary to make the objective reality. In Germany and Sweden however, several encouraging signs were observed and in certain respects these countries have made progress from which we may learn. We also had the benefit in meeting representatives of the Green Party, who expressed a clear perception of the initiatives necessary to make the three Rs the major elements of a waste management strategy.

REGULATION

Perhaps the best way to summarize our tour in terms of the lessons it provided of the regulatory approaches to waste incineration is to reproduce the new standards being proposed by the Swedish government to regulate the pollutants of primary concern from waste incineration:

Pollutant	Standards
Dust mg/nm^3	20
HCl mg/nm^3	100
HF(F) mg/nm_3	1
SO_x(S) mg/nm^3	50 - 400
NO_x(NO_2) mg/nm^3	200 - 400
Hg mg/nm^3	0.04 - 0.08
Cd mg/nm_3	0.01 - 0.02
Pb mg/nm^3	0.1 - 0.5
TCDD ekv ng/nm^3	.1 - .2
PAH ug/nm^3	0.01 - 0.1
Clorobenzene ug/nm^3	1 - 20
Chlorofenol ug/nm^3	1 - 20

In addition to the regulation of air contaminants, detailed requirements have been promulgated to ensure the proper and separate disposal, in engineered and lined landfill sites, of the residues of the waste incineration process. A debate continues as to whether to characterize fly ash residues as hazardous waste. At least one jurisdiction in the United States, California, has adopted this regulatory position.

RECOMMENDATIONS

The comprehensive and detailed study of energy from waste recently carried out by the Swedish government was enormously useful in establishing a regulatory strategy for dealing with the problems associated with existing waste incinerators and for establishing standards for new approvals. The approach is imminently reasonable and absolutely necessary if a rational waste management strategy is to be developed and costly environmental and economic mistakes avoided. For this reason we recommend that the Ontario government undertake a study similar to the one recently completed by Sweden that would:

- Identify the environmental impacts associated with all facets of waste incineration;

- Develop a remedial program for addressing existing problems (which in Sweden is a 5 year program to retrofit existing incinerators to reduce emissions by more than 90%)

- Establish standards and criteria that will provide the rules for any new approvals that may be sought, and;

- Compare the environmental impacts associated with waste incineration with those associated with landfill waste and recycling waste management options.

INTRODUCTION

I have organized the following report to reflect the actual emphasis of the study tour itself, which was somewhat different than the one the organizers of our tour may have included. For example, it is apparent that the planners of the tour anticipated a greater opportunity to meet with local citizen groups and other non-governmental organizations than was actually realized. On the other hand, we had considerable opportunity to learn of the technical and opperational aspects of the plants we visited. In Sweden we also had a particularly informative session with a representative of the National Environmental Protection Board and were presented with the results of a recent, detailed and excellent examination of virtually all facets of the energy from waste issue. The following, then attempts to present the lessons of our tour, as it actually unfolded.

Before beginning, I should offer the following caveat however, which is that my own first hand experience with the particular approach to municipal solid waste management is limited. While I have a lay knowledge of the excellent work that is being undertaken under the NITEP program in Canada, there is clearly a great deal about waste incinceration and resource recovery plants of which I am unaware. With that in mind then, this report begins with an overview of the major impressions of the energy from waste experience that we observed in Europe and the United States.

A. ENERGY FROM WASTE

An Overview

Each of the four countries we visited share a substantial interest in and commitment to waste incineration with energy recovery. In Sweden, with a population similar to Ontario's, 25 plants incinerate 1.4 million tons of waste annually and all but two plants involve some form of heat recovery. Other plants presently being planned or built will increase the total amount of waste incinerated in Swedent to 2.5 million tons annually, or approximately 30% of the waste generated in that country. When account is taken of the portion of the waste that is non-combustible, e.g. building rubble, the percentage of waste incinerated is even higher.

In Denmark, 45 plants incinerate 70% of the waste generated. Again all facilities involve energy recovery. In Bavaria, 50% of municipal solid waste is incinerated, with the proportion for Germany as a whole being approximately 30%. The Delaware Solid Waste Authority and the City of Baltimore similarly share a very substantial commitment to waste incineration with energy recovery.

It was also soon apparent that this common commitment to waste incineration was motivated by similar factors. By far the most important of these being the difficulties associated with locating and obtaining approvals for landfill facilities. By comparison the controversies that characterize similar efforts in Ontario seem mild and low-key. In Copenhagen for example, our host at the Vestforbaending plant described that City's impending waste management crisis, apparently the result of successful efforts by surrounding communities to prevent the establishment of new landfill facilities. Apparently Copenhagen's existing landfill capacity will soon expire, and will do so, before substitutes are available. Our host also very candidly described one disturbing consequence of that impasse, being the pressure to operate the municipal incineration plant beyond its limits. Thus the Vestforbaending plant is incinerating 290,000 tons of waste annually although designed for only 240,000 tons, and intended to operate at 200,000 tons. This, according to its manager, without sufficient maintenance time.

Fortunately the waste management embroglio described in other jurisdictions were less dramatic. However it was apparent that opportunities for landfill were considerably more constrained in the jurisdictions we visited than is presently the case in Ontario.

Another important motivation underlying the commitment to waste incineration that we observed was the desire to exploit waste incineration as a renewable energy resource. This seemed particularly true in Sweden where two factors made energy from waste particularly attractive. The first is a national energy policy to reduce dramatically Sweden's dependence upon imported oil together with an absence of locally available natural gas. The second is an extensive commitment to district heating schemes that in many municipalities make the delivery of heat services as commonplace as sewer and electrical services are in Canada. While the desire to recover the latent energy in waste was lessapparent elsewhere it is clear that the era of waste incineration without such recovery is over.

