Annex 3: Guideline for the case research on the Directives for Domestic Waste Incinerators

Second draft, Kris Lulofs, February, 9th 1999

Summary

To keep the workload within limits choices are made. The viscosity and also the challenge of the research on the implementation of the MWID’s is found in the multiplicity of the regulated substances and the multiple technology options for abatement. An abatement line is mostly composed of two or more steps. Most steps abate more than one substance. The distinguishable steps are interrelated and there are path-dependencies.

The clarification the national regulated substances:

In paragraph 1, besides an overview of differentiation patterns in the MWID, three templates are given to gather data on:

1 stricter and additional national regulation that is linked to the MWID’s;

2 stricter and additional national regulation that is not linked to the MWID’s but is relevant for the disentanglement problem;

3 efforts put into monitoring and enforcement.

The selection of pollutants, time series and research population

In order to raise the understanding of the relations between pollutants to be abated, the strictness of emission limits and the technological options, paragraph 2 gives bench-marks for strictness of regulation, being followed by an assessment of technology that can be used for the transformation process of incinerators. It ends with a template of primary and secondary technological options on which national veriﬁcation is required because it is used for the assessment of allocative efficiency. Paragraph 3 is about the choice of pollutants for which data have to be gathered, a template about time-series and the research population. A choice has been made to select only “existing” incinerators as they are defined in the MWID’s. The research population has to be at least five or more “existing” incinerators with a capacity of more than 6 tons/hour and at least five “existing” incinerators with a ca-
capacity of less than 6 tons/hour. Time series have to be gathered for the years 1985 and 1990 and 1997 (in some cases 1997 can be replaced by an earlier year, according to the year of adjusting of the incinerator and/or the date set in the national legislation). The pollutants for time series are minimal Dust and CO for existing incinerators with a capacity of less than 6 tons and Dust, CO, HCL, SO$_2$, and Cd+Hg (and if possible also HF, Pb+Cr+Cu+Mn and Ni+As) for existing incinerators with a capacity of more than 6 tons.

The assessment of Environmental Effectiveness

For the pollutants mentioned above, environmental effectiveness is straightforward calculated on the basis of two indicators: $Y = Y^1/Y^*_{EU} \times 100$ and $\Delta Y = (Y^0 - Y^1)/Y^0 \times 100$ ($\Delta =$ delta).

Also some information on the incineration sector as a whole is required.

The assessment of Allocative Efficiency

The differentiation pattern in use is straightforward measured with the indicator $\Delta Y = (Y^0 - Y^1)/Y^0 \times 100$ ($\Delta =$ delta). The cost-characteristics of individual sources is more complicated. The number, capacity and age of closed incinerators are indicators (of course: only if closed because of the emission limits). The direct indicator cost/tons is not used, in paragraph 5 is explained why. As indirect indicators the plant size (capacity), the plant age and the pre-existing level of pollution are used. Next to these indicators a template on the technology-grid is used to have an inventory of pre-existing and installed abatement measures (be it primary or secondary).

The assessment of Allocative assessment

For reasons of conformity the SPRU template is in “unchanged”.

Administrative and compliance costs

Straightforward assessment with as indicators Person months spent on implementation/number of licensed plants and Financial resources spent on the implementation; both with specification.

Causal analysis

In paragraph 8 some aspects of the causal analysis for the Netherlands are presented. It’s up to the individual team to assess the relevant factors in their own country. On two aspects explicit data are asked: on relevant changes on the composition of the waste (due to sorting or prevention) and on the “why” question of investments done in incinerators.
1. The clarification the national regulated substances

In this paragraph the “characterization of the implementation process” is not on the agenda, see the note on this from CERNA. However we can think of some specific additional aspects that could be relevant for the case research per country on domestic waste incineration. These are presented in paragraph 1.2. First we go into the differentiation patterns in the MWI-Directives.

1.1 Differentiation patterns in the MWI Directives

As far as outputs of sub-games are at stake it is important to get clear which European emission standards are relevant, given the characteristics of the incinerators in use:

Differentiation patterns in the Directives 89/369 and 49/429

Just refreshing the memory: 89/369 EEC deals with “new” incinerators (permitted before December 1st 1990); 89/429 EEC deals with “existing” incinerators (permitted after December, 1st 1990). Basically the difference is that until 1/12 1996, there is a transitional arrangement for existing incinerators with a capacity of more than 6 tons/hour, for plants with a capacity of less than 6 tons/hour there is a transitional arrangement until December, 1th 2000 with an “important” step taken at December 1th, 1995. So there is no fixed Y* being the emission limit for every incinerator (Y* being the emission ceiling according to the Directive). The Y* varies according whether it’s a new incinerator or an existing incinerator and the capacity of the incinerator.

Differentiation patterns in 89/369/EEG according to capacity of the “new" incinerator, emission limits mg/m3

Member states had to meet the requirements of 89/369/EEG before 1 December 1990.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Capacity</th>
<th>&lt; 1 ton/hour</th>
<th>1 ton/h.- 3 ton/h.</th>
<th>3 tons/h and more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust</td>
<td>200**</td>
<td>100</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Pb+Cr+Cu+Mn</td>
<td></td>
<td>5</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Ni+As</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Cd+Hg</td>
<td></td>
<td>0.2</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>HCl</td>
<td>250***</td>
<td>100</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>HF</td>
<td>“divided”</td>
<td>4</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>SO2</td>
<td></td>
<td>300</td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>CO</td>
<td></td>
<td>100</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Organic Compounds</td>
<td>20</td>
<td>20</td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>

*) standardized conditions 273 degrees K, 101,3 Kpa, 11% Oxygen or 9% CO2
**) if Oxygen = 17 %: 80, in special cases, and when the European Commission is informed and consulted a less
strict limit is possible up to 500 mg/m³
*** if Oxygen = 17 %: 100

Additionally, combustion gasses should be heated upto at least 850 degrees Celsius for two seconds, being Oxygen at least 6% or an alternative technology that performs at least as good at PCDD’s and PCDF’s, checked by the authorities.

