**Vielhauer, Trina**

**From:** Vielhauer, Trina
**Sent:** Sunday, September 28, 2003 9:26 PM
**To:** Hrydziusko, Wayne
**Subject:** Lee County Mercury info.

ayne,
irst, congrats!! I understand you're moving on to a new position in parks? That's great. I hope you'll enjoy that!

hen I spoke with Mike Joyner on Friday afternoon [after I spoke with you] he said do NOT come to the Cabinet eeting on Tuesday. So, unless I hear otherwise, I won't be coming. However, I'm sending ya a brief synopsis of the nswer to "so, why didn't we/ why don't we lower the mercury emission limits on units 1 and 2 since unit 3 is much wer?" Units 1 and 2 have a limit of 0.070 micrograms/dscm OR 85% reduction. Unit 3 has a limit of 0.028 icrograms/dscm OR 85% reduction. That "or 85% reduction" protects them in the event they have a strange, high inlet oncentration of mercury. In that event they may not meet the hard limit [.070 or .028] so they would rely on meeting e 85% reduction. That would still be considered compliance.

. Units 1 and 2 were NOT part of our Best Available Control Technology [BACT] review which occurs in onjunction with air construction permits. This is because units 1 and 2 received their construction permits in the early 990's. We don't believe we [in air, anyway] have jurisdiction to pull units 1 and 2 into this permitting process.

. When Units 1 and 2 received their construction permits, they were subject to our state rule which requires the 0.070 icrograms/dscm OR 85% removal. Presumably, BACT 10+ years ago was no more stringent than the rule we have on e books.

. Unit 3 will have the same mercury technology [mercury separation and carbon injection] as units 1 and 2.

. Units 1 and 2 appear to be meeting the same limit as Unit 3. The stack test for Units 1 and 2 in 2001 were 0.023 icrograms/dscm and 0.028 micrograms/dscm.

. As part of our BACT review for Unit 3, we looked at information from all over the country and Europe. For ercury, similar facilities in the northeastern United States have mercury limits of 0.028 micrograms/dscm OR 85% emoval- the same limit we applied to Unit 3.

f you have any questions, let me know.

rina

## LEE COUNTY RESOURCE RECOVERY MERCURY INFORMATION

Existing Units 1 and 2:

- Permits issued early 1990's
- Mercury limit is 70 micrograms/dry standard cubic meter OR 85% reduction from inlet concentrations
- This matches our current state rules

New Unit 3:

- BACT sets limit at 28 micrograms/dry standard cubic meter OR 85% reduction from inlet concentrations

Question 1: HOW has Lee County been able to reduce mercury emissions at the facility?

We would estimate 80% is from the reduction in mercury in batteries [their 1991 application indicates up to 89% of the mercury in solid waste was from batteries]

They did not provide guarantees for the mercury removal.

About another 17% may be attributable to technology (85% of remaining 20%)

We would not necessarily attribute anything to management.

Question 2: Why didn't we/ why don't we lower the mercury emission limits on units 1 and 2 since unit 3 is much lower?

- Units 1 and 2 were NOT part of this construction application nor our BACT determination
- Unit 3 will have the same mercury technology [mercury separation and carbon injection] as units 1 and 2
- Units 1 and 2 appear to be meeting the same limit as unit 3. The stack test for units 1 and 2 in 2001 were 23 micrograms/dscm and 28 micrograms/dscm
- When units 1 and 2 received their construction permits, they were subject to our state rule which requires the 70 micrograms/dscm OR 85% removal

Lee County Estimate

Per Lee County application, SNCR costs were estimated in the range of $2,000 to 2,600/ton $NO_X$ for long-term reduction of $NO_X$ from 260 to 150 ppm representing a reduction of 42 percent.

The cost-effectiveness values tend to decrease as the inlet concentration increases and also as the outlet objective is decreased.

No cost estimate was submitted for lower outlet objectives including the value of 110 ppm (long-term) given in our draft permit. Also no estimates were provided for combinations of SNCR and other technologies to given values lower than 150 ppm. The other possible technologies that can be used in tandem with SNCR and that are more cost-effective than SCR include:

IR pyrometry to optimize $NO_X$ removal and minimize ammonia slip. A Martin GmbH option.

Flue gas recirculation. A Martin GmbH option.

Water cooled grates. A Martin GmbH option.

Increased oxygen coupled with overfire air. A Martin GmbH option known as SYNCOM

Excess ammonia injection coupled with "light duty" scrubber/stripper. VonRoll, maybe Martin

Combinations of these technologies can achieve $NO_X$ values from about 40 to 110 ppm.

EPA Estimate

EPA published a study in 1994 that included comparisons between SNCR and SCR. The calculated cost-effectiveness value for reducing emissions from 250 to 137, 100, and 87.5 using conventional SNCR were approximately $1058, 940, and 986 respectively for a 750 TPD unit.

Assuming an inlet value of 260 ppm and a 660 TPD unit would not appreciably change these estimates. The negative side is the possibility of excess ammonia slip and visible plume.

EPA's short summary report included estimates for advanced SNCR to reduce emissions by 60 percent. The graphs for a 750 TPD unit indicate a cost effectiveness of roughly $1300 per ton removed. Thus the cost for reducing $NO_X$ from 260 to about 105 ppm would be about $1300 per ton.

Advanced SNCR simply means conventional SNCR plus some of the measures described previously. The EPA summary report described IR pyrometry and "additional process controls," most likely meaning flue gas recirculation. Under this case, the slip should be low.

European Commission JRC Estimate

This report on $NO_X$ and dioxin includes five examples of retrofitted or demonstration European units with baseline emissions ranging from 320 to 370 $mg/m^3$ (240 to 280 ppm) and achieving reduction of 41 to 70 percent. The reflect reductions to the range of 75 to 150 ppm. The same report gives a value for SCR control of 1500 Euros to 4000 Euros per ton $NO_X$ removed and comments that SNCR is generally 25 percent more economic.

The result is that control by SNCR costs somewhere between 1000 and 3000 Euros per ton of $NO_X$ removed. Historically the Euro has been within 10 percent of the value of a dollar. It is fair to conclude that the cost effectiveness is roughly between $1000 and 3000 per ton. The low value probably represents large units (like Lee County) while the higher value represents small units. Presumably the units achieving the lowest emissions have FGR or a scrubber/stripper built into the process.

| TURBINE BACT DETERMINATION MATRIX | (2) Duke Energy - Lake<br>PSD - FL - 308<br>0694835-001-AC | (6) Lakeland McIntosh<br>PSD-FL-245<br>1050004-004-AC | (7) Palmetto Power<br>PSD-FL-227A<br>0970073-001-AC |
|---|---|---|---|
| Date of Determination | April 4, 2001 | July 10, 1998 | June 2, 2000 |
| Date of Permit | July 19, 2001 | July 10, 1998 | November 13, 2001 |
| Permit Engineer | Jeff Koerner | Al Linero / Teresa Heron | Jeff Koerner |
| Turbine Model | GE PG7121EA (7EA) | Westinghouse 501G | Westinghouse W501FD |
| Turbine Mode | Simple cycle | Simple cycle | Simple cycle |
| Turbine Operation | Peaking | Continuous | Peaking |
| MW Rating (each) | 80 MW | 250 MW | 170 MW |
| No. of Turbines | 8 | 1 | 3 |
| Total MW | 640 MW | 250 MW | 510 MW |
| Applicant SCR Control Costs | | | |
| * Technology | Hot SCR | Hot SCR | Hot SCR |
| * Applicant $/ton NOx | ~$30,000 | $5,236 | $13,635 |
| * Replacement Power Included? | Energy impact from pressure drop was calculated. Not sure if cost for replacement was included in $/ton. Energy loss estimated at 612,500 kWh/turbine, or "about 0.3% per inch of pressure drop." | Unknown. | Original estimate of $11,850 included an energy penalty; revised cost does not, but it includes other FDEP concerns. |
| FDEP SCR Control Costs | | | |
| * Technology | Hot SCR | Hot SCR | Hot SCR |
| * FDEP Estimated $/ton NOx | >$20,000 | $3,500 - $4,000 | $9,900 - $11,200 |
| * Discussion | Even at max operation (5000 hrs/yr on any one unit), FDEP estimated costs at >$13,000. | National Park Service estimated costs at $3,500, including an energy penalty. FDEP estimated $4,000 by scaling a similar project's costs. | |
| SCR Rejected Because... | Cost effectiveness | Hot SCR not rejected...forestalled. | Cost effectiveness |
| * Cost considered excessive | >$13,000 | Ultra Low NOx burners to 9 ppmvd by 2002 or install Hot SCR or convert to combined cycle and meet 7.5 ppmvd with SCR. | ~$10,000 not cost effective; implied that other scenarios with costs in the $3,000 to $6,000 range would be cost effective. |
| * Explain technically infeasible | SCR not technically feasible for simple cycle. | SCR not feasible for project at its inception, because it is a simple cycle unit. Hot SCR is technically feasible and cost effective. | Hot SCR only technically feasible add on control technology. |
| NOx Control Required | DLN | DLN now; ULN and/or Hot SCR by 2002; WI when firing fuel oil. | DLN |
| Limits on Operation | 2500 hr/yr-unit average, 5000 hr/yr-unit max | None. | 3750 hr/yr-unit |
| Fuel Oil Backup | No | Yes (250 hours) | No |
| Fuel 1 | Natural gas | Natural gas | Natural gas |
| NOx Limit | 9.0 ppmvd @ 15% O2 (initial 3-hr test) | 25 ppmvd @ 15% O2 (DLN); 9 ppmvd @ 15% O2 (ULN or Hot SCR after 4/30/02); 7.5 ppmvd @ 15% O2 (if converted to combined cycle) | 15.0 ppmvd @ 15% O2 |
| Averaging Time | 3-hour rolling average | 24-hour average | 3-hour block average |
| Compliance Method | CEMS (vs 12.0 ppmvd @ 15% O2) | CEMS | CEMS |
| Fuel 2 | | Fuel oil | |
| NOx Limit | | 42 ppmvd @ 15% O2 (DLN or ULN); 15 ppmvd @ 15% O2 (if ULN doesn't work and Hot SCR is required to attain 9 ppmvd on natural gas); 15 ppmvd @ 15% O2 (if converted to combined cycle) | |
| Averaging Time | | 3-hour average | |
| Compliance Method | | CEMS | |
| Fuel 3 | | | |
| NOx Limit | | | |
| Averaging Time | | | |
| Compliance Method | | | |