Another common element of the facilities we visited, with one exception, was that all were owned by public corporations. In Sweden, Denmark and Germany those corporations are organized by and accountable to the municipalities they served. In these European countries such public enterprises commonly provide district heating services that most often depend upon other sources of fuel as well. In Delaware, the Solid Waste Management Authority is constituted by the State government. In Baltimore, the only exception, the plant we visited is owned and operated by Signal Environmental Systems Inc., the American partner of a very large Swiss firm, Von Roll.

Also by way of overview, I should note one other common characteristic of the EFW facilities we visited is that their components were manufactured by relatively few and very large corporations specializing in waste incineration technology. While we were told of a number of smaller companies involved with EFW, the market seems overwhelmingly dominated by very few and very large corporations, with the manufacturers of choice being Volund, Martin and Von Roll, for the furnace and boiler components of the waste incineration facilities. These companies are based in Denmark, Germany and Switzerland respectively. While more market diversity appears to characterize the choice of gas cleaning equipment, the Swedish firm FLAKT is particularly prominent.

One last common theme should be noted and perhaps emphasized, which is that virtually everyone we spoke with described EFW as still ascending a pronounced learning curve. Virtually all of our hosts were very candid in describing a variety of problems from malfunctioning computers to disintegrating furnace grates. The distinct impression left is one of an industry still actively grappling with the problems of burning waste efficiently, cleanly and economically.Several major aspects of the incineration process remain to be definitively resolved including such matters as fundamental as the design of secondary air ports to ensure effective incineration of toxic stack gases, and the nature and configuration of stackgas cleaning equipment. The rule of the day appears to be that considerable down time should be anticipated by those installing new facilities while adjustments, modifications and maintenance matters are attended to.

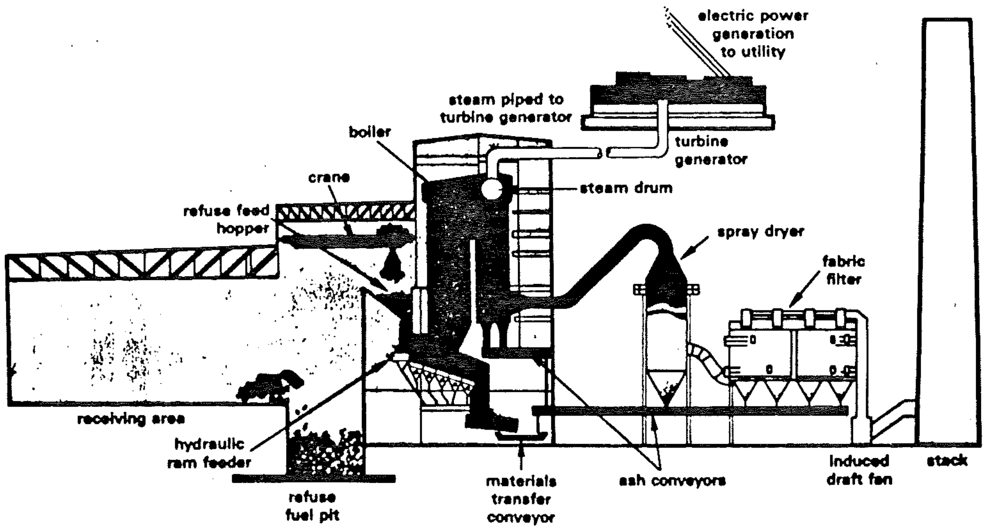
While all of the reasons for these difficulties are far from apparent, some factors surely include the variable characteristics of the waste streams from one country or region to another. Efforts to make energy recovery more efficient and projects designed to particular markets and sites may account for other variations that effect performance and reliability.

It was also very apparent that rapidly changing expectations about environmental performance are also requiring everything from adjustment to closure of EFW facilities presently operating, some commmissioned as recently as 1984. Thus in both Sweden and Germany we were told that virtually all EFW facilities in those jurisdictions would require modification in order to meet new air emission criteria.

2. TECHNOLOGY

Our tour of incineration plants in Sweden, Denmark, Germany and the United States provided several opportunities to visit and tour some of the most modern waste incineration plants in the world. It is clear however, that we observed only a limited sample of a very diverse array of waste incineration technologies that range in size from small modular mass-burn units intended to serve single industrial establishments, to much larger facilities designed to serve entire municipalities. In addition to considerable variation in size, waste incineration technologies range in character form mass-burn systems with moveable grates, pulse hearths and rotary kilns to entirely different principles of incineration including pyrolysis and fluidized bed combustion.

The prevailing technological approach appears to be a mass-burn, moveable grate system with several companies offering variations on a common theme. The following schematic diagram provided by a major EFW consortium offers a good illustration of the general configuration of such units, this one equipped with scrubber and baghouse to clean stack gases.



In recent years, a number of other technological approaches have been adopted including, as noted, fluidized bed and pyrolysis systems. For example, of the 23 incinerator plants operating in Sweden, 18 are mass burn plants and five have fluidized beds. Pyrolysis units appear to remain in the experimental phase with several pilot and demonstration plants having been built in Sweden and other countries. It may be of interest in this regard to note that the mass-burn facility we visited in Baltimore was recently built on a site originally occupied by a pyrolysis plant that never successfully operated and that was demolished to make room for the facility we visited. The experience offers one illustration of the high stakes in an area still in the development stage.