Finally, as far as technology is at stake all new incinators have to be equipped with auxiliar burners.

**Differentiation patterns in 89/429/EEG according to capacity of the “existing” incinerator, emission limits mg/m³:**

Member states had to meet the requirements of 89/429/EG before 1 December 1990.

- If the capacity of the incinerator is 6 tons/hour or more:

  - The existing incinerator has to meet the same emission limits as new incinerators on December, 1th, 1996, compare table 1.

  - By December, 1th, 1996, Combustion gasses should be heated upto at least 850 degrees Celsius for two seconds, being Oxygen at least 6% or an alternative technology that performs at least as good at PCDD’s and PCDF’s, checked by the authorities. If there are serious technical problems implementing these requirements, the deadline can be postponed until the ovens are renewed.

- If the capacity of the incinerator is 6 tons/hour or less:

  - The existing incinerator has to meet the same emission limits as new incinerators on December, 1st, 2000, compare table 1.

  - The existing incinerator has to meet transitional emission limits on December 1st 1995.

**Table 2: Differentiation patterns in 89/429 for the period December 1st 1995 until December 1st 2000 for incinerators with a capacity of less than 6 tons/hour, according to capacity, emission limits mg/m³**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Capacity</th>
<th>&lt; 1 ton/hour</th>
<th>1 ton/h.- 6 tons/h.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust</td>
<td></td>
<td>600**</td>
<td>100</td>
</tr>
<tr>
<td>Pb+Cr+Cu+Mn</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ni+As</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cd+Hg</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HCl</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HF</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SO2</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CO</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Organic Compounds</td>
<td></td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

*) standardized conditions 273 degrees K, 101,3 Kpa, 11% Oxygen or 9% CO2
** if Oxygen = 17 %: 240

- By December, 1th, 1995, Combustion gasses should be heated upto at least 850 degrees Celsius for a regulated time-span, being Oxygen at least 6% or an alternative technology that performs at least as good at PCDD’s and PCDF’s, checked by the authorities. The regulated time-span has to be “sufficient” and is set by the authorities.

1.2 Implementation in national texts and permits

As far as outputs of sub-games are at stake it is important to get clear how the European emission standards are implemented in national texts and permits:

**Netherlands as illustration: not adapting differentiation patterns in regulation**

In the experimental phase we assessed to what extend these differentiation patterns were present in national regulation: In Dutch regulation capacity of the incineration plant is no factor, all incinerators are treated the same. The date on “new” versus “existing” is set a bit different compared to the EU-Directives. For “existing incinerators” there is a transitional arrangement until January, 1th 1995. For most substances, after January 1th, 1995 “existing” have to meet the same emission limits as “new” incinerators (the exceptions are minor and in line with EEC). And finally in the Netherlands the emission limits are set stricter and we have limits on more substances than required by the EU. In Netherlands (and also in France as I understood from CERNA), the influence of permitting authorities on emission limits is marginal in the case of Domestic Waste Incineration (In the Netherlands the situation on LCP’s is quite different with regard to the influence of the permitting authority).

**Relevance of the required data**

Of course data on stricter and additional regulation is essential for the causal analysis/the disentanglement problem. Parallel to the indicator \( ^\wedge Y = \frac{Y^1}{Y^{*EU}} \times 100 \) (first indicator for environmental effectiveness) we should pay attention to stricter and additional emission limits by using as a variant

\( ^\wedge Y = \frac{Y^1}{Y^{*National}} \times 100 \), so in theory we have \( Y^{*fr}, Y^{*ge}, Y^{*nl} \) and \( Y^{*uk} \)

But the emphasis should be on the pollutants that are regulated in the Directives first, second the additional and stricter regulated pollutants that can be perceived as part as the implementation of the Directives and only thirdly (if) additional and stricter regulated pollutants that are regulated but cannot be linked to the implementation of the European. To argue the importance of the last category: The regulation on dioxins makes additional steps
in the abatement line necessary that have large impacts on the emissions of other regulated substances (see the paragraph on technology).

**Differentiation on what is a “new” incinerator and what is an “existing” incinerator**

In the experimental phase we assessed to what extend these differentiation patterns were present in national regulation: In Dutch regulation capacity of the incineration plant is no factor, all incinerators are treated the same. The date on “new” versus “existing” is set a bit different compared to the EU-Directives. For “existing incinerators” there is a transitional arrangement until January 1th 1995. For most substances, after January 1th, 1995 “existing” have to meet the same emission limits as “new” incinerators (the exceptions are minor and in line with EEC). And finally in the Netherlands the emission limits are set stricter and we have limits on more substances than required by the EU.

**Monitoring and enforcement**

As monitoring and enforcement can be a relevant aspect it is important to have information on (1) the efforts put in monitoring, (2) the level of non-compliance (3) enforcement steps taken.