1998- present
rejected SCR
costs

| TURBINE BACT DETERMINATION MATRIX | (8) Granite Power<br>PSD-FL-281<br>0490044-001-AC | (9) IPS - Avon Park<br>PSD-FL-284<br>0270016-001-AC | (10) JEA Brandy Branch<br>PSD-FL-310<br>0310485-003-AC |
|---|---|---|---|
| Date of Determination | August 4, 2000 | June 29, 2000 | April 26, 2001 |
| Date of Permit | August 7, 2000 | June 30, 2000 | Not issued (?) |
| Permit Engineer | Al Linero | Al Linero | Mike Halpin |
| Turbine Model | GE 7FA, WH 501F or 501D5A | GE PG7241FA (7FA) | GE PG7241FA (7FA) |
| Turbine Mode | Simple cycle | Simple cycle | Combined cycle (conversion) |
| Turbine Operation | Peaking | Peaking | Continuous |
| MW Rating (each) | 170 / 170 / 120 MW | 170 MW | 170 MW |
| No. of Turbines | 3 | 3 | 2 (of the 3 existing 7FA's) |
| Total MW | 510 / 510 / 360 MW | 510 MW | 570 MW |
| Applicant SCR Control Costs | | | |
| * Technology | Hot SCR | Hot SCR | SCR |
| * Applicant $/ton NOx | >$9,394 | $11,350 | $4,200 |
| * Replacement Power Included? | $9,394 is minimum levelized cost for the three models under consideration. Applicant implied replacement power is not included. | Unknown. | Unknown if SCR figure includes replacement power. Cost for top technology (SCONOX at $62,000 per ton of NOx) did include replacement power and lost revenues. |
| FDEP SCR Control Costs | | | |
| * Technology | Hot SCR | Hot SCR | SCR |
| * FDEP Estimated $/ton NOx | | | |
| * Discussion | No comment on applicant's $/ton figure. Implicit that $/ton is too high. References are made to FDEP precedence and other projects. | No comment on applicant's $/ton figure. FDEP "does not necessarily adopt" the figure. | Implicit acceptance of $4,200 and of that figure being cost effective. Disagreed with SCONOX costs. |
| SCR Rejected Because... | Cost effectiveness | Cost effectiveness | SCR not rejected. |
| * Cost considered excessive | >$9,394 (by implication) | $11,350 (by implication) | Note FDEP estimated <$10,000 for SCONOX and concluded it was "not likely cost-effective." |
| * Explain technically infeasible | SCR, SCONOX not feasible for simple cycle. | SCR, SCONOX not feasible for simple cycle. | |
| NOx Control Required | DLN; WI when firing fuel oil. | DLN; WI when firing fuel oil. | DLN and SCR |
| Limits on Operation | 3000 hr/yr-unit | 3390 hr/yr-unit average, 5000 hr/yr-unit max | |
| Fuel Oil Backup | Yes (500 hr/yr-unit) | Yes (1000 hr/yr-unit) | Yes |
| Fuel 1 | Natural gas | Natural gas | Natural gas |
| NOx Limit | 15.0 ppmvd @ 15% O2 (Westinghouse); 10.5 ppmvd @ 15% O2 (GE 7FA) | 9 ppmvd @ 15% O2 | 3.5 ppmvd @ 15% O2; 5 ppmvd ammonia slip |
| Averaging Time | 24-hour block average | 24-hour block average | 3-hour block average |
| Compliance Method | CEMS | CEMS | CEMS |
| Fuel 2 | Fuel oil | Fuel oil | Fuel oil |
| NOx Limit | 42 ppmvd @ 15% O2 | 42 ppmvd @ 15% O2 | 15 ppmvd @ 15% O2; 9 ppmvd ammonia slip |
| Averaging Time | 3-hour block average | 3-hour block average | 3-hour block average |
| Compliance Method | CEMS | CEMS | CEMS |
| Fuel 3 | | | |
| NOx Limit | | | |
| Averaging Time | | | |
| Compliance Method | | | |

| TURBINE BACT DETERMINATION MATRIX | (11) Peace River Station<br>PSD-FL-292<br>1050336-001-AC | (12) FPL Ft. Myers<br>PSD-FL-298<br>0710002-009-AC | (13) IPS - Shady Hills<br>PSD-FL-280<br>1010373-001-AC |
|---|---|---|---|
| Date of Determination | September 20, 2000 | December 21, 2000 | January 11, 2000 |
| Date of Permit | December 27, 2000 | December 22, 2000 | January 13, 2000 |
| Permit Engineer | Jeff Koerner | Al Linero / Teresa Heron | Al Linero |
| Turbine Model | GE PG7241FA (7FA) | GE MS7241FA (7FA) | GE PG7241FA (7FA) |
| Turbine Mode | Simple cycle | Simple cycle | Simple cycle |
| Turbine Operation | Peaking | Continuous | Peaking |
| MW Rating (each) | 170 MW | 170 MW | 170 MW |
| No. of Turbines | 3 | 2 | 3 |
| Total MW | 510 MW | 340 MW | 510 MW |
| Applicant SCR Control Costs | | | |
| * Technology | Hot SCR | Netted out of PSD for NOx. | Hot SCR |
| * Applicant $/ton NOx | $10,500 | | $14,900 |
| * Replacement Power Included? | Likely. Applicant estimated lost power and increases in other pollutants caused by running harder to make replacement power. BACT determination mentions "high costs are partially the result of ... energy consumption." | Contemporaneous shut down of older residual oil fired unit. | Unknown. |
| FDEP SCR Control Costs | | | |
| * Technology | Hot SCR | Netted out of PSD for NOx. | Hot SCR |
| * FDEP Estimated $/ton NOx | $9,000 - $12,000 | | >$10,000 |
| * Discussion | | | "FDEP does not accept nor endorse applicant's cost estimate. No bright line but Hot SCR is not cost effective." |
| SCR Rejected Because... | Cost effectiveness | Netted out of PSD for NOx. | Cost effectivness |
| * Cost considered excessive | >$9,000 | | >$10,000 |
| * Explain technically infeasible | SCR, SNCR, NSCR, SCONOX not feasible for simple cycle. XONON not a proven technology. | | SCR, SCONOX not feasible for simple cycle. XONON not a proven technology. |
| NOx Control Required | DLN; WI when firing fuel oil | DLN; WI when firing fuel oil | DLN; WI when firing fuel oil |
| Limits on Operation | 3390 hr/yr-unit | 500 hr/yr-unit "high power mode" operation | 3390 hy/yr-unit average; 5000 hr/yr-unit max |
| Fuel Oil Backup | Yes (720 hr/yr-unit) | Yes (500 hr/yr-unit) | Yes (1000 hr/yr-unit) |
| Fuel 1 | Natural gas | Natural gas | Natural gas |
| NOx Limit | 9.0 ppmvd @ 15% O2 (initial 3-hr test) | 10.5 ppmvd @ 15% O2 | 9.0 ppmvd @ 15% O2 |
| Averaging Time | 3-hour rolling average | 30-day average | 24-hour block average |
| Compliance Method | CEMS (vs 10 ppmvd @ 15% O2) | CEMS | CEMS |
| Fuel 2 | Fuel oil | Natural gas (high power mode) | Fuel oil |
| NOx Limit | 42.0 ppmvd @ 15% O2 | 15 ppmvd @ 15% O2 | 42 ppmvd @ 15% O2 |
| Averaging Time | 3-hour rolling average | 24-hour average | 3-hour block average |
| Compliance Method | CEMS | CEMS | CEMS |
| Fuel 3 | | Fuel oil | |
| NOx Limit | | 42 ppmvd @ 15% O2 | |
| Averaging Time | | 30-day average | |
| Compliance Method | | CEMS | |

| TURBINE BACT DETERMINATION MATRIX | (14) IPS - Vandolah<br>PSD-FL-275<br>0490043-002-AC | (15) Reliant Energy - Osceola<br>PSD-FL-273<br>0970071-001-AC | (16) FPC - Intercession City<br>PSD-FL-268<br>0970014-003-AC |
|---|---|---|---|
| Date of Determination | December 15, 1999 | December 23, 1999 | December 9, 1999 |
| Date of Permit | December 16, 1999 | December 28, 1999 | December 13, 1999 |
| Permit Engineer | Al Linero | Mike Halpin | Jeff Koerner |
| Turbine Model | GE PG7241FA (7FA) | GE PG7241FA (7FA) | GE PG7121EA (7EA) |
| Turbine Mode | Simple cycle | Simple cycle | Simple cycle |
| Turbine Operation | Peaking | Peaking | Peaking |
| MW Rating (each) | 170 MW | 170 MW | 87 MW |
| No. of Turbines | 4 | 3 | 3 |
| Total MW | 680 MW | 510 MW | 261 MW |
| Applicant SCR Control Costs | | | |
| * Technology | Hot SCR | Hot SCR | Hot SCR |
| * Applicant $/ton NOx | $14,900 | $28,509 | $12,890 |
| * Replacement Power Included? | Unknown. | Unknown. | BACT determination implies cost of lost power was included in applicant's analysis. |
| FDEP SCR Control Costs | | | |
| * Technology | Hot SCR | Hot SCR | Hot SCR |
| * FDEP Estimated $/ton NOx | >$10,000 | ~$10,000 | $10,008 |
| * Discussion | "FDEP does not accept nor endorse applicant's cost estimate. No bright line but Hot SCR is not cost effective." | "FDEP does not accept or endorse applicant's cost estimate." BACT determination explicitly says Hot SCR is cost-effective for simple cycle continuous units operating on natural gas or oil. | Applicant requested flexibility (10,170 hr/yr total with for all 3 units) and used average firing for cost analysis. Should have used maximum baseline NOx (i.e., 5760 hours on gas and 3000 hours on oil). |
| SCR Rejected Because... | Cost effectivness | Cost effectivenes | Cost effectiveness |
| * Cost considered excessive | >$10,000 | ~$10,000 | $10,008 |
| * Explain technically infeasible | SCR, SCONOX not feasible for simple cycle. XONON not a proven technology. | SCR, SCONOX not feasible for simple cycle. XONON not a proven technology. | SCR, SNCR, NSCR, SCONOX not feasible for simple cycle. XONON not a proven technology. |
| NOx Control Required | DLN; WI when firing fuel oil | DLN; WI when firing fuel oil | DLN; WI when firing fuel oil |
| Limits on Operation | 3390 hy/yr-unit average; 5000 hr/yr-unit max | 3000 hr/yr-unit | 10,170 hr/yr total for all 3 units |
| Fuel Oil Backup | Yes (1000 hr/yr-unit) | Yes (750 hr/yr-unit) | Yes (2500 hr/yr total for all 3 units) |
| Fuel 1 | Natural gas | Natural gas | Natural gas |
| NOx Limit | 9.0 ppmvd @ 15% O2 | 10.5 ppmvd @ 15% O2 | 9.0 ppmvd @ 15% O2 and 32.0 lb/hr |
| Averaging Time | 24-hour block average | 24-hour block average | 3-hour average |
| Compliance Method | CEMS | CEMS | CEMS (vs 10 ppmvd @ 15% O2) |
| Fuel 2 | Fuel oil | Fuel oil | Fuel oil |
| NOx Limit | 42 ppmvd @ 15% O2 | 42 ppmvd @ 15% O2 | 42.0 ppmvd @ 15% O2 and 167.0 lb/hr |
| Averaging Time | 3-hour block average | 24-hour block average | 3-hour average |
| Compliance Method | CEMS | CEMS | CEMS |
| Fuel 3 | | | |
| NOx Limit | | | |
| Averaging Time | | | |
| Compliance Method | | | |