Whatever the particular technological approach, it seems clear that very substantial advances have been made in recent years in aid of ensuring complete, efficient and environmentally sound methods for waste incineration. Among these advances is a much better understanding of the variables that influence full and complete combustion of waste incineration gases. . Characteristically, certain minimum conditions of temperature

(1200 - 1300o celsius), turbulence and retention time (2 seconds) are now understood as essential for the destruction of certain problematic and toxic by-products of the incineration process. As recent NITEP work reveals however, efficient incineration is only a solution to one aspect of the problem, as some toxics, notably dioxins, appear to form in stack gases across the boiler or in the stack itself.

Equally clear is the fact that those most familiar with waste incineration expect that future developments will similarly yield substantial technological and performance advances. In a recent study conducted by DRV, the association of Swedish solid waste management corporations, the following technological developments are anticipated over the next several years.

Technological Developments

- improved fuel infeed
- more efficient regulation
  - increased speed of regulation
  - improved regulation at small and older plants
- improved air distriution in the combustion area
  - high pressure drop across the grate
  - more efficient secondary air system
- start and stop plus temporary interruptions in operation
  - tests with additional fuel such as oxygen, wood chips or oil
- monitoring of operation
  - increased availability and operational stability of instruments

Environment

- increased knowledge on how to maintain optimum operational conditions
- increased knowledge about the chemistry of mercury in the combustion process

- further developed and improved techniques for the removal of mercury
- further developed and improved techniques for the removal of hydrochloric acid
- control over the emission of organic compounds
- development of indicator parameters to reduce and simplify the costs of analytical work, which is often considerable, particularly as regards organic compounds

Given this expert estimate, it is not unreasonable to assume that the next decade will yield similar advances to those of the last seveal years. Together with greater analytical capabilities and a more sophistocated understanding of the environmental effects of waste incineration, the trend in favour of increasingly stringent regulatory standards should also continue. This should be particularly true given the popularity of establishing standards based upon the best available technology. If this analysis and recent history are to guide then, the technology of today may be obsolete before it is fully amortized. For those with little option, the risks of making substantial investments in technology that may become outmoded are simply unavoidable. Conversely those with an opportunity to delay such investments may be in a particularly advantageous position to reap the benefits of others trials and errors.

3. ENVIRONMENTAL IMPACTS

(I have in the following discussion emphasized the need to compare the environmental impacts of incineration with those of landfill. I have not made a similar argument with respect to recycling because I do not believe that anyone would seriously challenge the clear environmental advantage of recycling. In the case of recycling the debate centers on logistics and economics.)

The enthusiasm with which EFW facilities are being embraced by many in Ontario suggests a "great expectation" that this approach to waste management will resolve many of the difficult environmental problems associated with other waste disposal options while providing a "renewable" source of energy in the bargain. As will be discussed below, the present economics of EFW make it far more costly than the land-filling. The presumption appears to be then, that this additional cost is justified because of the environmental benefits that waste incineration offers.

It was for that reason that I sought out, in all of the countries we visited, any comparative analysis of the environmental costs and benefits associated with landfill on the one hand, and waste incineration, on the other. Surprisingly, no such analysis appears to have been carried out. The lack of critical evaluation in this regard is striking, and at odds with a rational approach to planning waste management programs that will minimize risks to public health, the environment and local and provincial budgets. For those jurisdictions with no opportunity to licence new landfill facilities this shortcoming may be understandable. Where alternatives exist however, one must seriously question the wisdom of making very substantial environmental and economic commitments based only upon an untested assumption that EFW is somehow preferable to landfill. To do so is to promote EFW as a panacea for a host of waste management problems that are becoming increasingly difficult to confront.

The environmental impacts associated with waste incineration are far from trivial however, and as the following discussion will suggest, there are several reasons to doubt that EFW would win an environmental comparison with landfill. For the material and analysis that follows I am greatly indebted to the excellent and detailed work carried out by the Swedish Environmental Protection Board and under Environment Canada's NITEP program.

Air Emissions

> "Current emissions of pollutants into the atmosphere from waste incineration plants are far too high. This applies, in particular, to certain heavy metals such as mercury and cadmium, to such acidic substances as hydrogen chloride, and to dioxins and other organic pollutants. The emissions must therefore be reduced to levels that are acceptable from the point of view of health and the environment.
>
> The limited information available today from various sources in Sweden indicates that waste incineration may be the largest source of dioxin emissions. The emissions must therefore be reduced radically.
>
> Waste incineration is also the largest source of uncontrolled release of mercury."

These quotations are reproduced from the excellent and detailed report "Energy From Waste", a study conducted by the national Environmental Protection Board and National Energy Administration of Sweden. The study, which was initiated in 1985, was an outgrowth of reports revealing high dioxin in fish and mothers' milk which were so disturbing that the Swedish government declared a moratorium on the construction of new waste incineration plants. The many similarities between Sweden and Ontario make much of this Swedish analysis of particular interest in this province.

The data collected by the Swedes is revealing of the relative seriousness of the problem of the air pollutants associated with waste incineration. Tables 1 and 2 that follow are reproduced from a summary of this Swedish report and the data reproduced here immediately reveals the basis for their ranking of dioxin and mercury as the two most problematic emissions from waste incineration.