**Summarizing: Template of questions to be answered on national emission limits related to MWID**

Are there *stricter* emission limits in national legislation that are connected to the implementation of the EU-Directives (MWID)?

Are there *stricter* emission limits in permits that are connected to the implementation of the EU-Directives (MWID)?

Are there *additional* emission limits in national legislation that are linked to the implementation of the EU-Directives (MWID)?

Are there *additional* emission limits in permits that are linked to the implementation of the EU-Directives (MWID)?

Are there *stricter or additional* emission limits in permits that are *not* linked to the implementation of the EU-Directives (MWID)?

Are the concepts “new” and “existing” incinerators defined different from the EU-Directives (MWID)?

Are the same categories on capacity used as in the EU-Directives (MWID)?
Summarizing: Template of questions to be answered on relevant national limits that are not connected to the implementation of the European MWI Directives

Are there relevant previous or stricter emission limits in national legislation that are not connected to the implementation of the EU-Directives (MWID)?

Are there relevant previous or stricter emission limits in permits that are not connected to the implementation of the EU-Directives (MWID)?

Are there relevant additional emission limits in national legislation that are not linked to the implementation of the EU-Directives (MWID)?

Are there relevant additional emission limits in permits that are linked to the implementation of the EU-Directives (MWID)?

Summarizing: Template of questions to be answered on national monitoring and enforcement

What efforts are put in monitoring?

What was the found level of progress/compliance?

Which enforcement steps were taken?

2. Strictness of emission limits and technology-options applied

Technology options are related to the emission limits that have to be achieved. Stricter limits require more technology. Paragraph 2.1 and 2.2 elaborate the expected contingencies between emission limits and technology options.

2.1 Emissions without purification equipment

To be able to judge the strictness of limits, the benchmarks are found in estimates of the emissions of incinerators without purification-equipment.

Table 3: Emissions of domestic waste incinerators without purification equipment

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust</td>
<td>4000 - 10000 mg/m³</td>
</tr>
<tr>
<td>HCl</td>
<td>400-2000 mg/m³</td>
</tr>
<tr>
<td>HF</td>
<td>3-20 mg/m³</td>
</tr>
<tr>
<td>CO</td>
<td>30-200 mg/m³</td>
</tr>
<tr>
<td>Organic compounds</td>
<td>1-10 mg/m³</td>
</tr>
</tbody>
</table>
2.2. Technology options on abatement

There are primary measures and secondary measures. Primary measures are process integrated, secondary measures are end-of-pipe technology.

**Primary measures**

Primary measures on the input side of the oven.

If substance that do not burn well are removed C and CO decreases.

If there is no PVC in the waste that has to be incinerated, HCl can decrease by 50%. The same is valid of course for heavy metals. F and S are also components that are on the agenda to remove on the input-side of the oven. If an individual incinerator is trying to decrease these substances in the composition of the waste (to be burned) it is indeed a primary measure. Costs can be made to sort substances out of the incoming streams.

The substance CO have to be abated by optimizing the burning process. The aim is constant and complete burning, the design of the burner and oven can be optimized, raise burning temperature and a better mixture of waste and air (Higher Reynolds characteristics, this means more turbulence, which yes, raises the concentration of dust). The temperature should be held on a high enough level for a long enough period. Auxiliary burners are usually perceived as primary technology. Primary measures on dust are possible by controlling the speed of air flows (and thus the speed of the burning process in the fireplace/oven. The result is of course more dust in the residual.

**Secondary measures**

Secondary measures come in steps that can be added to existing equipment. Usually the order of steps is as the order of the enumeration below:

**Step 1** in the abatement line

For secondary measures two technologies are most frequently used for the abatement of
dust. First, most frequently used there is the electric filter (abates up to 95 %), the “and/or” alternative is the canvas-filter (abates up to 99.9%). A canvas-filter performs better on small particles. A multiple electric filter is also possible. Side effect of abating dust is that heavy metals with a high boiling point are reasonable well abated. If an electric filter is not sufficient, following steps in the abatement technology usually abate enough dust and metals. In certain cases this is not a valid statement for low boiling metals, like mercury, they are not so well abated. If still problematic, substances can be added that increase abatement of these metals in following wet steps (to abate acid substances) in the abatement technology. Another theoretical thinkable alternative secondary measure is an active coal filter, this is usually an element of the abatement equipment that abates dioxins.

**Step 2 in the abatement line**

In order to abate the acid substances HCl, HF and SO2 a second step can be added to the abatement equipment. In principle there are four options. All use in order to absorb Ca (CaO) or NaOH: in a dry system the absorbing substance is blown in the combustion gasses. In a semi-dry system the absorber is in a slurry, the process starts wet and ends dry. In a wet system the absorbents are in a total wet washing process. Finally there is a semi-wet system. This last alternative is basic a wet washer. The wet residual is added to the stream of combustion gasses in a spraying-tower. Experts claim that the investment costs and the running costs usually increase in the direction that these options are presented here. In this second step a percentage of Mercury, Dust and Dust on which heavy metal stick are also abated as a side-effect. Also some of the organic compounds (C\textsubscript{x}H\textsubscript{y}) will be removed. Nox and dioxins are not removed well in this step. The advantage of the semi-wet system is that the solid residual is small and there is no emission to water (that has to be abated depending on regulation). An strategic advantage can be found in a dry system when it is combined with the injection of active coal and CaOH. It abates dioxines well and can replace the active coal filter (third step).