| TURBINE BACT DETERMINATION MATRIX | (1) DRAFT Enron - Pompano<br>PSD-FL-304<br>0112515-001-AC | (3) DRAFT El Paso - Manatee<br>PSD-FL-318<br>0810199-001-AC | (4) DRAFT El Paso - Broward<br>PSD-FL-316<br>0112545-001-AC |
|---|---|---|---|
| Date of Determination | December 15, 2000 (received) | June 27, 2001 (received) | June 27, 2001 (received) |
| Date of Permit | March 7, 2001 (TEPD) | September 11, 2001 (TEPD) | August 17, 2001 (TEPD) |
| Permit Engineer | Al Linero | Al Linero / Teresa Heron | Al Linero |
| Turbine Model | GE PG7241FA (7FA) | GE PG7241FA (7FA) | GE PG7241FA (7FA) |
| Turbine Mode | Simple cycle | 2 simple cycle, 1 combined cycle | 3 simple cycle, 1 combined cycle |
| Turbine Operation | Peaking | (S) Peaking; (C) Continuous | (S) Peaking; (C) Continuous |
| MW Rating (each) | 170 MW | 175 MW | 175 MW |
| No. of Turbines | 3 | 3 | 4 |
| Total MW | 510 MW | (S) 350 MW; (C) 250 MW | (S) 525 MW; (C) 250 MW |
| Applicant SCR Control Costs | | | |
| * Technology | Hot SCR | (S) Hot SCR; (C) SCONOX | (S) Hot SCR; (C) SCONOX |
| * Applicant $/ton NOx | $20,700 | (S) $22,052; (C) $24,187 | (S) $22,052; (C) $24,187 |
| * Replacement Power Included? | Unknown. | | |
| FDEP SCR Control Costs | | | |
| * Technology | Hot SCR | (S) Hot SCR; (C) SCONOX | (S) Hot SCR; (C) SCONOX |
| * FDEP Estimated $/ton NOx | $11,350 | (C) SCR at $3,535 is cost effective | (C) SCR at $3,535 is cost effective |
| * Discussion | Cites similar analyses for different projects, does not accept applicant's cost ("high end"), $11,350 "probably more accurate." | Disagreed with cost for (S) and (C), but did not present alternative cost estimate. Noted that these technologies were not cost effective even at half of applicant's estimates. | Disagreed with cost for (S) and (C), but did not present alternative cost estimate. Noted that these technologies were not cost effective even at half of applicant's estimates. |
| SCR Rejected Because... | Cost effectiveness | Cost effectiveness | Cost effectiveness |
| * Cost considered excessive | $11,350 | (S) $11,026; (C) $12,093 | (S) $11,026; (C) $12,093 |
| * Explain technically infeasible | SCR, SNCR, SCONOX not feasible for simple cycle. XONON not a proven technology. | (S) SCR, SCONOX not feasible for simple cycle. (C) SCONOX not cost effective. (S) and (C) XONON not a proven technology. | (S) SCR, SONOX not feasible for simple cycle. (C) SCONOX not cost effective. (S) and (C) XONON not a proven technology. |
| NOx Control Required | DLN; WI when firing fuel oil | (S) DLN; (C) SCR | (S) DLN; (C) SCR |
| Limits on Operation | 3500 hy/yr-unit average; 5000 hr/yr-unit max | (S) 5000 hr/yr-unit | (S) 5000 hr/yr-unit |
| Fuel Oil Backup | Yes (1000 hr/yr-unit) | No | No |
| Fuel 1 | Natural gas | (S) Natural gas | (S) Natural gas |
| NOx Limit | 9 ppmvd @ 15% O2 | (S) 9 ppmvd @ 15% O2 | (S) 9 ppmvd @ 15% O2 |
| Averaging Time | 24-hour block average | (S) 24-hour average | (S) 24-hour average |
| Compliance Method | CEMS | (S) CEMS | (S) CEMS |
| Fuel 2 | Fuel oil | (C) Natural gas | (C) Natural gas |
| NOx Limit | 42 ppmvd @ 15% O2 | (C) 2.5 ppmvd @ 15% O2 | (C) 2.5 ppmvd @ 15% O2 |
| Averaging Time | 24-hour block average | (C) 24-hour average | (C) 24-hour average |
| Compliance Method | CEMS | (C) CEMS | (C) CEMS |
| Fuel 3 | | | |
| NOx Limit | | | |
| Averaging Time | | | |
| Compliance Method | | | |

| TURBINE BACT DETERMINATION MATRIX | (5) DRAFT El Paso - Belle Glade PSD-FL-317 0990594-001-AC |
|---|---|
| Date of Determination | June 27, 2001 (received) |
| Date of Permit | September 5, 2001 (TEPD) |
| Permit Engineer | Al Linero / Teresa Heron |
| | |
| Turbine Model | GE PG7241FA (7FA) |
| Turbine Mode | 2 simple cycle, 1 combined cycle |
| Turbine Operation | (S) Peaking; (C) Continuous |
| MW Rating (each) | 175 MW |
| No. of Turbines | 3 |
| Total MW | (S) 350 MW; (C) 250 MW |
| | |
| Applicant SCR Control Costs | |
| * Technology | (S) Hot SCR; (C) SCONOX |
| * Applicant $/ton NOx | (S) $22,052; (C) $24,187 |
| * Replacement Power Included? | |
| | |
| FDEP SCR Control Costs | |
| * Technology | (S) Hot SCR; (C) SCONOX |
| * FDEP Estimated $/ton NOx | (C) SCR at $3,535 is cost effective |
| * Discussion | Disagreed with cost for (S) and (C), but did not present alternative cost estimate. Noted that these technologies were not cost effective even at half of applicant's estimates. |
| | |
| SCR Rejected Because... | Cost effectiveness |
| * Cost considered excessive | (S) $11,026; (C) $12,093 |
| * Explain technically infeasible | (S) SCR, SCONOX not feasible for simple cycle. (C) SCONOX not cost effective. (S) and (C) XONON not a proven technology. |
| | |
| NOx Control Required | (S) DLN; (C) SCR |
| Limits on Operation | (S) 5000 hr/yr-unit |
| Fuel Oil Backup | No |
| | |
| Fuel 1 | (S) Natural gas |
| NOx Limit | (S) 9 ppmvd @ 15% O2 |
| Averaging Time | (S) 24-hour average |
| Compliance Method | (S) CEMS |
| | |
| Fuel 2 | (C) Natural gas |
| NOx Limit | (C) 2.5 ppmvd @ 15% O2 |
| Averaging Time | (C) 24-hour average |
| Compliance Method | (C) CEMS |
| | |
| Fuel 3 | |
| NOx Limit | |
| Averaging Time | |
| Compliance Method | |

Institute for Energy

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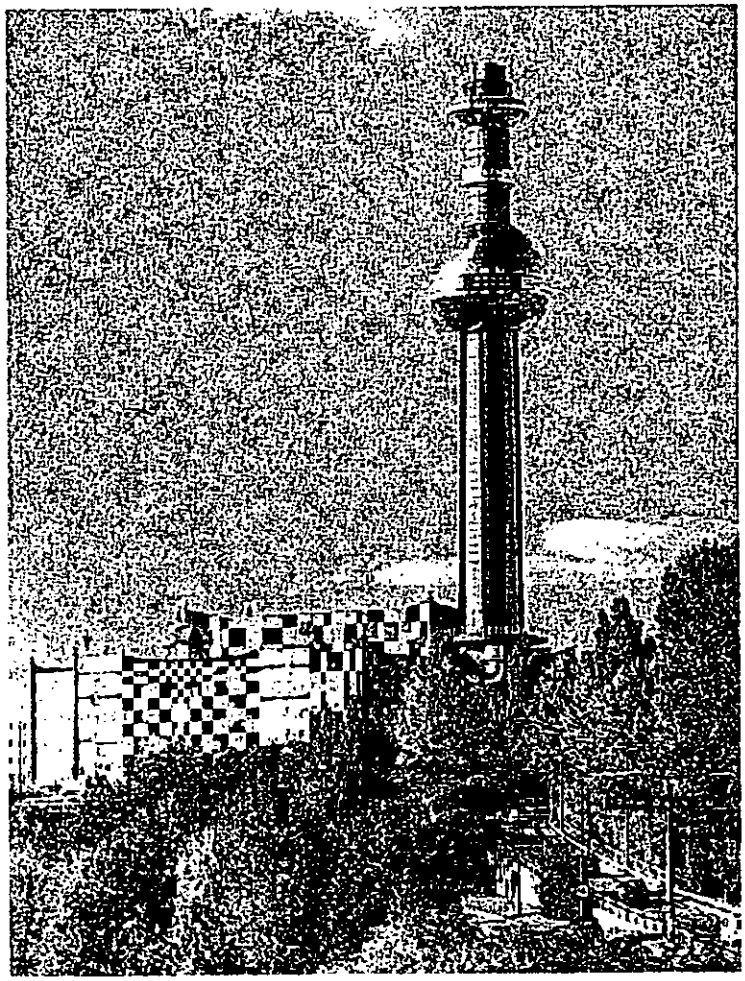
# $NO_x$ AND DIOXIN EMISSIONS FROM WASTE INCINERATION PLANTS




*E. TZIMAS and S.D. PETEVES*

*DG-JRC*

*ENERGY TECHNOLOGY OBSERVATORY*

*INSTITUTE FOR ENERGY*



EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

**EUR 20114 EN**

Table 6 Comparison of SCR and SNCR technologies for $NO_X$ control [30]

| Parameter | SCR | SNCR |
|---|---|---|
| ***$NO_X$ reduction efficiency*** | 80-95% | 30-50(80)% |
| ***Operating temperature*** | 300-450°C (high dust)<br>180-200 °C (tail-gas) | 850-1100 °C |
| ***Cost*** *(see Section 6.2)* | €1500-4000 | There is no information available to the authors related with the cost of SNCR technology installed recently to incinerators. Nevertheless, previous work on methods to control $NO_X$ emissions from large combustion plants had revealed that, in general, SNCR technology is 25% more economic than SCR [29]. |
| ***Additive*** | Ammonia, urea | Ammonia, urea |
| ***$NH_3/NO_X$ ratio*** | 0.8-1.0 | 1.5-2.5 |
| ***$NH_3$ slip*** | <5 ppmv | <3ppmv |
| ***Availability*** | >98% | >97% |
| ***Pressure drop in the catalyst*** | 400-1000 Pa | Not applicable |
| ***Residence time within temperature range*** | Not applicable | 0.2-0.5 s |
| ***Remarks*** | Ammonia slip increases with increasing $NH_3/NO_X$ ratio, which may cause problems, e.g. with a too - high ammonia content in the fly ash; this can be solved by using a larger catalyst volume and/or by improving the mixing of $NH_3$ and $NO_X$ in the flue gas. Incomplete reaction of $NH_3$ with $NO_X$ may result in the formation of ammonium sulphates, which are deposited on downstream facilities such as the catalyst and air preheater, increased amounts of $NH_3$ in flue gas desulphurisation waste waters, the air heater cleaning water, and increased $NH_3$ concentration in the fly ash. | Though some manufacturers report a $NO_X$ reduction level of over 80%, the common view is that SNCR processes are in general capable of 30 – 50 % reduction as an average covering different operational conditions. |

# 6. Experience with $NO_X$ and dioxin/furan abatement techniques

In Germany in 2001, out of 59 MSW incinerators, 17 were equipped with SNCR process and 42 with SCR. Furthermore, in 11 of the plants equipped with SCR technology, an oxidation catalyst is used additionally for dioxin/furan control [8].

In the Netherlands, in the mid-90s, a project was undertaken to evaluate SNCR and SCR technologies for reducing $NO_X$ species in full operational scale. Two plants were equipped with SCR technology, at Rotterdam and Rozenburg, and two others with SNCR, in Amsterdam and Duiven. The program showed that both technologies are reliable and can easily achieve emission limit values of 70 mg/m$^3$. Since 1995, 5 more plants were commissioned and 2 old ones were equipped with an emission control technology, one of them with SNCR technology while the remaining were equipped with SCR. During the duration of the demonstration program, the cost of SCR technology varied from €4000 to €4050 per tonne of $NO_X$ removed. 65% of the cost was capital cost and the remaining was labour, maintenance and material costs. The cost per tonne of waste incinerated varied from €5.5 to €8.2. It was concluded that SCR is suitable for larger plants from the economic point of view. On the other hand, the cost of SNCR was from €4000 to €4500 per tonne of NOx removed, 60% of which was capital cost. The cost per tonne of waste ranged from €5.0 to €6.0, indicating that this technology is more suited for smaller plants [40].