TABLE 1

Emission of metals into the atmosphere in Sweden

Total emission 1977/78 Substance	Tons	*Largest single emission 1977/78* Source	Tons	*Waste incineration plants 1985* Tons	% of total emission
Arsenic (As)	130	Metalworks	75	0.3	0.2
Cadmium (Cd)	12	Metalworks	6	0.4	3
Chromium (Cr)	160	Iron and steelworks	160	0.2	0.1
Copper (Cu)	280	Metalworks	200	1.7	1
Nickel (Ni)	180	Oil firing	140	0.02	.
Lead (Pb)	1 600	Traffic	1 140	25	1.5
Vanadium (V)	460	Oil firing	460	-	-
Zinc (Zn)	1 200	Iron and steelworks	530	54	4.5
Mercury (Hg)	6	Waste incineration	1	3.3	55

TABLE 2

Emission of dioxines with flue gases from various sources

Source	Estimated annual emission in g/oz.	
	g.	oz
Refuse incineration (1.4 million tons of waste)	90	[illegible]
Forestry industry	2	0.08
Iron and steel industry	50	2
Aluminium smelting plants	5-10	0.2 - 0.4
Cable combustion	2-10	0.1 - 0.4
Coalfired power stations	1	0.04
Vehicles	10-150	0.4 - 5
Hazardous waste	1-2	0.04 - 0.08
Hospital furnaces	30	1

It is important at this point to place these Swedish figures for dioxin emissions in a Canadian context. The comparison is a disturbing one.

In September, 1985, the Ministry of the Environment for Ontario released a report on dioxins titled "Scientific Criteria Document for Standard Development No. 4-84". The report, which deals at great length with dioxins and furans, includes the following figures for dioxin emissions in Ontario from waste and sewage sludge incinerators.

TOTAL PCDD AND PCDF EMISSIONS FOR ONTARIO

Swaru, Commissioners Street and Ashbridges Bay	22,000 grams/yr
1200 Apartment Building Incinerators in Metro	?
Other Sewage/Sludge Incinerators Operating in Ontario	?
Estimated Total	28,000 - 32,000

Please note that in Table 2 the level of dioxin emissions from waste incineration in Sweden, that prompted the moratorium on new approvals, was 90 grams (2 3 7 8 TCDD equivalent) a year. Canadian figures are unfortunately not expressed in like units but rather represent total PCDD and PCDF emissions. Expressing the Ontario figures in Swedish units is somewhat imprecise, but Pollution Probe estimates that anywhere from 10 - 40% of total dioxins and furans represents a 2 3 7 8 equivalent depending on the particular characteristics of emissions in any particular stack sample.

Taking 10%, the more conservative of these values, emissions from waste and sewage sludge incineration in Ontario would represent between 2,800 - 3,200 grams of 2 3 7 8 TCDD equivalent per year. The number is of course over 30 times higher than the emissions that prompted aggressive regulatory action in Sweden.

Since the figures reproduced in the Ministry's report were gathered, efforts have been made to address the most serious of the pollution sources, being the Swaru incinerator located in Hamilton, Ontario. However the remaining two major point source contributors remain unmodified. The report from which these emission figures were taken also concludes that combustion sources are the major contributing source of dioxin to the environment and that exposure to ambient air in the vicinity of waste incineration is the major route of human exposure.

Given the existence of a problem in Ontario that seems far more severe than that identified by the Swedes in 1985, the swift and effective response of the Swedish government stands in sharp contrast to our own:

- The Swedes were so concerned about the waste incineration pollution problem that they declared a moratorium on new approvals. We have not.

- After careful assessment, the Swedes announced a five-year program to modify <u>all</u> incinerators to reduce emissions by approximately 90%. We have not even studied the problem and many of our most serious waste emission problems remain ignored.

- Realizing that even advance gas cleaning could not satisfactorily address all of the air pollution problems associated with waste incineration, the Swedes instituted an ambitious program to clean the waste stream before incineration.

In addition to dioxin the Swedes have also identified hydrogen chloride, mercury and cadmium as particularly problematic pollutants emitted by waste incinerators. With respect to mercury, the problem is particularly difficult as stack gas cleaning equipment has proven less than effective for thoroughly removing this heavy metal from flue gases. For that reason a battery reclamation project in aid of substantially decreasing the level of mercury emissions that would otherwise be associated with waste incineration.

Finally on the subject of air emissions, a point that was noted by a representative of the Ogden Martin Company, which is that, unlike landfill impacts, where the community exposed to potential pollution is limited, air pollution effects us all. For persistent organics and heavy metals, human exposure may occur through several media, including fish and wildlife that may bioconcentrate the toxins, and may not occur until months and even years after the initial release. Once a substance does escape from the incinerator stack, containment is no longer an option.

Slag and Fly Ash Disposal

Slag and fly ash represent the solid residues of the waste incineration process. Where a wet scrubbing system is used liquid effluents must also be dealt with. Combined slag and fly ash represents by volume, 10% of the original waste. By weight these residues represent 25% of the initial waste stream.

While further work needs to be done in this area, the NITEP results from Prince Edward Island and Quebec City strongly suggest that many of the contaminants in the original waste are simply concentrated in the slag and fly ash. This is particularly true for heavy metals. As of this writing the results of the NITEP investigation of the leachablity of the toxins remaining in the slag and fly ash remain unreleased. The Swedish Environmental Hearing Board's report however, indicates that at least for mercury and copper leaching rates may be fifty to one hundred times greater than for those same substances in the initial waste stream. Apparently the process of incineration itself transforms these substances in a manner that makes them more soluble.