This could very well be the end of the list of abatement technology that is necessary to perform according to requirements of the MWI-Directives. It will not be the end of technology installed in Germany and the Netherlands in order to meet national requirements:

**Step 3 in the abatement line**

The third step is the active coal filter. Coal is used as an absorbent for dioxines, furans, PCB’s and an-organic substances like dust, heavy metals (good on Hg, Cd and Pb), HCl, HF and SO2.

In active coal filters there are two categories of processes. Firstly a physical absorption process that is effective on heavy metals, HCl, HF and Dust. The second category are
chemical processes: A catalytic reaction that absorbs organic compounds. SO2 is oxidized to SO3 by O2. Mercury reacts under the catalytic influence of coal to HgS. Under certain circumstances emission of CO can raise. An active coal filter is in the Netherlands by the trade association also known as the so called “Polizeifilter”: For dioxines it is an often necessary step, it is tricky to try it without. It offers the secure feeling that also for SO2, mercury and dust the Dutch emission limits can be reached, even is there is a malfunction in other steps of the abatement equipment

**Step 4** in the abatement line

On fourth place there is the deNox step. There are primary measures (controlling the process of burning by manipulating the supply of air) and secondary measures. Primairy measures can decrease Nox by about 60%. When that is not enough end-of-pipe technology is inevitable. That end-of-pipe technology is available in three packages: selective non catalytic reduction (SNCR), reduction between 50 and 70 percent, selective catalytic reduction (SCR, up to about 90 %) and a wet system (oxydation-absorption-reduction) (upto 95 % but also of SO2). DeNox equipment is expensive. Costs increase in the order the options are presented. Therefor it is not always first choice as a step in the abatement equipment (although Nox abatement in the “second step” is very small).

NSCR has a disadvantage: NH3 emissions and CO emissions increase if Nox concentration is going below 50 mg/m3. If the abatement is well controlled, Nox level is stable at 70mg/m3, the negative effects are very small.

SCR can also work on dioxins: Dioxins and furans are oxidized to CO2, H2O and (being a regulated substance) HCl. The efficiency for Nox abatement decreases if this option is used. Besides that, SCR is a “tail-end system”. This increases the use of energy. An alternative is to place it behind an high temperature Electric filter, combustion gasses don’t need to be heated again in this situation. It is more expensive because of the limited life-span of the catalytic converter (3 years), even if it is placed tail-end.

Temperature control and control of additional substances

When all steps are added into a line of abatement equipment temperature control and the control of the added substances becomes extremely important. A lot of abatement can be gained by optimizing. Especially the emissions of dioxins are influenced by the process control in different and between steps.

Finally it is possible that an incinerator is in the research project where the deNox step is integrated in the active coal filter. It requires extreme process control.
The template on the next page is the one to be verified by national experts in order to assess whether it can be used (compare assessment on allocative efficiency):

<table>
<thead>
<tr>
<th>measure</th>
<th>installed before 1990</th>
<th>overhauled since 1990</th>
<th>added since 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>sorting waste</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optimizing burning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optimizing oven</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>auxiliary burners</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>electric filter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>canvas filter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dry system*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>semi dry-system*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wet-system*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>semi-wet system*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>active coal filter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>deNO₂, SNCR**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>deNO₂, SCR**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>deNO₂, wet system**</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*: Mostly aiming at abatement of HCl, HF and SO₂: in a dry system the absorbing substance is blown in the combustion gasses. In a semi-dry system the absorber is in a slurry, the process starts wet and ends dry. In a wet system the absorbents are in a total wet washing process. Finally there is a semi-wet system. This last alternative is basic a wet washer. The wet residual is added to the stream of combustion gasses in a spraying-tower.

**: Selective non catalytic reduction (SNCR), selective catalytic reduction (SCR) and a wet system, abates also SO₂ (oxydation-absorption-reduction).

3. Selection of pollutants, time series and research population

How to select pollutants for the gathering of data is topic of paragraph 3.1, the research population is discussed in paragraph 3.2.

3.1 Pollutants for time-series

Time series

In principle the set of substances that is regulated by the European Directives can be used to gather data on air pollution by the incineration sector. Relevant time series cover the years 1985-1990 and 1997, being the period 1990-1997 the years in which adjustment of existing incinerators took place in the Netherlands and probably will have in other countries. Expanding the time series to previous years until 1985 seems necessary in order to have suitable time-series for the causal analysis. A sufficient time series would be 1985, 1990 and 1997. Of course 1997 can be a problem. The reason for this recent year are the dates set in
the European Directives: The latest compliance date is December 1\(^{\text{th}}\) 1995 for existing incinerators with a capacity < 6 tons/hour and December 1\(^{\text{th}},\) 1996 for incinerators with a capacity of more than 6 tons/hour. If transformation process of incinerators is already finished, or the date in national legislation is set earlier, it might as well be 1995.

Pollutants

Pollutants that are regulated by the MWID: dust, heavy metals (3x), hydrochloric acid (HCl), hydrofluoric acid (HF), sulphur dioxide (SO2), carbon monoxide (CO) and organic compounds, all mg/m\(^3\). Collecting data for these time series provides us with the necessary data to calculate some indicators and a basis for the causal analysis/the disentanglement problem. But not all incinerators are regulated on all pollutants.

All existing incinerators are regulated on Dust and CO

Until December 1th, 2000 the only limits for existing incinerators with a capacity of less than 6 tons/h. are on Dust and CO.