## 6.1 Case studies of selection of $NO_X$ and dioxin abatement techniques

Three case studies of incinerators that have implemented systems to reduce $NO_X$ and dioxin/furan emissions, a hazardous waste incinerator, a sludge incinerator and a MSW incinerator, are described below, taken from presentations at the International Conference on Industrial Atmospheric Pollution, held at Paris, France, in March 2001. They demonstrate the complexity of the issues involved when selecting the optimal abatement technology as well as cost estimates.

### *6.1.1 The hazardous waste incineration plant Entsorgungsbetriebe Simmering* in Austria [9]

The *Entsorgungsbetriebe Simmering* is the only incineration plant in Austria for hazardous waste and sludge. It operates 2 rotary kilns and 3 fluidised bed incinerators. The total capacity of the rotary kilns is 70000 tonnes of waste per year and of the fluidised bed incinerators is 200000 m$^3$ of sludge per year. The volume of flue gas emitted is 464000 m$^3$/h.

In 1989, a pilot plant program was initiated to identify the optimum technology or combination of technologies to reduce $NO_X$ and dioxin/furan emissions. Prior to the implementation of this plan, dioxin/furan emissions were not regulated and the maximum $NO_X$ emissions were 350 mg/m$^3$. Three different possibilities were compared prior to the installation of the pilot plants aiming at achieving maximum $NO_X$ emissions of 100 mg/m$^3$.

a. Adsorption of dioxins/furans by activated carbon and catalytic reduction of $NO_X$ by activated carbon
b. Adsorption of dioxins/furans by activated carbon and SNCR technology for $NO_X$

represents a 10-15% increase of the investment cost with a marginal increase in the running costs of the installation (mainly electrical consumption due to the extra pressure drop across the catalyst).

### 6.2 Costs

The above examples reveal that the cost of $NO_X$ control, expressed in euros per tonne $NO_X$ removed, can vary significantly. The reason is that each installation is unique and has different requirements. For example, for SCR technology, the total cost is a combination of (i) cost of ammonia (€100-200/tonne), (ii) hardware depreciation, (iii) the capital cost, (iv) catalyst depreciation (catalyst should be treated as an operating cost since its lifetime is limited), (v) additional steam cost. In average, costs run from €1000 to €4000 with a decreasing trend with accumulated experience. Nevertheless, examples where costs are significantly higher can be encountered, as in the example of the sewage treatment plant in Colombes, France, described above. In this case, the high cost has resulted from the small size of the plant, the very tight environmental and the very difficult installation conditions.

## 7. Emissions monitoring and reporting

The Directive requires continuous measurements for $NO_X$ emissions and twice-yearly measurements fro dioxins/furans. The most common method to measure $NO_X$ emissions from MSW incineration plants is the on-line chemiluminescent analysis [42]. This method has been designated as the reference measurement principle for the measurement of $NO_2$ emissions both by EU and US legislation. In this method, $NO_X$ emissions are reduced into NO. Then, NO reacts with ozone, producing $NO_2$. Some of the resultant $NO_2$ is produced in an electrochemically excited state that emits light decaying in the ground state (*chemiluminescence*). The intensity of the light generated is proportional to the concentration of NO. The lower detection limit can be as low as 0.01 mg/m$^3$. The measured levels of $NO_X$ emissions are reported under standard (normal) conditions, namely at 11% $O_2$ at a temperature of 0°C and 101.3 kPa pressure. Therefore, simultaneous measurements of oxygen content, fuel or exhaust gas flow rate and for ambient conditions are required. Experience from the gas turbine sector has demonstrated that uncertainties rise with the $NO_X$ emission measurements. There are a number of parameters that have to be measured that give rise to a range of uncertainty of the measurement of the emission levels. The imposed uncertainty is related to instrumentation (e.g., $NO_2$ to NO converter, sensitivity of measurements, etc.), calibration of the measurement device, set-point errors, ambient correction errors, and sample uncertainties. The total uncertainty is estimated as ±20% for emissions above 60 mg/m$^3$, and at an absolute level of ±10-12 mg/m$^3$ for lower emissions levels [43].

The emission limit values set by the Directive are regarded as being complied with if:

- none of the daily average values exceeds the emission limit values in Table 1 (page 16).
- either none of the half-hourly average values exceeds any of the emission limit values, showed in Table 1 and marked as (100%), or, 97% of the half-hourly average values over the year do not exceed the emission limit values, showed in Table 1 and marked as (97%).

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EPA/600/SR-94/208 March 1995

EPA

# Project Summary

# $NO_x$ Control Technologies Applicable to Municipal Waste Combustion

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**Several technologies are available for reducing nitrogen oxide ($NO_x$) emissions from municipal waste combustors (MWCs), including combustion controls, natural gas injection (NGI), selective non-catalytic reduction (SNCR), and selective catalytic reduction (SCR). The full report documents the key design and operating parameters, commercial status, demonstrated performance, and cost of NGI, SNCR, and SCR, and identifies technology research and development needs associated with them.**

**Two NGI processes have been developed: (1) Methane de-NOX℠ uses gas injection to inhibit $NO_x$ formation and appears capable of reducing $NO_x$ emissions from MWCs by approximately 60% and (2) reburning uses gas injection to create reducing conditions that convert $NO_x$ formed in the primary combustion zone to molecular nitrogen. Because of the relatively high temperatures required for these $NO_x$-reduction reactions, it may be difficult to successfully apply reburning to modern mass-burn waterwall MWCs. Long-term emission reductions are 45-65% for SNCR and 80-90% for SCR. Operation of SNCR processes near the upper end of their performance range can result in unwanted emissions of ammonia or other by-product gases. An advanced version of SNCR using furnace pyrometry and additional process controls appears capable of achieving high $NO_x$ reductions with less reagent than is needed for conventional SNCR. The combination of NGI and SNCR (advanced NGI) may be able to achieve overall $NO_x$ reductions of 80-85%.**

**Comparing costs, SCR is the most capital intensive, followed by advanced SNCR and advanced NGI. Capital costs of NGI and conventional SNCR are comparable. In terms of tipping fee impact and cost effectiveness, conventional SNCR generally has the lowest costs of the evaluated technologies. For NGI, these costs depend on whether waste is diverted and tipping fee revenues are lost when applying this technology, along with the price of natural gas. Depending on the selected NGI scenario, the resulting tipping fee impacts and cost effectiveness values can be the highest of the evaluated technologies. After specific NGI scenarios, the next highest tipping fee impacts and cost effectiveness values are for SCR. These high costs result from high capital costs, as well as the cost of catalyst replacement and disposal.**

***This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

## Introduction

Nitrogen oxides ($NO_x$) are of environmental significance because of their role as a criteria pollutant, acid gas, and ozone precursor. The current New Source Performance Standards (NSPS) for municipal waste combustors (MWCs) (40 CFR Part

60, Subpart Ea) limit $NO_x$ emissions to a daily average of 180 parts per million (ppm) at 7% oxygen ($O_2$), dry basis.* By comparison, typical $NO_x$ emissions from modern mass-burn waterwall (MB/WW) MWCs range from 220 to 320 ppm. To comply with the NSPS, most recently built MWCs have used a combination of combustion controls to limit $NO_x$ formation and selective non-catalytic reduction (SNCR) to convert $NO_x$ to molecular nitrogen ($N_2$). Because of pressure to achieve even lower emission levels, questions have been raised regarding the potential for advancements in $NO_x$ control technologies. To respond to these questions, the U.S. Environmental Protection Agency's (EPA's) Air and Energy Engineering Research Laboratory and the Department of Energy's National Renewable Energy Laboratory initiated this assessment of three alternative $NO_x$ control technologies: natural gas injection (NGI), SNCR, and selective catalytic reduction (SCR). The objectives of the assessment were to (1) document the key design and operating parameters, commercial status, demonstrated performance, and cost of each technology and (2) identify technology research and development needs.

The assessment of achievable $NO_x$ emissions presented by the report is based on the average $NO_x$ reduction potential of these technologies applied to "typical" MWCs. The assessment does not examine the potential severity or length of short-duration excursions in performance that can affect continuously achievable $NO_x$ emission rates associated with short averaging periods. The assessment also does not consider potential limitations on technology performance that may result from combustor-specific design or operating restrictions.

## $NO_x$ Formation

The chemistry of $NO_x$ formation is directly tied to reactions between nitrogen and $O_2$. To understand $NO_x$ formation in an MWC, a basic understanding of combustor design and operation is useful. Combustion air systems in MB/WW MWCs include both undergrate (also called primary) air and overgrate (also called secondary or overfire) air. Undergrate air, supplied through plenums located under the firing grate, is forced through the grate to sequentially dry (evolve water), devolatilize (evolve volatile hydrocarbons), and burn out (oxidize nonvolatile hydrocarbons) the waste bed. The quantity of undergrate air is adjusted to minimize excess air during initial combustion of the waste while maximizing burnout of carbonaceous materials in the waste bed. Overgrate air, injected through air ports located above the grate, is used to provide turbulent mixing and destruction of hydrocarbons evolved from the waste bed. Overall excess air levels for a typical MB/WW MWC are approximately 80% (180% of stoichiometric [i.e., theoretical] air requirements), with undergrate air accounting for 60-70% of the total air. In addition to destruction of organics, one of the objectives of this "staged" combustion approach is to minimize $NO_x$ formation.

$NO_x$ is formed during combustion through two primary mechanisms: fuel $NO_x$ formation and thermal $NO_x$ formation. Fuel $NO_x$ results from oxidation of organically bound $N_2$ present in the municipal solid waste (MSW) stream. Thermal $NO_x$ results from oxidation of atmospheric $N_2$.

Fuel $NO_x$ is formed within the flame zone through reaction of organically bound $N_2$ in MSW materials and $O_2$. Key variables determining the rate of fuel $NO_x$ formation are the availability of $O_2$ within the flame zone, the amount of fuel-bound $N_2$, and the chemical structure of the $N_2$-containing material. Fuel $NO_x$ reactions can occur at relatively low temperatures [<1,100°C (<2,000°F)]. Depending on the availability of $O_2$ in the flame, the $N_2$ compounds will react to form either $N_2$ or $NO_x$. When the availability of $O_2$ is low, $N_2$ is the predominant reaction product. If substantial $O_2$ is available, an increased fraction of the fuel-bound $N_2$ is converted to $NO_x$. Testing conducted in the 1970s and 1980s using coal showed that in $O_2$-rich, highly mixed systems approximately 50% of the fuel-bound $N_2$ can convert to $NO_x$; in $O_2$-starved staged-combustion systems, however, the rate of conversion decreases to near 5%. Other testing has shown that $N_2$ associated with volatile compounds is more readily converted to fuel $NO_x$ than $N_2$ associated with nonvolatile materials. Still other research involving coal and oil combustion indicates that the extent of conversion is related to the amount of $N_2$ available, with the degree of conversion decreasing as the amount of fuel-bound $N_2$ increases.