In addition to heavy metals, NITEP analyses also reveal the presence in fly ash of several contaminants in much greater quantities than they were present in the waste stream, notably dioxins, furans, PAH's and other chlorinated organics. For this reason it may be that fly ash should be characterized as a hazardous waste and dealth with accordingly. The issue is presently being debated in the U.S. with at least one state, California, classifying ash as a hazardous waste. In Sweden, mixing fly ash and slag is not allowed and each is disposed of separately in landfill sites specifically engineered to these particular wastes. In addition, household and slag are also segregated. While we observed a much more lax attitude to these residues in Denmark, this apparent lack of concern was anomolous and out of step with the other jurisdictions we visited.

It was not possible for us to get a very accurate picture of the extend or character of other environmental impacts associated with waste incineration such as noise, odour and nuisance effects. Virtually all of the facilities we visited attempted to keep the tipping bays or floors under negative air pressure to contain odours. However the sub-zero temperatures and the lack of any opportunity to meet with local residents presented no opportunity to assess the efficacy of such measures.

With respect to noise, no particular problems were noted with the exception of the waste incineration plant associated with the Delaware Solid Waste Authority and Recovery Facility near Philadelphia. Apparently the plant was in the process of being commissioned and was venting steam. The noise was truly deafening even at some distance from the plant and one must wonder about the impacts of such incidents, even if of limited duration, where the plant is located in or near an urban environment.

Neither was information available with respect to other nuisance impacts. However, traffic might reasonably be of concern given the size of some of the facilities being contemplated in Ontario and the need to remove slag and fly ash to landfill sites which may actually increase the number of truck visits associated with the disposal of any given quantity of waste.

This description of the environmental impacts associated with waste incineration is obviously annecdotal and incomplete. However it is quite apparent that significant environmental impacts are associated with this particular approach to waste management. Several fundamental questions remain unanswered and any conclusion that incineration is preferable to landfill is simply not supported on the evidence available.

4. POLLUTION CONTROL

The technological advances that have been made during the last several years to provide more effective incineration flue gas cleaning are truly impressive. Perhaps the best and most thorough assessment of the capability of this new generation of gas cleaning equipment is offered by the NITEP report of the Flakt pilot plant in Quebec City. Those particular tests calculated the removal efficiencies of this technology for a variety of pollutants. With the notable exception of mercury, these efficiencies were consistently in the high 90's. The Flakt system provides a combination of scrubber and baghouse and offers a dramatic advance over the electrostatic precipitators (ESPs) which have conventionally been used as the only pollution abatement equipment for many municipal incinerators. ESPs unfortunately perform poorly with respect to acid gases, fine particulates and certain metals and would fall considerably short of the emission standards established in Sweden and Germany.

The incinerator plant we visited in Malmo, Sweden apparently was the first to utilize this particular pollution abatement technology in 1981. Since that time, gas scrubbers with baghouses appear to be the rule in the European countries we visited. One exception is the plant we visited in Uppsala, Sweden which uses an entirely different and innovative gas cleaning system that was devised to combine gas cleaning and heat recovery in such a manner as to make the very process of pollution abatement pay for itself. In Germany and Denmark the plants we visited were fitted with gas cleaning systems of or similar to the Flakt design. In Bavaria, the province of Germany that we visited, we were advised that a major retrofit program was underway, driven by emission standards that are consistent with the performance capabilities of these new gas cleaning systems. We observed one example of the impact of these new requirements at the incineration plant serving Munich, Apparently half of which been closed in 1985 in order to meet new standards.

The other dimension of pollution control and abatement necessary for environmentally sound waste incineration are the engineered landfill sites for slag and fly ash disposal respectively. While some description was offered of these landfill sites, equipped with liners and leachate collection systems, we had little opportunity to learn very much about the handling or disposal of waste incineration by-products.

While the performance of sophistocated pollution abatement equipment is impressive, it is important to note that even at the levels of efficiency observed during the NITEP program at Quebec City, levels of emissions are still significant and on occasion in excess of the new Swedish standards. Even at levels of removal efficiency in excess of 99%, 10s and even 100s of grams of PCDDs and PCDFs are emitted to the environment from the waste incineration process. While only a smaller portion of these quantities would be the particularly toxic forms of these substances, it is important to note that at current acceptable daily intake levels of 600 picograms per adult per day, one gram of 2 3 7 8 equivalent dioxin represents the acceptable daily intake for 1.6 billion people.

It is not surprising then that the DRV, when commenting on the performance of these new pollution abatement systems, identified the need for "important and necessary development projects, aiming at improvement in environment and technology (which would) include:

- Improved retention of mercury
- Control of the release of organic compounds such as dioxins
- Improve measurement and control techniques
- Improve start and stop operation
- Flue gas condensation etc."

5. OPERATIONS

Operator Training

The point that was most often stressed by those in charge of EFW plant operations was the need for adequate personnel training. We were repeatedly told that poor operation would easily defeat the most advanced pollution abatement systems. Not only must plant managers be highly skilled but so must other plant employees, and in particular the crane operators, who must ensure a well mixed and steady supply of refuse to the furnaces.

Apparently a refuse supply that varies significantly in BTU content or moisture can make the task of maintaining well moderated and adequate combustion conditions very difficult. Fluctuations in operating temperatures have very dramatic effects upon the efficiency of the combustion process and the generation of toxic by-products. For that reason great care has to be exercised in starting up and cooling down the furnace with operating licences often specifying the particular process conditions that must be achieved before waste is actually introduced.

The demanding requirements of plant operation have apparently prompted the DRV to characterize the need for special training of plant personnel as an "urgent question". Again the Swedes appear to be leading the way in this regard having recently established an operator training school that the managers of both the Stockholm and Malmo plants highly recommended.