Compared with the EU limits set, limits on dust seem to require technology. Dust usual is abated partly by an electric filter, the alternative being a canvas filter (which is also part of an advanced equipment in a step further down the equipment line). In average abatement lines Dust is also abated in step 2. In advanced equipment the active coal filter also abates dust.

CO has to be abated by primary measures. It is questionable to which extend the Eu-limits require substantial investments.

*All existing incinerators with a capacity > 6 tons/h. are also regulated on HCl, HF and heavy metals (Pb+Cr+Cu+Mn; Ni + As; Cd + Hg)*

The emission limits on HCl, probably HF and probably SO2, require technology. There are possibilities for primary measures (compare paragraph on technology). These primary measures could be sufficient for existing incinerators (< 6 tons/h), compare table 1, 2 and 3. The regulation on heavy metals also requires technology.

*Limits on organic compounds don’t seem to be too serious*

The limits on organic compounds don’t seem to imply technology.

**Template on minimal data requirements: time series 1985, 1990 and 1997 (1997 can be replaced by 1995, see the arguments above)**

Dust and CO for “existing” incinerators with a capacity < 6 ton/h.
Dust, CO, HCl, SO₂ and Cd + Hg (and if possible HF, Pb+Cr+Cu+Mn and Ni + As) for existing incinerators with a capacity of more than 6 tons/h.

Of course data on more substances is appreciated for all incinerators in the research population.

Data availability:

Sometimes problems can be solved knowing that the amount of m³ combustion gasses produced per ton domestic waste incinerated is relatively stable. It would not be right to say the amount of m³ is absolutely stable. Theoretically, it depends on the composition of the waste that is burned. The volume of air that is necessary to burn 1 kilo of waste can be calculated. Theoretically the input volume of air = 0.0895 x C + 0.2685 x H + 0.0335 x S - 0.0335 x O (C, H, S and O being the determined weight of relevant chemical elements in the waste). Usually the necessary input of air will be between 2.0 and 2.6 m³. Often/almost always an overflow of air is used up to 200 - 250 %. Combustion gases per kilo incinerated waste will then raise up to an empirical average between 4 and 6.5. The empirical value of 4.75 m³, is calculated for the Netherlands.

The expected averages of 4.7 (Netherlands 1995) - 5.2 (Belgium, late eighties) have to be checked whether the are valid for other countries.

So knowing the tons waste incinerated and emissions in kg. or tons makes it possible to calculate average mg/m³. If the percentage of compliance is known and the amount of waste incinerated, the emissions in kg. and tons can be calculated etc. By that we can assess goal attainment and the level of compliance for the domestic waste incineration sector as a whole or for individual incinerators.

Additional national limits

If there are additional national limits, those limits can be used additionally (not “in stead of”). An example are additional national requirements like those on nitrogen-oxide and dioxins in the Netherlands. But the emphasis should be on the pollutants that are regulated in the Directives first, second the additional regulated pollutants that can be perceived as part as the implementation of the Directives and only thirdly (if) additional regulated pollutants that are regulated but cannot be linked to the implementation of the European Directives.

3.2 Research population

A first step to be taken is to determine the structure of the national incineration sector and the assessment to what extend the necessary data (time series on emissions) are available.
for the whole incineration sector and for every incinerator separately. Bilateral between CSTM as coordinator of the MWI-case and CERNA, SPRU and UFZ we can discuss the research population.

Anticipating on these short bilateral deliberations we can say something about priorities:

**Sampling**

Of course most alluring is the situation where complete set of data for the sector as a whole and all individual incinerators can be collected. If there is only a limited number of incinerators we can study all. If this is not practicable because of difficulties in getting the necessary information efficient (workload per incinerator) or the number of incinerators (total workload) a sample can be considered. For France, where there are 70 large incinerators and 300 small ones, a sample has to be drawn. The outlines of such a sample are known. In the Germany and in the Netherlands the incineration plants are generally speaking large. In the larger incinerators (more than 6 tons/hour) probably best conditions are there for comparison. In France and probably the UK there are also small incineration plants. Cerna believes that these small incinerator are the ones that are not complying and besides that they are of significant interest by themselves. Small incinerators are part of the research project also. Probably only a comparison can be made between less than four countries. But that is no problem.

---

*Data on the aggregate level of the whole municipal waste incineration sector*

Data on the whole incineration sector (aggregate level) are also appreciated. It makes it possible to qualitative assess to what extend the incinerators in the research population perform above or below average (and give an indication to what extend they are “out-layers”).

These data include number, age and capacity of incinerators and aggregate time series on emissions.

If sampling is necessary, see to it that at least five existing incinerators with a capacity of more than 6 tons/hour are in the sample and at least five existing incinerators with a capacity of less than 6 tons/hour are in the sample.

If cement ovens are part of the research population, this should be explicit. Regulation can be different from a normal incinerator. The differences should be explained.

**Sampling strategies**

Possibilities for generalization of results depend on the sampling and the assumptions we accept. The sampling method is relevant. A random sample is always attractive. But there can
be arguments for a non random sample. A possible selection criterion should be, see above, the capacity of the incinerator. Other criteria could be the level of pre-existing pollution, the age etc. Nevertheless there should be, if available anyway, enough larger incinerators in the population. Simple because if in the Netherlands and Germany only large incinerators exist and are being researched. As a strategy we could start selecting and then see if the necessary data can be obtained. A second possibility is to first find out for which incinerators the changes of gathering the data are good. The emissions for 1990 (and less essential 1985) could well be the crucial factor. When using the second strategy it has to be checked if we are not selecting on good boy/bad boy by this.