Thermal $NO_x$ is formed in high-temperature flame zones through reactions between $N_2$ and $O_2$ radicals. The key variables determining the rate of thermal $NO_x$ formation are temperature, the availability of $O_2$ and $N_2$, and residence time. The key reactions resulting in thermal $NO_x$ formation are

$$N_2 + O \rightleftarrows NO + N \qquad (1)$$

followed by

$$N + O_2 \rightleftarrows NO + O \qquad (2)$$

$$N + OH \rightleftarrows NO + H \qquad (3)$$

Because of the high activation energy required for Reaction (1), thermal $NO_x$ formation does not become significant until flame temperatures reach 1,100°C (2,000°F). Kinetic calculations (assuming 30% excess air, average MSW properties, and residence time of 0.5 second) predict thermal $NO_x$ concentrations of <10 ppm in MWCs. However, local flame temperatures may exceed 1,100°C and thermal $NO_x$ concentrations may be greater than these calculated model results.

Examination of MWC operating conditions suggests that most of the $NO_x$ emitted from MWCs (>80%) is attributable to fuel-bound $N_2$. Based on typical MSW $N_2$ contents of 0.3-0.7%, the expected $NO_x$ emissions—assuming all of the fuel-bound $N_2$ is converted to $NO_x$—would be 1,000-2,500 ppm at 7% $O_2$. As noted earlier, however, actual emissions are generally between 220 and 320 ppm at 7% $O_2$, indicating that perhaps 10-30% of the fuel $N_2$ is converted to $NO_x$, with most of the remainder forming $N_2$.

A number of evaluations of MWC $NO_x$ emissions data have attempted to define the role of $N_2$-containing materials in MSW (e.g., grass, leaves, wood, and food wastes) on $NO_x$ emissions. The first of these evaluations was presented in 1987 and suggested that fluctuations in measured $NO_x$ levels were attributable to seasonal fluctuations in MSW composition. This evaluation was based on $NO_x$ compliance test data obtained from a number of MWCs in the U.S. and overseas at different times of the year, and concluded that the seasonal variations in measured $NO_x$ concentrations might be the result of variations in the amount of yard waste in the MSW at different times of the year. A similar comparison of $NO_x$ emission concentrations versus time of year for a number of U.S. MWCs compiled by EPA in 1989 to support the MWC NSPS did not show any significant relationship between $NO_x$ concentration and time of year.

A more recent evaluation of $NO_x$ continuous emission monitor data from 11 MWCs located in the northeast U.S. found no seasonal variations in $NO_x$ concentrations. This evaluation compared monthly average $NO_x$ data from the individual MWCs (covering 12-36 consecutive months of operation for each unit) with the estimated fraction of yard waste found in northeastern MSW during each of the four seasons. Monthly average $NO_x$ concentrations from these units varied from

* Unless otherwise noted, all $NO_x$ concentrations used in this summary are corrected to 7% $O_2$ and are on a dry basis.

140 to 310 ppm but did not show any consistent relationship between $NO_x$ concentrations and the estimated percentage of yard waste.

Yet another evaluation compared $NO_x$ concentrations measured during nine test runs conducted at the MB/WW MWC in Burnaby, British Columbia, to the amount of high-$N_2$ organics (grass, leaves, brush, stumps, wood, food waste, textiles, rubber, and footwear) in the MSW fired during each run. During these tests, high-$N_2$ organics accounted for 25-47% and yard waste accounted for 4-30% of the total waste stream. The estimated average $N_2$ content of the entire stream during each run ranged from 0.34 to 0.66%. $NO_x$ concentrations in the flue gas during the runs varied from 261 to 304 ppm. Statistical analysis of the MSW and flue gas data from each run showed no relationship (at a screening 80% confidence level) between $NO_x$ concentrations and MSW characteristics. The data suggest that, because of the staged-combustion design of the Burnaby MWC and other modern MB/WW MWCs, variations in $NO_x$ emissions appear to be attributable to differences in combustor design and operation, rather than waste composition.

## $NO_x$ Control Technologies

$NO_x$ control technologies can be divided into two subgroups: combustion controls and post-combustion controls. Combustion controls limit the formation of $NO_x$ during the combustion process by reducing the availability of $O_2$ within the flame and lowering combustion zone temperatures. These technologies include staged combustion, low excess air, flue gas recirculation (FGR), and NGI. Staged combustion and low excess air reduce the flow of undergrate air in order to reduce $O_2$ availability in the combustion zone. Another option is FGR in which a portion of the combustor exhaust is returned to the combustion air supply to both lower combustion zone $O_2$ and suppress flame temperatures by reducing the ratio of $O_2$ to inerts [$N_2$ and carbon dioxide ($CO_2$)] in the combustion air system. One or more of these approaches are used by most modern MWCs. Test data for these techniques indicate that they can reduce $NO_x$ concentrations by 10-30% compared to baseline levels from the same units. For NGI, two processes have been developed: (1) Methane de-$NO_x$℠ uses gas injection to inhibit $NO_x$ formation and (2) reburning uses gas injection to create reducing conditions that convert $NO_x$ formed in the primary combustion zone to $N_2$.

The most used post-combustion $NO_x$ controls for MWCs include SNCR and SCR. SNCR reduces $NO_x$ to $N_2$ without the use of catalysts. With SNCR, one or more reducing agents are injected into the upper furnace of the MWC to react with $NO_x$ and form $N_2$. SNCR processes include Thermal DeNO$_x$™, which is based on ammonia ($NH_3$) injection, $NO_x$OUT™, which uses urea injection, and the addition of urea followed by methanol. Thermal DeNO$_x$ and $NO_x$OUT have been used predominantly to date.

SCR is an add-on control technology that catalytically promotes the reaction between $NH_3$ and $NO_x$. SCR systems can use aqueous or anhydrous $NH_3$, with the primary differences being the size of the $NH_3$ vaporization system and the safety requirements.

## Technical Approach

This assessment was conducted using information obtained from published literature and contacts with technology vendor and MWC industry personnel. For each technology, information was collected on the key process variables; commercial applications in Europe, Japan, and the U.S.; recent research and development activities; and costs. In addition to the current versions of NGI and SNCR, advanced concepts for the two technologies were examined, including advanced NGI (which combines conventional NGI and SNCR) and advanced SNCR (which employs additional process control equipment to enhance conventional SNCR performance). This information was then used to develop a series of computer-based spreadsheets designed to maintain basic material and energy balances for the technology and to calculate technology costs.

The output from these spreadsheets is presented in two formats. The first format is a table presenting capital costs, tipping fee impacts, and cost effectiveness levels** for each $NO_x$ control technology as a function of MWC size and a second key technology variable. An example of this output, based on conventional SNCR, is shown in Table 1. For example, the estimated capital cost for SNCR operating at 60% $NO_x$ reduction on a 400 ton per day (tpd) MWC is $1,980/tpd of capacity. For the same $NO_x$ reduction level and MWC size, the tipping fee impact is estimated at approximately $1.50 per ton of MSW processed, and the cost effectiveness is approximately $1,270 per ton of $NO_x$ removed from the flue gas.

The second output format is a graph showing the sensitivity of tipping fee impact and cost effectiveness to key process variables. An example of this output, also based on conventional SNCR, is presented in Figure 1. For example, the process variable having the greatest effect on cost is MWC size. Compared to the 400 tpd "reference" MWC, reducing plant size to 100 tpd increases the tipping fee impact from roughly $1.50 per ton of MSW to almost $4.00 per ton (shown on the left Y-axis), and increases the cost effectiveness value from $1,270 per ton of $NO_x$ removed to $3,380 per ton (shown on the right Y-axis).

## Technical Status of Evaluated Control Technologies

The technical status of each evaluated control technology is summarized in Table 2. As noted, two NGI processes have been developed. Methane de-$NO_x$ uses gas injection to inhibit $NO_x$ formation and appears capable of reducing $NO_x$ emissions from MWCs by approximately 60%. The second approach, reburning, uses gas injection to create reducing conditions that convert $NO_x$ formed in the primary combustion zone to $N_2$. Because of the relatively high temperatures required for these $NO_x$-reduction reactions, it may be difficult to successfully apply reburning to modern MB/WW MWCs. Short-duration tests of these processes have been conducted at MWCs in the U.S. and Europe. However, neither process has been adequately developed and demonstrated to be considered ready for commercial applications.

Both SNCR processes (Thermal DeNO$_x$ and $NO_x$OUT) and SCR are considered to be commercially available. Long-term $NO_x$ reductions are 45-65% for SNCR and 80-90% for SCR. Operation of these processes near the upper end of their performance range can result in unwanted emissions of unreacted $NH_3$ or other by-product gases. An advanced version of SNCR using furnace pyrometry and additional process controls has been tested on at least two MWCs and appears capable of achieving high $NO_x$ reductions with less reagent than is needed for conventional

**Capital costs include purchased equipment costs, installation, engineering and home office expenses, and process and project contingencies. Tipping fee impact is calculated by dividing the technology's total annualized cost by the annual tonnage of MSW processed. Tipping fee impact is an incremental cost that indicates the potential cost of the technology on the MSW generator. However, it does not necessarily reflect the amount by which the plant's tip fee will increase as a result of applying the control technology. Cost effectiveness is calculated by dividing the technology's total annualized cost by the tonnage of reduced $NO_x$ emissions and indicates the cost of the control relative to its environmental benefit.

**Table 1.** *Model Plant Cost Estimates for Conventional SNCR* [a]

| | Total Capital Cost ($1000/TPD Capacity) | | | Tipping Fee Impact ($/ton MSW) | | | Cost Effectiveness ($/ton $NO_x$) | | |
|---|---|---|---|---|---|---|---|---|---|
| $NO_x$ Reduction (%) | 45 | 60 | 65 | 45 | 60 | 65 | 45 | 60 | 65 |
| 100 TPD Mass Burn MWC | 5.05 | 5.06 | 5.07 | 3.74 | 3.91 | 4.06 | 4,308 | 3,378 | 3,235 |
| 400 TPD Mass Burn MWC | 1.97 | 1.98 | 2.00 | 1.30 | 1.47 | 1.62 | 1,496 | 1,268 | 1,289 |
| 750 TPD Mass Burn MWC | 1.49 | 1.50 | 1.52 | 0.92 | 1.09 | 1.24 | 1,058 | 940 | 986 |