Even with properly trained operators, other factors can obviously interfere with proper plant operation, among them being pressures to serve priorities other than environmental performance. A graphic illustration of this was provided by the manager of the Forbraending plant in Copenhagen, where the absence of alternative waste disposal operations had lead to a situation where the plant was being operated substantially above design capacity and without adequate downtime for maintenance.

Monitoring

All of the plants we visited in Europe were owned and operated by public authorities accountable to municipalities and their constituencies. For private companies, who may be tempted to cut corners to meet contractual commitments or to optimize profits, no such mechanism of accountability exists.

While the plants we visited were all equipped with several "real time" process and flue gas monitors, all of our hosts agreed that no tamper-proof monitoring system exists. Neither of course is there any way to continuously monitor stack gases for many of the pollutants of greatest concern. While periodic sampling may be carried out for such substances as dioxins and mercury, tests are very expensive and elaborate and may provide little indication of the actual day to day performance of the particular facility. Neither is it practical to have an environmental policeman on duty at all times to ensure proper operation.

At the end of day, the only real safeguard of public health and the environment rests with the integrity and competence of plant personnel, managers and owners.

Availability

Waste incinerators and their associated pollution control systems need continual and substantial maintenance. One illustration is offered by the maintenance schedule for the Baltimore incinerator, which requires for each of its boilers, a 21 day period each year for major overhauls and repairs. In addition 2 or 3 days are scheduled every 8 weeks for inspection and minor modification or repair. Unscheduled interruptions can also occur because of equipment failure and the measure of the fraction of the planned operational time which waste is actually being supplied to the furnace is known as the unit's "availability". A survey by the DRV of Swedish plants found levels of operational availability between 76 and 99 percent.

As explained by a Signal-Von Roll's representative, new plant design, configurations or applications will invariably present new and often unanticipated problems. These may be as severe as complete plant failure, as was the case for that company's predecessor on the site of its Baltimore facility, to destruction of the plant's sub-structure, as happened with one of Signal's plants recently constructed in the United States.

Providing sufficient downtime for maintenance and repair and allowing for unanticipated interruptions appears essential to responsible plant management. Also clear is the need for the substantial financial resources necessary to whether the storm of these additional costs.

6. ECONOMICS

We were presented with a very diverse array of facts and figures associated with the economics of waste incineration. In addition to capital and operating costs the two major factors that will determine profitability of EFW are the market potential for energy sales and the cost and availability of other waste management options. Transposing from Uppsala, Sweden to Metro Toronto may provide little indication of the economic viability of EFW in our context. Some facts did emerge however and provide a general outline of the potential economics of waste incineration in Ontario.

In Germany the Martin Company together with its Canadian and American partners provided an estimate of the cost for Toronto's planned 400,000 tonnes per year refuse fired steam plant, of $170 million Canadian. The general consensus appears to be that together with operating costs, this would require a tipping fee in excess of $40, assuming energy sales in today's market. Von Roll's American partner indicated that tipping fees for such a facility would probably be in the range of $40 - 60 were it to build and operate such a plant for the City of Toronto. This compares with an $18 - 22 fee presently charged for tipping wastes into the landfill sites operated by Metro.

It may be interesting to note that at these cost projections, a capital investment of approximately $1 billion would be necessary to build the facilities capable of incinerating 75% of the 3.1 million of waste generated annually in the Metropolitan Toronto area. In addition, the landfill facilities would be necessary for non-combustible portions that could not be recycled. Special landfill sites (if the Swedish example is to be followed) would also be needed to dispose of the 600,000 tons of slag and fly ash that would remain after incineration.

If these costs are then added to those associated with the EFW facility itself, energy from waste may represent an option 2 - 3 times as expensive as landfill. These additional costs may indeed be justified if environmental benefits are to be derived from this waste management approach. With entirely no assessment of whether this would indeed be the case, it is hard to regard the substantial economic commitments that are presently being made, as responsible.

7. REFUSE DERIVED FUEL

Refuse derived fuel (RDF) is the product of a variety of processes intended to remove non-combustible fractions from the waste stream leaving a "fuel" particularly well-suited to waste incineration. In addition to providing a more combustible waste, RDF also offers the promise of removing from the waste stream various fractions that can be recycled or reused. For that reason RDF plants are often described as resource recovery facilities.

Our tour included visits to two such plants, the PLM Sellsbergs' Kovik plant, near Stockholm, and the Delaware Solid Waste Management Authorities Plant, near Philadelphia. Both are designed to remove metals, glass and organic waste from the unsorted municipal solid waste stream. Of the two, the Delaware plant is the much larger and processes 1000 tons of waste per day.

The notion of taking unsorted MSW and separating it into various components that can then be reused, recycled and even incinerated has considerable appeal. Those who promote these facilities also claim that RDF provides a fuel that obviates the need for sophistocated gas cleaning. Emission test results that would substantiate the latter claim have yet to be provided.

For these reasons, considerable interest has been shown in this particular approach to waste management and indeed in Sweden some 15 plants were built around 1980. An interesting assessment of the Swedish experience in this regard is a major part of the DRV report to which I have referred.

Unfortunately experience to date suggests that a great deal of the promise of resource recovery has not been realized. To begin with, compost derived from the substantial proportion of organic waste recovered has proven too contaminated by heavy metals and plastics to be usable as an agricultural fertilizer and is instead being landfilled. Secondly, markets for other materials, such as paper, glass and ferrous metals are not always available and the revenues from sales are very modest. Thirdly, RDF plants require a great deal of maintenance and repair and pose some very particular problems, among them, the explosions that from time to time occur in the waste shredding devices that are a necessary precondition for separation. Finally, RDF plants are expensive and may offer little, if any advantage, unless recovered fractions are fully utilized.