4. Environmental Effectiveness

Indicators for environmental effectiveness

We prefer two indicators for environmental performance, being the first one an indicator that includes the normative ambition level ($Y^*$):

$$Y = \frac{Y^1}{Y^{*EU}} \times 100$$

Calculated for Dust and CO for “existing” incinerators with a capacity < 6 tons/h.

Calculated for Dust, CO, HCl, SO$_2$ and Cd + Hg (and if possible for HF, Pb+Cr+Cu+Mn and Ni + As) for existing incinerators with a capacity of more than 6 tons/h.

With $Y^1$ being the environmental result and $Y^{*EU}$ being the environmental objective in the Directive. With $Y^1$ now stating the emission for relevant years and $Y^{*EU}$ the emissions ceiling set out in the Directive. Of course this indicator, showing percentage compliance, makes meaningful comparison between countries possible. But it is easy to see that being the other parameters fixed, percentage compliance depend on the normative ambition level ($Y^{*EU}$). In the case of the Municipal Waste Incineration the EU-Directives take into account the date of permitting and the capacity of the plant ($Y^{*EU}$ varies).

For existing incinerators not only the capacity is relevant. If the capacity is 6 tons/h or more the incinerator has to meet the same limits as a new one on December, 1th, 1996. If the capacity is less than 6 tons/h, the relevant date is December 1th 1995 and December 1th 2000 (compare table 2). For incinerators with a capacity of less than 6 tons/hour there is a small complication: only since December 1th, 1995 they are regulated on dust and CO and only by December 1th, 2000 they are regulated (almost) the same as new incinerators with an equal capacity. Because we evaluate compliance we have to recognize that the existing rules for dust and CO are in fact intermediary goals. The final goals for 2000
comprehend more substances and include stricter limits. We would suggest to use the intermediate goals/existing rules for Dust and CO for assessing compliance for these incinerators.

The second indicator

\(^Y= \frac{(Y^0-Y^1)}{Y^0} \times 100\)  
\(^ = \) delta

Calculated for Dust and CO for “existing” incinerators with a capacity < 6 ton/h.

Calculated for Dust, CO, HCl, SO\(_2\), and Cd + Hg (and if possible for HF, Pb+Cr+Cu+Mn and Ni + As) for existing incinerators with a capacity of more than 6 tons/h.

where \(Y^0\) is the initial level of emission in 1990 and \(Y^1\) being the environmental result. This is just one of several options to express goal attainment and just gives pollution abatement as percentage of the initial pollution, in other words pollution abatement (Keeping other factors as the amount of waste incinerated fixed). It is a simple, efficient indicator. It indicates to what extend the sector is moving towards the goals \((Y^*)\), not stating the exact level of compliance (leaving the normative ambition level \((Y^*)\) out).

For every incinerator the capacity and the year it was brought into use has to be clarified.

5. Allocative efficiency

Allocative efficiency has been defined as the “fit” between the differentiation of abatement effort of the emission sources and the pollution abatement cost characteristics of the sources.

Step 1: Get knowledge about the differentiation patterns in use:

So basically the outcome of the analysis could be a description of the differentiation patterns in pollution abatement.

The proposed indicator:

The indicator expresses directly the decrease of emissions as percentage of the original pollution.

\(^Y= \frac{(Y^0-Y^1)}{Y^0} \times 100\)

Where \(Y^0\) is the initial level of pollution in 1990 and \(Y^1\) is the actual level of pollution in 1997 (1997 can be replaced by, for instance, 1995, see the arguments in paragraph 3.2) (to be expressed both in mg/m3 and tons)
- Calculated for Dust and CO for “existing” incinerators with a capacity < 6 ton/h.
- Calculated for Dust, CO, HCl, SO₂ and Cd + Hg (and if possible for HF, Pb+Cr+Cu+Mn and Ni + As) for existing incinerators with a capacity of more than 6 tons/h.

Both in tons and in mg/m³, for suggestions see paragraph 3.1 data-availability

**Step 2: Cost-characteristics of individual sources**

The direct indicator “tons of abated pollution/costs” is not used. At the end of this paragraph this will be explained.

A first category of costs can be found if some old incinerators are closed because of the costs to transform them in order to comply with the emission limits set. We need to assess whether old incinerators are closed down because of the MWID. To quantify the costs can of course be very difficult.

**Template on costs for closing down incinerators**

The number, capacity and age of the closed incinerators should be the indicators.

The second category of costs are those made to adjusting incinerators:

**Template on costs for adjusting incinerators**

We use *indirect* indicators as proposed by Cerna:

Indicator: the plant size (in terms of quantity of output)
Operational measured as the quantity of input: capacity (tons/year)

Indicator: the plant age

Indicator: the initial environmental performance, i.e. the pre-existing level of abatement (based on Y⁰)
Operational: emissions 1990

On the status of the indicators: During the experimental phase we concluded that the costs for abatement correlated with the pre-existing emissions, both in tons as in mg/m³. Correlation between capacity and costs and between age and costs are present but less perfect. Because plant size and age are easy to access and also necessary to describe the sample incinerators in the context of the whole national incineration sector, we gather all three.
In order to have additional information on technology and not be too vulnerable in our assumptions made by the use of indirect indicators, we use the following template:

<table>
<thead>
<tr>
<th>Template on technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please indicate what abatement measures were taken before 1990 and indicate renewals or additions since 1990</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>measure</th>
<th>installed before 1990</th>
<th>overhauled since 1990</th>
<th>added since 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>sorting waste</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optimizing burning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optimizing oven</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>auxiliary burners</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>electric filter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>canvas filter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dry system*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>semi dry-system*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wet-system*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>semi-wet system*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>active coal filter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>deNOx, SNCR**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>deNOx, SCR**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>deNOx, wet system**</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*: Mostly aiming at abatement of HCl, HF and SO₂: in a dry system the absorbing substance is blown in the combustion gasses. In a semi-dry system the absorber is in a slurry, the process starts wet and ends dry. In a wet system the absorbents are in a total wet washing process. Finally there is a semi-wet system. This last alternative is basic a wet washer. The wet residual is added to the stream of combustion gasses in a spraying-tower.