[a] *$/ton can be converted to $/Mg by multiplying by 1.1.*

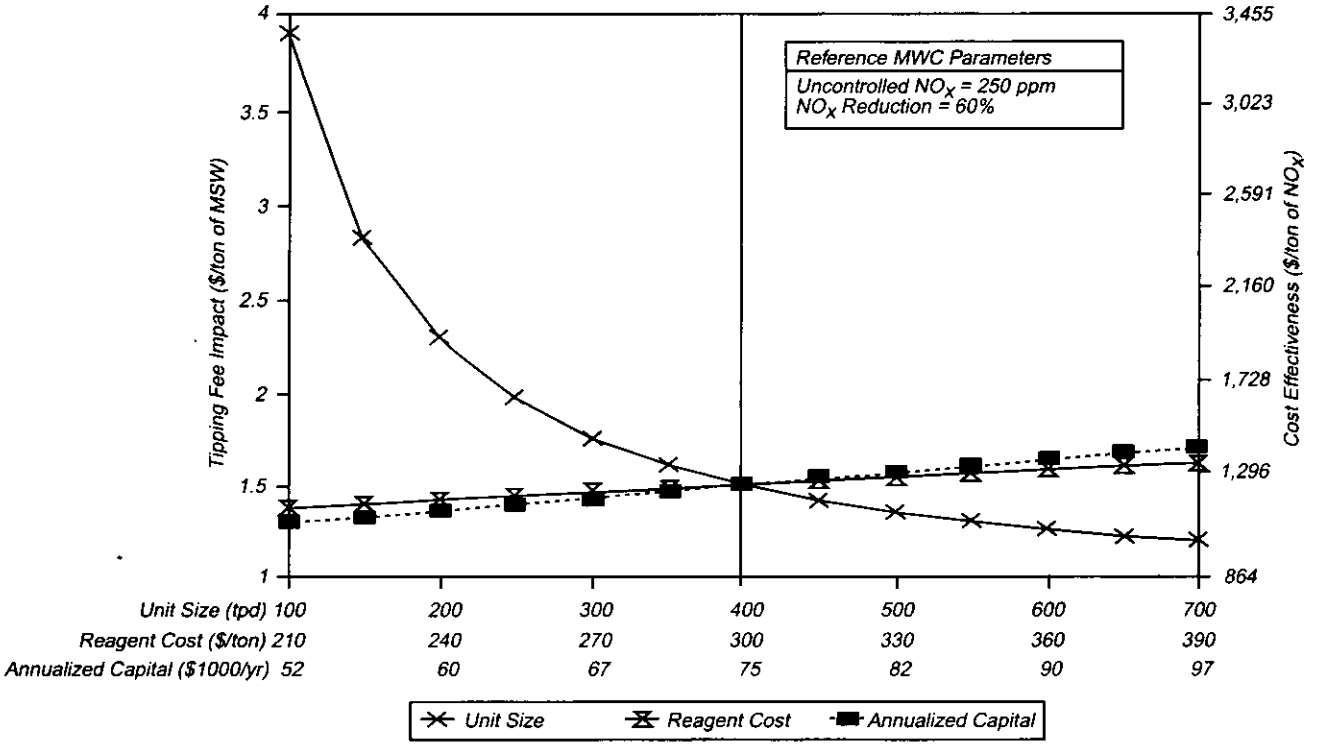


***Figure 1.*** *Effect of unit size, reagent cost, and annualized capital on tipping fee impact and cost effectiveness for conventional SNCR.*

SNCR. Combining NGI and SNCR to achieve an overall $NO_x$ reduction of 80 - 85% may be feasible but will require testing to evaluate the interactions between the temperature and residence time requirements of each technology.

## Comparative Costs of Evaluated Control Technologies

As part of this study, cost evaluations were conducted for several variations of NGI, SNCR, and SCR. For the evaluation of NGI, two scenarios were examined. The first scenario, referred to as NGI-100, assumes the MWC is firing MSW at 100% of its design heat input capacity. Therefore, under this scenario, the rate of waste fired must be reduced by an amount comparable to the heat input from natural gas. This results in a reduction of tipping fee revenues. The second scenario, referred to as NGI-85, assumes that the MWC is firing MSW at 85% of its design heat input capacity because of insufficient MSW flow or because the unit was designed with excess heat input capacity. In this case, natural gas can be used to reduce $NO_x$ emissions without displacing any waste and, therefore, without a loss of tipping fee revenues. The average $NO_x$ reduction assumed in both scenarios is 60%.

Four variations of SNCR technology were examined: (1) conventional SNCR, with an average $NO_x$ reduction of 60%, (2) advanced SNCR, with an average $NO_x$ reduction of 60% with lower reagent use compared to conventional SNCR, (3) a second advanced SNCR option with a $NO_x$ reduction of 70% at a higher reagent feed rate, and (4) advanced NGI, which combines conventional NGI with conventional SNCR to achieve a $NO_x$ reduction of 80%. The SCR evaluation focused on a cold-side system with a $NO_x$ reduction level of

*Table 2. Technical Overview of Evaluated $NO_x$ Control Technologies*

| Technology | Commercial Status | $NO_x$ Control Performance | Technical Issues |
|---|---|---|---|
| NGI: Methane $deNO_x^{SM}$ | Tested on MWC in Olmsted County, Minnesota. | Testing achieved up to 60% $NO_x$ reduction without increasing CO emissions. | Scaleup of technology to larger furnaces (> 100 tpd). |
| NGI: Reburning | Applied to fossil fuel boilers; use on MWCs limited to test program in Malmo, Sweden. | MWC testing encountered high CO levels when $NO_x$ reductions exceeded 30 - 40%. | Reburn zone temperatures in MWCs may be too low for $NO_x$ reduction reactions. |
| SNCR: Thermal $DeNO_x^{TM}$ | Applied to six MWCs in U.S. plus others overseas. | Achieved short-term reductions of 45 - 75%, depending on $NH_3$ injection rate. Plume visible at higher reduction levels. | Impact of furnace temperature swings on $NO_x$ and $NH_3$ emissions. Control of $NH_3$ slip and visible plume. |
| SNCR: $NO_xOUT^{TM}$ | Applied to two MWCs in U.S. plus others overseas. | Comparable to $NH_3$ injection. | Similar to $NH_3$ injection. $N_2O$ emissions also of concern. |
| Advanced SNCR (improved process control) | Tested at MWCs in Lancaster, Pennsylvania, and Munich, Germany. | Achieved 60 - 75% $NO_x$ reduction with less reagent than is needed with conventional SNCR. Plume visible at higher reduction levels. | Demonstration of long-term performance capability. Additional process controls may benefit other combustor operations. |
| Advanced NGI (conventional NGI plus SNCR) | Concept only. | Potential for 80% reduction. | Interaction of temperature and residence time needs for each technology. |
| SCR | Installed at 20 MWC plants in Europe and Japan. | 80 - 90% $NO_x$ reduction. | Catalyst life in hot-side systems. |

80%. A limited evaluation of a hot-side SCR system was also conducted.

Costs for the different control technologies are compared in Figures 2, 3, and 4. Figure 2 presents the capital costs for each of the technologies. The advanced SNCR system with the 70% $NO_x$ reduction and the hot-side SCR system are not represented, since only a limited analysis of these scenarios was conducted. As shown by the figure, the capital costs for each of the technologies increase with increasing unit size. SCR is the most capital intensive of the technologies, costing 4 to 5 times more than the next highest technology. Advanced SNCR and advanced NGI have the next highest capital costs, with both technologies estimated to cost $1 to 2 million per combustor. The capital costs associated with NGI and conventional SNCR are comparable, at less than $1 million per combustor.

The tipping fee impacts and cost effectiveness values presented in Figures 3 and 4, respectively, include both annualized capital costs and operating and maintenance costs. Conventional SNCR generally has the lowest costs of the technologies. NGI-100 has the highest tipping fee impacts for all but the 100 tpd MWC, for which SCR has slightly higher costs. Cost effectiveness values for NGI-100 are the highest for all combustor sizes. Both of the NGI-100 and NGI-85 scenarios result in an incremental cost increase; however, the revenue loss associated with diverting MSW when firing natural gas under NGI-100 results in much higher costs for this control technique. These revenues are not lost with the NGI-85 scenario, plus revenues are received under this scenario from sale of additional electrical production. The other key variable affecting both NGI scenarios is the price of natural gas. The average gas price used in these figures is $3.50/$10^6$Btu.

The high tipping fee impacts and cost effectiveness values with SCR result from the high capital costs for this technology, as well as from the cost of catalyst replacement and disposal. Advanced SNCR and advanced NGI have higher costs than NGI-85 applied to the small combustor size but are fairly similar when applied to the medium and large combustor sizes.