B. RECYCLING, REDUCTION AND REUSE

It is difficult to find a waste management plan, study or report that does not begin with an emphasis upon the need to reduce, recycle and reuse waste as the first priority of any waste management endeavour. Harder to find however, are the legislative initiatives, programs and other resources necessary to make the objective reality. In Germany and Sweden however, several encouraging signs were observed and in certain respects these countries have made progress from which we may learn. We also had the benefit in meeting representatives of the Green Party, who expressed a clear perception of the initiatives necessary to make the three Rs the major elements of a waste management strategy.

Unfortunately our tour provided only indirect evidence of the efforts being made in this area and we had little opportunity to meet with those with immediate responsiblity for the more innovative and aggressive three R programs underway in the countries we visited. In this regard, I would recommend Thomas Rhan's report with respect to this issue. As Pollution Probe's representative on our tour, Mr. Rhan made special efforts to seek out such programs and lengthened his stay in Germany to visit various recycling projects that were not on our itinerary. The following comments then, offer a synopsis of the major impressions that our tour offered of this dimension of waste management.

In both Sweden and Germany we learned of the legislation that encourages and in some instances mandates recycling of certain products. Again the most detail was available of Swedish initiatives. In that country statutory requirements exist for recycling paper, glass and metal waste. Swedish law also mandates recycling of 75% of aluminium cans on the market. A new regulation will require the separation and recycling of used batteries. Other initiatives apply to producers of dangerous substances.

The Swedish government puts as its first priority the recovery of waste and waste products and recognizes the need to make substantial progress. Efforts to date have met with significant success as is illustrated by the fact that: 70 - 80% of all reduceable paper is collected for recycling; 75% of small batteries are now being recovered, and; in several municipalities 15% of the entire municipal waste stream is being recycled. Several municipalities also have established curbside separation programs.

Bavarian initiatives to recycle waste were described by a representative of that State's Environmental Protection Agency, who enthusiastically described the success of pilot programs that have resulted in 20 - 25% of the domestic waste stream being recycled. In addition, financial support for such initiatives appears to be quite significant and is in the order of $50 million Canadian in Bavaria, a state with a population of 10 million people.

In Germany we also had the opportunity of meeting with representatives of the Green Party, who expressed determined support for a variety of initiatives intended, in the first instance, to reduce the quantities of waste being generated by society, and in the second, to recycle and reuse those fractions that remained. The Greens support a variety of legislation initiatives that would address various facets of the problem including the proliferation of packaging, the lack of markets for certain recovered materials and the need to prohibit the use of non-refillable bottles and plastic containers. The Greens were also sharply critical of EFW facilities and regard waste incineration as inimicable to effective three R programs for 2 major reasons.

The first is the argument that when those materials that can be recovered from the waste stream are removed from it, the remainder is not particularly combustible. Thus EFW facilities and recyclers would compete for high BTU content waste such as papers and plastic. The second and related point is that the EFW industry is a large and well organized lobby and represents a significant interest group opposed to efforts that may remove from the waste stream substances that make incineration profitable.

From representatives of the EFW industry however, we heard that the industry welcomes initiatives to recycle wastes, notably glass and metals. The first acts as an abrasive that wears incineration technology, the latter is obviously not combustible. However it is difficult not to credit the potential competition for the highly combustible elements of municipal solid waste.

It is very difficult to forsee a waste management future that does not make very substantial progress to reduce, reuse and recycle large percentages of the waste stream well in excess of the 20 or 25% presently discussed by recycling's most committed advocates. The imperatives for such progress are simply impossible to ignore forever and we are increasingly being confronted by the enormous costs of poor and incomplete utilization of natural resources, on the one hand, and the increasingly apparent impacts of waste disposal on the other. It would be an enormous error to make major commitments to waste incineration if those commitments may impede efforts to get on with the inevitable task ahead of us. Again the need to fully assess the implications of waste incineration before such commitments are made, is underscored.

C. REGULATION

While our tour provided several insights into the regulatory approaches to waste incineration that have been developed in the countries we visited, it of course did not provide an opportunity for detailed assessment. The information we acquired however, did make it clear that there is a great difference in the degree of regulatory sophistocation among the countries we visited. Once again, the Swedes are leading the way.

What little was available in the way of information about the licencing procedures for new project approvals did reveal a marked similarity with the regulatory process in Ontario. Notably, public hearings appear to be an essential component of the approvals process in all of the countries we visited. In addition, given the very substantial and obviously mandatory retrofit programs underway in both Germany and Sweden, there are apparently effective mechanisms for modifying and amending the regulatory requirements that may have been engendered in any project approval as technological advances and environmental impacts are further identified.

Air Emissions

It may be appropriate to begin here by reproducing the standards that have been developed in Sweden in consequence of the EFW study that I have referred to so often above. These standards are essentially technology based and have been specifically devised to address the pollutants emitted by waste incinerators.

No other jurisdiction has gotten nearly this far in terms of its regulatory agenda and it is likely that Sweden's progress will have a very significant influence upon those presently in the process of developing their own regulatory standards and approaches.