**: Selective non catalytic reduction (SNCR), selective catalytic reduction (SCR) and a wet system, abates also SO₂ (oxydation-absorption-reduction).

So we have insight in \( Y^0 \), \( Y^1 \), the age, capacity and measures being taken. This should be enough to make us not too vulnerable on our indicators.

**On not using the indicator “tons of pollution abated/costs”**

Normally the adjustment of incinerators is done in a package. This package consists of primary steps (controlling the incineration process more careful) and secondary steps (adding end of pipe technology). The adjustment is not a continuous process, and so the marginal cost curve exhibits discontinuities. And more precisely, at first sights it is made out of flat segments (like a stairway). It is complicated by the fact that there is no marginal cost-curve for all pollutants but there is a curve for every pollutant and these curves are not independent: there is a range of pollutants on which incinerators probably are, under the influence of the implementation of the European Directives, shifted from a lower percentage point of emission abatement to a higher percentage point of emission abatement. The abatement solution of each pollutant is not independent from other pollutant abatement options, and consequently also not independent from the national context (stricter and additional emission limits that might as well be not connected to the MWID). Equipment aiming for one pollutant can have positive or negative side-effects on other pollutants. The longer the line
of abatement equipment is, the more complicated it gets (see the paragraph on technology options).

And there are *path dependencies*: For existing incinerators the costs to reach for required abatement levels is not only dependent on their starting-position of emissions in a quantitative way but also depending on previous decisions in a qualitative way. Sometimes previous abatement equipment is compatible with new steps, in other cases these new steps become more costly because they also require replacement or changes in existing abatement equipment. So in practice extreme expensive new steps can follow on cheap predecessors, and extreme cheap new steps can follow on previous expensive measures.

There is a disentanglement problem also. A sound assessment requires often a qualitative description of what happened in terms of technology. Description of which abatement-technology was present before the MWID’s and which changes in primary and secondary technology were added is inevitable. In the easy cases there are only primary measures, an E-filter (step 1, compare paragraph on technology) and an “acid step” (step 2, compare paragraph on technology). The E-filter might be there before MWID and it might be renewed. If there is a longer line of abatement equipment installed we should be aware that these additional steps raise the abatement of the pollutants we are focusing on, but are primary installed for the abatement of other pollutants. It would be a mistake to conclude that marginal costs are raised on the basis of quantitative data without admitting that the costs are made for abatement of NOx or dioxins, or even worse: to include SCR-equipment in the costs for HCl abatement. It adds HCl, it doesn’t abate HCl. So to know what is installed is as important as to know why it is installed.

The solution to avoid all problems and to keep the workload low is to work with the indirect indicators in combination with insight in the technology-grid of the incinerator.

### 6. Productive efficiency

The assessment of productive efficiency will be a matter of qualitative methods.

With a template on productive efficiency the following information is gathered:

1. Constraint put on incinerators
2. The degree of freedom of choice left to the management of the incinerator
3. The informational “events” that are taking place in the course of the implementation process which increase the technical decision maker’s information level
iv The degree of flexibility pertaining to the timing of compliance (the degree of freedom let to firms regarding the date of compliance)

<table>
<thead>
<tr>
<th>Template on productive efficiency</th>
</tr>
</thead>
</table>

1. **Were any new constraints on existing incinerators introduced as a result of the implementation of the MWID?**
   
   Yes/No

2. **Was the abatement technology to be adopted specified for existing incinerators?**
   
   Yes/No

   If yes, 
   
   a) give details of technology specified...
   
   b) by what date was this technology to be installed?

3. **Were there external constraints upon operators’ commercial freedom with respect to:**
   
   - the closure of plants  
   - take primary measures (sorting waste, optimising burner/oven, optimising burning process)  
   - use of end-of pipe technology

   Yes/No

4. **If yes, please specify (in particular were these constraints internal or external to the MWID implementation regime?)...**

5. **Has a timetable been specified for upgrading existing incineration plant to the new standards?**
   
   Yes/No

   If yes, by what date must this be achieved?

   And,

   Where was this requirement specified: i.e. in the National Programme, plant licence, etc (give details)?

6. **Were (if applicable) multi-site operators provided with any flexibility regarding the location of the emissions reductions to be achieved?**
   
   Yes/No

   If yes, please specify...

7. **Describe any informational “events” that took place in the course of the implementation process, which were promoted by the regulator as measures accompanying the implementation processes.**

**7. Administrative and compliance costs**

We suggest as indicators:

i Person months spent on implementation/number of licensed plants
Operational: dissaggregate between government and industry. In the category government dissaggregate if possible between implementation and monitoring and enforcement and to the level of government.