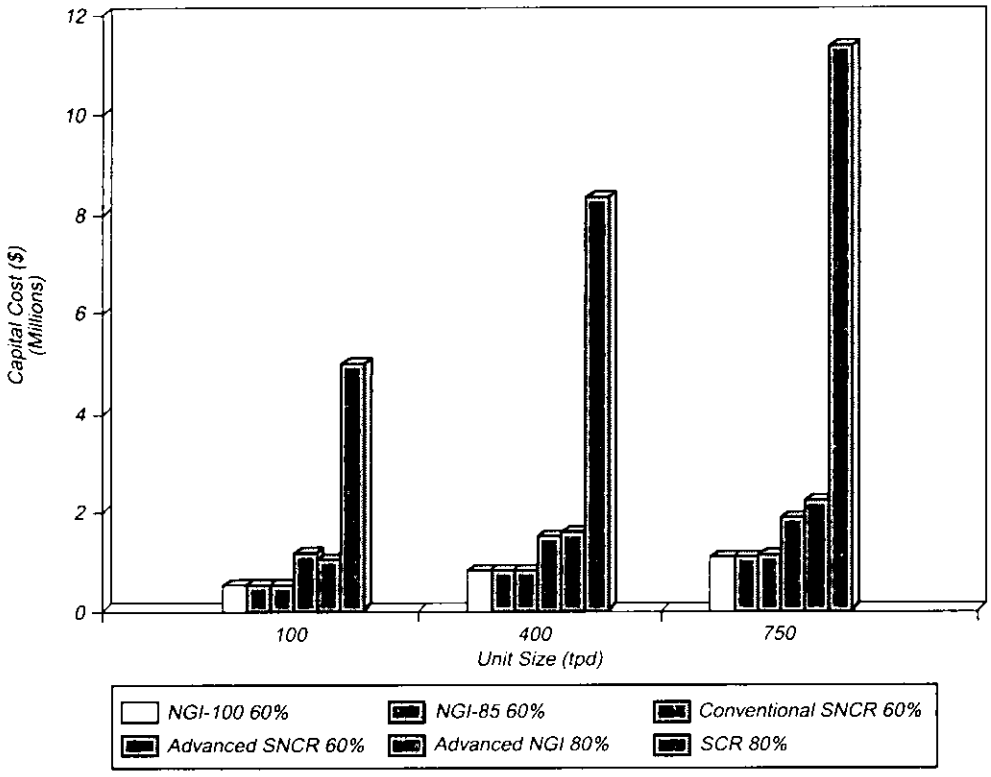


***Figure 2.*** *Comparison of capital cost.*

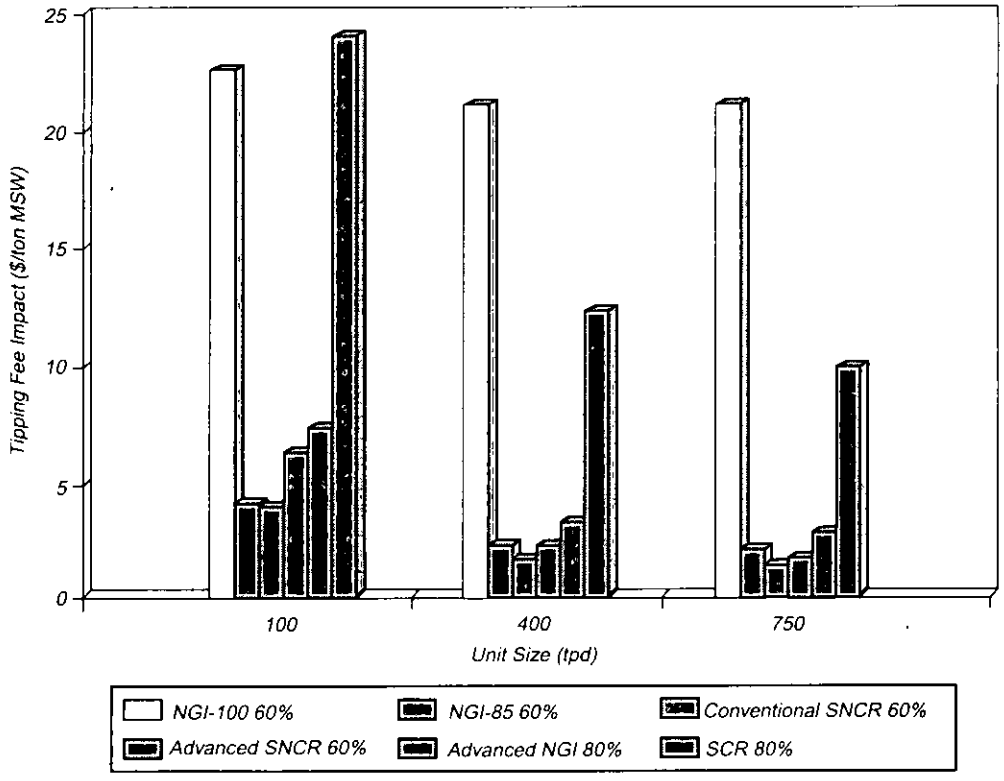


***Figure 3.*** *Comparison of tipping fee impact.*

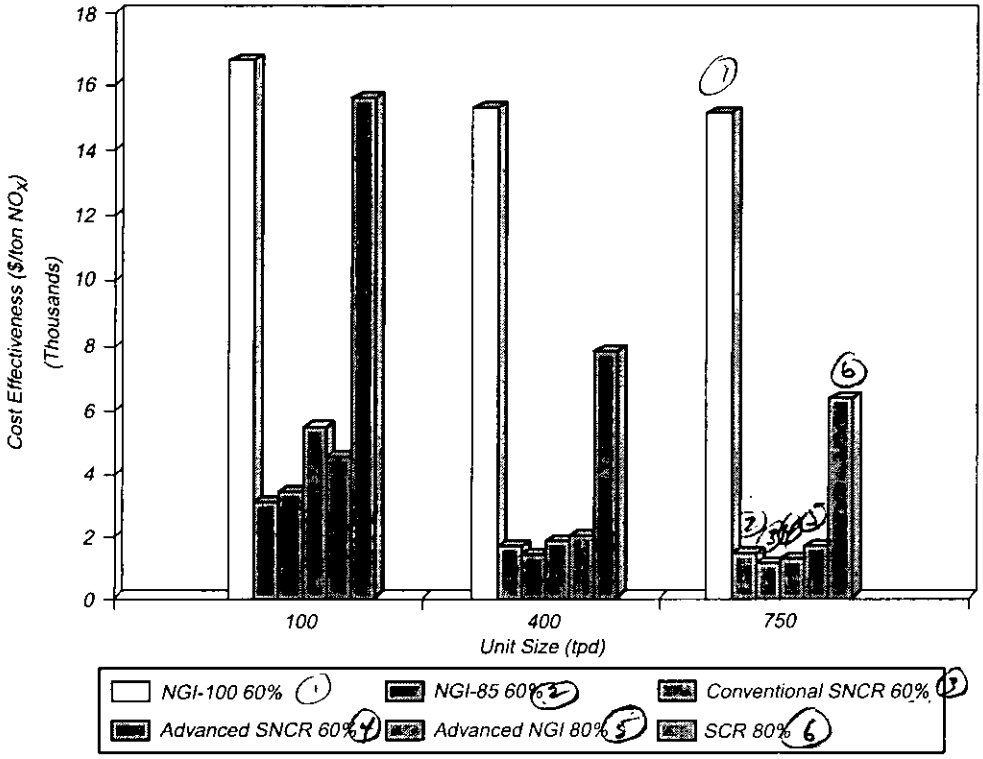


***Figure 4**. Comparison of cost effectiveness.*

(1) = NATURAL GAS INJECTION @ 100% NT INPUT & 60% NOX reduction

(2) NATURAL GAS INJECTION @ 85% NT INPUT & 60% NOx REDUCTION

(3) CONVENTIONAL SNCR @ 60% reduction

(4) ADVANCED SNCR (LOW AMMONIA SLIP) @ 60% Reduction
→ not including ignition of flue gas

(5) NATURAL GAS INJECTION.. PLUS SNCR = 80% NOx Reduction

(6) SCR @ 80% Reduction

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***James D. Kilgroe** is the EPA Project Officer (see below).*
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Feature

# Can Utility Deregulation Subsidize Clean Air Retrofits at WTE Facilities in Your State? It Has in Massachusetts, but Not Without Problems

By John Merritt

Electric-utility restructuring has a variety of important implications for waste-to-energy (WTE) facilities and, therefore, for the municipalities that contract with or operate these facilities. Among them are impacts on existing power purchase contracts, emerging new markets for sale of generated power, and whether or not WTE will be considered a "renewable energy" source with respect to mandated fractions of state or federal portfolios of energy production. In Massachusetts, there is an additional interesting and creative outcome of the state's statute restructuring the electric utilities. That new element is the creation of a trust fund by establishing a mandatory surcharge on most power sold in the state, a portion of which is being used to assist municipalities facing escalating tipping fees as a result of retrofits required under the Clean Air Act. This fund has been titled the Massachusetts Renewable Energy Trust Fund (RETF).

The RETF experience in Massachusetts is worth reviewing from two key perspectives. First, to determine if a similar program might make sense in other jurisdictions currently developing utility-restructuring legislation. Second, to review actual issues that arose during the creation and implementation of the RETF in Massachusetts in order to avoid similar problems in new programs. To this end, this article will provide a brief history of the Massachusetts fund creation, delineate key provisions that apply to WTE facilities, discuss actual issues that arose during program implementation, describe the financial benefits to municipalities, characterize the current status of the fund, and make recommendations for others who would seek to establish a similar program elsewhere.

**Brief History of the Massachusetts RETF**

During the mid-'90s, representatives of a regional consortium of

Massachusetts communities, facing stiff Clean Air Act retrofit costs at their WTE disposal facility, joined with other interested parties to lobby the legislature to establish a fund to offset some of those costs as part of the restructuring of the electric-power industry in the state.

Prior to passage of Massachusetts's restructuring statute in 1997, taxpayers in many communities using WTE as their primary means of disposal were already facing the high costs of retrofits typical of facilities across the country, many of which were constructed in the '80s. They viewed the coming restructuring bill as an opportunity to find some funding relief. The tack was to make a strong case for WTE as renewable and worthy of support. Retrofit costs were characterized as a burden that could threaten the viability of some facilities and hence remove one or more renewable sources of energy.

The proponents of the fund were successful, and the bill included Section 68: *"There is hereby established and set up ... a separate trust fund to be known as the Massachusetts renewable energy trust fund ... for the public purpose of generating the maximum economic and environmental benefits over time from renewable energy to the ratepayers of the commonwealth...."* And thus the RETF was established. The revenue to fund the trust is derived from a "renewables charge" currently itemized on every consumer's electric bill, except customers of municipal power companies. The language establishing the authority for collecting the money to implement this fund is found in Section 20: *Beginning on March 1, 1998, the department is hereby authorized and directed to require a mandatory charge per kilowatt-hour for all electricity consumers of the commonwealth, except those consumers served by a municipal lighting plant which does not supply generation service outside its own service territory or does not open its service territory to competition at the retail level, to support the development and promotion of renewable energy projects in accordance with the provisions of section 4E of chapter 40J. Said charge shall be the following amounts: three-quarters of one mill ($0.00075) per kilowatt-hour in calendar year 1998; one mill ($0.001) per kilowatt-hour in calendar year 1999; one and one-quarter mill ($0.00125) per kilowatt-hour in calendar year 2000; one mill ($0.001) per kilowatt-hour in calendar year 2001; three-quarters of one mill ($0.00075) per kilowatt-hour in calendar year 2002; and one-half of one mill ($0.0005) per kilowatt-hour in each calendar year thereafter.*

In spring 2000, the process of implementing the Massachusetts RETF began, with the goal of distributing approximately $50 million to eligible municipalities in accordance with the provisions of the new statute. The process ultimately involved the Massachusetts Technology Collaborative (MTC), the responsible state agency charged with administering the RETF, state legislators, and more than 125 municipalities and their organizations and representatives. After more than six months

and an elaborate dispute resolution process, a distribution formula was finally agreed upon. Grant funds will begin flowing to eligible communities during 2001.

**Key Provisions**

The following paragraph provides the basis for WTE ratepayer assistance for retrofits:

*In calendar year 1998 through calendar year 2002, the revenues derived from one-quarter of one mill ($0.00025) of the charge assessed pursuant to the preceding paragraph in each such year shall be set aside and expended pursuant to implementing the provisions of paragraph (2) of subsection (i) of section 4E of chapter 40J.*

The cited "paragraph (2)," which carves out retrofit funds, follows:

*(2) The board shall make available from monies in the fund in accordance with subsection (a) grants to municipalities and other governmental bodies to provide debt service assistance in conjunction with alleviating payment obligations incurred by said municipalities and other governmental bodies through an existing contractual agreement pursuant to the installation of pollution control technology and the implementation of other operational improvements to existing renewable energy projects and facilities in the commonwealth utilizing waste-to-energy technology as a component of municipal solid waste plant technology in commercial use, or the closure of any such existing facilities.*

The section delineates a fairly long list of activities eligible for the balance of the funds provided. However, WTE receives the only specific earmarking of a set fraction of the funding. The other activities eligible for support are delineated as follows:

*For the purposes of expenditures from the fund, renewable energy technologies eligible for assistance shall include the following: solar photovoltaic and solar thermal electric energy; wind energy; ocean thermal, wave, or tidal energy; fuel cells; landfill gas; waste-to-energy which is a component of conventional municipal solid waste plant technology in commercial use; naturally flowing water and hydroelectric; low emission, advanced biomass power conversion technologies, such as gasification using such biomass fuels as wood, agricultural, or food wastes, energy crops, biogas, biodiesel, or organic refuse-derived fuel; and storage and conversion technologies connected to qualifying generation projects; provided, however, that expenditures related to waste-to-energy projects or facilities shall be limited to funds segregated pursuant to paragraph (2). Such funds may also be used for appropriate joint energy efficiency and renewable projects, as well as for investment by distribution companies in renewables and distributed generation opportunities, if consistent with the*

*provisions of this section. The following technologies or fuels shall not be considered renewable energy supplies: coal, oil, natural gas except when used in fuel cells, and nuclear power.*

So it is fair to say that this provision, coupled with WTE's likely inclusion in the mandated Renewable Portfolio Standard currently in the final stages of being established, represents a pretty good recognition of these facilities as an integral part of not only Massachusetts's waste management infrastructure, but also its valued renewable-energy generation.

**Language That Led to Difficulties in Implementation**

As mentioned in the introduction, certain aspects of the language adopted by the legislature led to problems during implementation of the grant fund. The key language to review is found above as "paragraph (2)."

This language includes two key ambiguous phrases, which ultimately required a difficult and confrontational process to determine exactly what formula for fund distribution would be not only consistent with this troublesome language, but also fair to all communities impacted by air-pollution-control retrofit expenses. Those phrases are "debt service assistance" and "an existing contractual agreement pursuant to the installation of pollution control technology and the implementation of other operational improvements."

The parties that lobbied for the legislation did not consult widely with potentially impacted stakeholders at other facilities in the state before moving forward. As a result, this ultimately very troubled language was drafted because it seemed to fit what they believed would be the specific profile of their impacted facilities when implemented by the MTC. However, when all eligible stakeholders began to review the circumstances at their facilities, it became immediately apparent that more care should have been given to drafting the language establishing eligibility.

**Initial Stakeholder Meetings**

An effort to start the process of identifying an appropriate grant fund eligibility process began with only certain parties included. Representatives of facilities that initially sought this legislative relief invited representatives of some, but not all, municipalities with contractual relationships with WTE facilities in the state to initiate a "stake-holder process." This process was independent of, but included some consultation with, the MTC, which has ultimate responsibility for establishing and implementing the RETF. The meetings were an attempt to provide a distribution formula and a speedy basis on which MTC could move forward.