TABLE 3

ASSESSMENT OF EMISSION LEVELS FROM EXISTING WASTE INCINERATION PLANTS BEFORE AND AFTER IMPLEMENTATION OF MEASURES

Pollutant	Current Situation	After Measures
Dust mg/nm^3	1 - 100	20
HCl mg/nm^3	500 - 1000	100
HF(F) mg/nm_3	5 - 10	1
SO_x(S) mg/nm^3	100 - 400	50 - 400
$NO_x(NO_2)$ mg/nm^3	200 - 400	200 - 400
Hg mg/nm^3	0.3 - 0.4	0.04 - 0.08
Cd mg/nm_3	0.05 - 0.1	0.01 - 0.02
Pb mg/nm^3	0.5 - 3	0.1 - 0.5
TCDD ekv ng/nm^3	5 - 100	.1 - .2
PAH ug/nm^3	1 - 100	0.01 - 0.1
Clorobenzene ug/nm^3	1 - 100	1 - 20
Chlorofenol ug/nm^3	1 - 100	1 - 20

The range of values for several pollutants may reflect the difference between requirements for new facilities as opposed to existing ones. On other occasions the precise standard has yet to be determined. Thus Swedish environmental agencies are recommending a .1 ng/nm^3 for TCDD equivalents whereas the Association of EFW Corporations is advocating a standard of .5. The Table is also interesting because of the data provided with respect to the performance of existing facilities.

A comparison with Ontario standards reveals three significant differences. The first is the fact that stack gas concentrations are adopted as opposed to point of impingement standards. Among the benefits of the Swedish approach are ease of measurement and enforcement. The point of impingement approach is also of questionable value for pollutants that are persistent, stable and pose significant public health threats, but not primarily because they are inhaled from the air near specific point sources.

The second difference between the Swedish and Ontario approach is that Swedish standards address certain pollutants for which there are presently no standards in Ontario including PAHs, Chlorophenols and Dioxins. Thirdly, the Swedish limits impose in some instances more stringent standards than exist under Reg. 308 of the Environmental Protection Act. While it is difficult to transpose between the two, it is clear that in a variety of circumstances the Swedish standards are far more stringent than present regulatory requirements in Ontario.

Operations

During the course of our tour, requests were made for the terms and conditions of licences issued to incinerator operators. Once such licence has subsequently been provided but has yet to be translated. A consideration of the requirements of the licences issued, in jurisdictions with considerably more experience than we have with waste incineration, may be very helpful in writing project approvals in this province.

I earlier noted one common condition of approvals which requires minimum conditions of temperature to be achieved in the furnace before waste is introduced. Other conditions of operations that have been highlighted by the DRV include:

- i) Specific requirements placing maximum percentages by weight of the waste remaining unburnt in the slag;
- ii) Similar requirements with respect to unburnt material in the fly ash;
- iii) Minimum temperatures for combustion;
- iv) Maximum concentration for carbon monoxide in the stack gases;

CONCLUSION

As the preceding discussion should indicate, the issues that arise when one considers EFW are varied and complex. It is clear however, that the economics and environmental implications of this approach to waste management are very significant. I would hope that my colleagues on tour might all agree that we should carefully and thoroughly assess all of the options available for dealing with the ever growing quantities of waste generated in our society before substantial commitments are made to waste incineration.

Such an assessment may well demonstrate that waste incineration does have a role to play in particular waste management plans. To come to that conclusion however, based primarily upon untested assumptions, is a recipe for disaster that will in all probability make the whole issue of waste incineration much more controversial and problematic than it need be.

Let me then conclude by reiterating the comment that I introduced this report with and that is on various sides of this issue, of the common objective that we all share to identify rational solutions to our waste management problems that will protect our health, the environment, and provide a wise use of public funds.

KEY DATA

Household waste

Approximately 300 kg per person and year. Quantity currently fairly constant.

Contents as percentage by weight:

Paper	35%
Organic waste	25%
Plastics	8%
Glass	6%
Metals	3%
Textiles	2%
Other, non-combustible	11%
Other, combustible	10%

Industrial waste

Composition and volume vary from place to place. Influenced by business structure and economic situation. The waste referred to in this text is nonenvironmentally hazardous industrial waste. Hazardous waste is treated separately by, for example, SAKAB in Kvarntorp.

TABLE 1

Emission of metals into the atmosphere in Sweden

Total emission 1977/78		*Largest single emission 1977/78*		*Waste incineration plants 1985*	
Substance	Tons	Source	Tons	Tons	% of total emission
Arsenic (As)	130	Metalworks	75	0.3	0.2
Cadmium (Cd)	12	Metalworks	6	0.4	3
Chromium (Cr)	160	Iron and steelworks	160	0.2	0.1
Copper (Cu)	280	Metalworks	200	1.7	1
Nickel (Ni)	180	Oil firing	140	0.02	-
Lead (Pb)	1 600	Traffic	1 140	25	1.5
Vanadium (V)	460	Oil firing	460	-	-
Zinc (Zn)	1 200	Iron and steelworks	530	54	4.5
Mercury (Hg)	6	Waste incineration	1	3.3	55

TABLE 2

Emission of dioxines with flue gases from various sources

Source	Estimated annual emission in g*/oz.	
	g.	oz
Refuse incineration (1.4 million tons of waste)	90	3
Forestry industry	2	0.08
Iron and steel industry	50	2
Aluminium smelting plants	5-10	0.2 - 0.4
Cable combustion	2-10	0.1 - 0.4
Coalfired power stations	1	0.04
Vehicles	10-150	0.4 - 5
Hazardous waste	1-2	0.04 - 0.08
Hospital furnaces	30	1

* *based on earlier readings. Later studies indicate, however, that the real values for current emissions may be 2-3 times higher.*

B

KEY DATA

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