In order to assess the hypotheses we need also have knowledge about other costs that were made for the implementation.

ii Financial resources spent on the implementation

We do suggest to elaborate to what extend resources other than personnel is spend that should be considered as administrative costs: coordinating costs, studies on technology options, demonstration-projects and subsidies.

8. Causal Analysis

Some remarks on the start of the causal analysis that requires some additional information:

The second indicator for environmental effectiveness states compliance (be it for all incinerators or for pragmatic reasons only for a random or select sample of incinerators):

\[^\gamma = \frac{\gamma^1}{\gamma^{EU}} \times 100\]

The first indicator for environmental effectiveness states the decrease of the initial pollution that has to be explained by the EU Directives or other factors:

\[^\gamma = \frac{(\gamma^0 - \gamma^1)}{\gamma^0} \times 100\]

The time series on pollutants indicate how much has been achieved during the crucial period in which the incineration sector had to be adjusted on account of the EG-directive (be it for all incinerators or for pragmatic reasons only for a random or select sample of incinerators). In the context of the time series alternative explanations can be reviewed.

First of all being autonomous developments/external factors an explanatory factor. Of course the time series is a first instrument for assessing whether autonomous developments can explain a part of the environmental outcome.

Stricter National Limits

A special case of autonomous development/external factors is stricter national regulation that is not driven by the translation of the EU Directives into national legislation. The next indicator for environmental effectiveness gives an answer to whether more assessment on this point is necessary:
\[ \hat{y} = \frac{Y^{1/N} \text{National}}{Y^{1/N} \text{EU}} \times 100 \]

When \( \hat{y} = \frac{Y^{1/N} \text{National}}{Y^{1/N} \text{EU}} \times 100 \) is larger than \( \hat{y} = \frac{Y^{1/N} \text{EU}}{Y^{1/N} \text{EU}} \times 100 \) the question has to be assessed whether the stricter national legislation is trickered by the EU-Directives or by other factors. The answer might come from the study on the Characterization of the Implementation process, sometimes additional qualitative information could be necessary.

When \( \hat{y} = \frac{Y^{1/N} \text{National}}{Y^{1/N} \text{EU}} \times 100 \) is smaller than \( \hat{y} = \frac{Y^{1/N} \text{EU}}{Y^{1/N} \text{EU}} \times 100 \) the question has to be assessed why the EU-Directives are not implemented by the country. The Environmental outcomes could be smaller than if the country would have implemented the EU-Directives.

The same holds for emission limits on additional substances.

**Causal analysis**

In the experimental phase we came across a number of -not necessarily independent- factors that also explain events and cannot be considered as part of the implementation of the European Directives:

1. Growing awareness and knowledge of environmental problems
2. Intensified “progressive” national environmental policy
3. Environmental incidents with waste incineration plants that potential endanger human health and the economic important dairy-food sector
4. Previous and stricter regulation for air-emissions of waste incinerators
5. Soil pollution near landfills (“controlled dumping”), leading to a shift in waste policy from “landfilling” to incineration: growing amount of waste incinerated
6. Market characteristics/industrial structure: ownership in public hands/markets closed
7. Monopoly-power- net costs can be given through to the owners and market/customers
8. Increasing knowledge on the possibilities to reduce air emissions from waste incinerators, seeing other countries do it
9. Development of technology

In the Netherlands the plausible model for explanation includes a stricter environmental policy and growing environmental awareness in the late eighties. Incidents with land-filling led to a shift in the waste policy from land-filling to incineration. The implementation of
this shift was endangered by incidents with existing incinerators. Extension of incineration capacity was only political feasible under strict regulation. The incidents concerned meanly dioxins. Technology for abatement of dioxins was available in the late eighties. Regulating dioxines and using this technology led to over-compliance on other substances. The market structure (closed markets), ownership structure (governments) and the system of retributions did not make the costs most important. Besides these events, the waste policy did include prevention of waste and sorting of waste. Finally incineration-plants were keen on their image.

This enumeration of explaining factors we came across in the experimental phase is relevant for the Dutch situation, to what extend these or other relevant factors are explaining in France, Germany and the United Kingdom is a job for the individual research team.

Finding an answer to what extent the input has changed could be essential:

Information is necessary to what extend the amount of waste to be incinerated increased or decreased from 1990 to 1997 and to what extend the amount of substances like bad burning substances, Cl, F, S was decreased.

If there is over-compliance, image could be an explaining factor (at the level of the Dutch waste-board it is perceived that in Germany this is even a stronger driver for incinerators than in the Netherlands), the “why-question” becomes relevant next to the template on productive efficiency:

A simple model explains:

There is the real or true rational world:

- Alternatives (technology and timing)
- Consequences of alternatives (emission-abatement/costs)

There is the subjective world of the decision-maker:

- Information on alternatives
- Information on the consequences of alternatives

There is decision-making:

- Weighting the alternatives and their consequences by the decision-maker on the basis of the information the decision-maker has at his disposal.
For assessing the weighting of alternatives and consequences the next template could be used:

**Draft template for the national assessment of productive efficiency**

<table>
<thead>
<tr>
<th>To what extend was meeting the emission requirement an important factor?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1= not important 5= very important</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To what extend was anticipating on future emission an important factor?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1= not important 5= very important</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To what extend was the image of the company as an environmental friendly company important?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1= not important 5= very important</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To what extend was over-compliance important?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1= not important 5= very important</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To what extend were the costs important?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1= not important 5= very important</td>
</tr>
</tbody>
</table>