Because of ambiguity in the previously cited language, early in that process, however, these meetings led to substantial

disagreement among representatives of several facilities. In addition, parties representing certain of those communities that sought the legislation in the first place made claims in these public meetings that they were "entitled" to up to half of all available grant funds simply because of their role in seeking the legislation. Given that the fund was built on contributions from virtually everyone that paid an electric bill in virtually every community in the state, however, claims such as that were met with extremely negative reactions from the stakeholders who would have been left to split up the remains. It became clear fairly early that this series of meetings would not reach an amicable resolution of key fund-distribution issues.

**Final Stakeholder Process**

As a result of the severe breakdown in this early, independent stakeholder process, most parties to the discussion felt a more balanced approach would be necessary. Therefore requests were made to the legislators of several communities unhappy with the direction these talks were taking to intervene and ensure that a fair process evolved. Several legislators did formally request that MTC ensure that a fair and balanced approach to grant fund distribution be established. Based upon the unfortunate result of the early and limited stakeholder meetings and the requests from legislators, MTC moved aggressively to establish a new stakeholder process early in 2000. Elements of their comprehensive approach included employing the services of a professional dispute resolution firm and legal, accounting, and technical firms. From this point forward, MTC and its team took firm control of the implementation process.

There were several key objectives to be addressed. First, eligibility requirements consistent with the statutory language would need to be determined. Once a fair basis for eligibility was established, claims by all facilities needed to be measured in light of the established eligibility criteria. Second, a specific mechanism for stakeholders had to be established to formally apply for and be granted funds from the trust.

Once the new process was initiated, MTC made very substantial outreach efforts to ensure that every municipality that might be included in these discussions would have a place at the table. Without making this important effort, not undertaken in the abortive early stakeholder process, potentially eligible parties left out of the process could have challenged any negotiated agreement. By the end of the process, contract communities at all six currently existing WTEs and one that closed were represented and took part in extensive discussions and negotiations resulting in a comprehensive agreement. It was clear early in the process that the universe of possibly eligible retrofit expenditures was far larger than the total funds that would likely be generated into the trust, based on the legislative formula in the restructuring bill. Therefore, identifying the totality of eligible calls on the fund, so an appropriate distribution

formula could be established for each eligible community, became the primary focus of all stakeholders participating in the process.

**Specific Issues Addressed**

As mentioned above, the issues of what constitutes "debt service assistance" or "an existing contractual agreement pursuant to the installation of pollution control technology and the implementation of other operational improvements" provided the basis for some of the most difficult discussions regarding "legislative intent" and how it should be translated into eligibility.

The initial petitioners that sought the legislation argued that their intention was to only provide funds for retrofits that would be required by the latest clean-air requirements. However, representatives of facilities that had already paid for pollution-control equipment at earlier points in their facility's history argued that it would be unfair for them not to receive some of the financial benefits promised by the RETF simply because they had already been good citizens and paid for improvements.

It is somewhat unclear why the term "debt service assistance" was included in the statute's language. However, its presence required a very interesting legal and financial analysis of all the projects before an approach that was acceptable to all stakeholders was identified. In short, it was determined that any community that had a contract at any time to pay tip fees to any facility that used *any* debt to install pollution control equipment could be eligible for grant funds.

Once that milestone was achieved and agreed upon, the task remained to establish an equitable formula for division of the available grant funds, which were not sufficient to meet 100% of the aggregate pollution-control equipment installation expenses identified at all facilities. The solution that was finally agreed upon totaled all such expenses and determined a proration for each facility, based upon the funds actually available. A mechanism was also included to give credit for other steps taken at all facilities, such as battery separation programs mandated by the Massachusetts Department of Environmental Protection. Finally, further distribution formulae were established should more funds become available through the program. Toward that end, the stakeholders are reviewing the possibility of asking the legislature for amendments to the program that might expand the amount of funds available to stakeholder communities.

An essential element of the negotiated stakeholder agreement on all of these issues was the fact that all claims would be subject to independent technical and financial review by the specialists hired by MTC for this purpose. This vetting has to take place for every claim before any funds are granted to communities.

With these key elements agreed upon, MTC has established a grant application process that should result in funds being received by some communities during 2001. A key requirement for any grant is that the retrofit or other eligible activity be fully implemented or completed, so the technical and financial review can be final.

**Financial Impacts on Communities**

The total amount currently estimated to be collected and earmarked for WTE retrofit funding is approximately $50 million. The share of the fund for which the author's community is eligible to receive grant reimbursement will be approximately $400,000 when all facility retrofit construction is completed. This is a fairly typical outcome for the 100-plus communities that have eligible claims under this program.

**Conclusions**

Once a process was established for a fair and balanced application of this statute, there is no question that substantial, actual relief for taxpayers bearing the burden of retrofit expenses at their WTE facility has been achieved. The approach can be seen as justified because of the renewable energy source that WTE represents, as well as the fact that the clean-air retrofits benefit all that breathe the air in Massachusetts.

With respect to improving the process that unfolded with the Massachusetts RETF, the key conclusion to be drawn is how important it is to carefully consider the language that will determine eligibility for expense relief for any identified pollution-control construction or other activities. Efforts must be focused on what method(s) might be employed to identify not only all eligible types of pollution-control improvements, but also how to unambiguously identify which communities or stakeholders are eligible to receive reimbursement.

A far better approach for others to follow might be to include all potential stakeholders at the earliest possible point and include them in all discussions from the earliest efforts to draft and lobby for passage of relief language. The failure to proceed in this fashion will almost inevitably result in the sorts of disputes that arose when the availability of millions of dollars in grant funds became generally known. This effort would obviate at least some of the stakeholder problems that arose during the Massachusetts experience as well as provide the widest possible base of community and legislator support for such relief during the lobbying period.

For current details on the implementation of this program in Massachusetts, the MTC Web site provides a great deal of public information at www.mtpc.org/massrenew/wastetoenergy.htm. For further

information or referrals to key participants in the Massachusetts process, contact the author by e-mail at jam@merrittcom.com or by phone at 508/655-4951.

*John Merritt is principal with Merritt Communications in Natick, MA.*

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*This article addresses the question—Amidst the changes in garbage flow, where does waste-to-energy fit?—by looking at both elements of WTE: waste disposal and energy generation.*

# Is the Waste-to-Energy Industry Dead

**By Eileen B. Berenyi and Marc J. Rogoff**

By Eileen B. Berenyi and Marc J. Rogoff





The solid waste industry has been undergoing great change for a number of years. Many companies have merged, and now a handful of full-service firms dominates solid waste collection and disposal. In conjunction with industry consolidation, the policies and politics of solid waste disposal have been shifting and reshifting. The specter of the "garbage barge" of 1993—plying the waters, looking for a place to dispose of waste—was replaced by landfills and other disposal facilities that, since 1995, have been bidding aggressively for waste and pushing disposal rates lower and lower in many regions. As of early 1999, the garbage barge has resurfaced as a symbol, again becoming a rallying cry of states seeking to stop the flow of garbage across their borders. Where does WTE fit in? Is it in its final death throes or are there signs of future life?

The WTE industry emerged from a twofold need in the 1970s: (1) the necessity of finding an environmentally sound means of disposing of refuse and replacing unregulated open dumps and (2) a need to develop alternative energy resources in the era of

the Arab oil embargoes, when it was thought that energy would be a scarce commodity and prices would continue to rise uncontrollably.

WTE facilities are primarily waste-disposal alternatives. Policy changes and industry shifts have undermined the position of many WTE facilities. First, a shortage of waste-disposal facilities, so feared in the early 1990s, did not materialize. Intense efforts to recycle, the construction of large new landfills, or the permitted expansion of existing landfills helped to mitigate the problem. Second, state and federal regulations originally favored WTE as a safe and environmentally sound alternative to landfills and an energy conservation method to boot. Federal incentives included grants for feasibility studies and pilot projects, investment tax credits, favorable tax treatment for equipment depreciation, and permitting many facilities to be publicly financed, so as to reduce interest rate burdens. After 1986, most of these regulatory incentives disappeared or were substantially curtailed. Recycling and source reduction have become the focus of many local policy initiatives. From the standpoint of waste disposal, policy initiatives have centered on achieving environmentally sound disposal, whether in a landfill or at a municipal waste combustor (MWC) facility. In addition, the control of the negative impacts of waste incineration and air pollution from these facilities became a major goal of federal regulations. Third, as the result of the 1994 US Supreme Court ruling in *Carbone* v. *Town of Clarkstown*, waste has been freed from any public regulation that impedes the cross-border interstate commerce of it.

As of 1999, there have been immense shifts in energy pricing and demand and waste generation and disposal. From the standpoint of energy, two major events have had a major impact on the power industry. First, the price of oil was at its lowest point in the beginning of 1999 since before the Arab oil embargo—$18/barrel as compared to its high of $35/barrel in 1978. In addition, natural-gas prices have dropped precipitously and are also at an all-time low. Dropping oil prices have spelled the death knell for the Public Utilities Regulatory Policies Act of 1978 (PURPA) and other state programs that have kept the price of electricity from WTE projects above avoided cost. Second, beginning in 1997, various states have begun to deregulate public utilities. Deregulation is changing the organization of energy generation and transmission, impacting pricing structures and helping to drive down energy prices and make the long-term institutional structure of energy generation cloudy or unstable. Thus, from the perspective of a WTE facility, the market for its product—energy—is undergoing change and is volatile in the near term.

It is in the midst of these developments that this article discusses the future of the WTE industry. In so doing, it will review the policy context and then examine the impact of policy and practice on the current state of the industry. As can be determined from

the introduction, the near-term prognosis of growth is not good. In most cases, facilities are finding it difficult to be price competitive for disposal. In addition, WTE does not have strong policy or political support. However, it is premature to prophesize an end to this industry in the long term.

## Review of Recent Legislative, Regulatory, and Judicial Initiatives

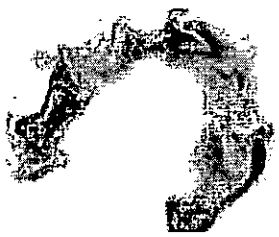
### *Clean Air Act Amendments*

In November 1990, Congress enacted the amendments to the Clean Air Act (CAA) of 1977. These amendments directed EPA to develop new emission guidelines for existing MWCs and New Source Performance Standards for new MWC facilities. Five years later, after much discussion, EPA published air-emissions guidelines for existing MWCs. The new guidelines covered not only large facilities (plant capacity greater than 248 tpd) but also contained requirements for smaller facilities. Though the requirements regarding smaller facilities were under challenge, they have been modified and are being implemented in 1999.

In sum, the new regulations require an aggressive approach to the reduction of toxic emissions through a combination of air-pollution-control (APC) systems, improved monitoring of emissions, application of tested combustion methods, training of personnel, and front-end materials-separation programs. Numerical limits were set for sulfur dioxide, hydrogen chloride, cadmium, lead, and mercury emissions. In addition, more stringent limits were set for dioxins and furans as well as for nitrogen oxides and fugitive fly and bottom ash. Facilities must adopt maximum-achievable control technology to reach acceptable levels of air emissions and must install continuous emissions monitoring systems. The deadline for large facilities to meet these criteria is 2000.

The result of this renewed emphasis on air-emissions control has been twofold: (1) certain smaller, older projects have shut down, calculating that it was no longer economically feasible to continue to operate given the large capital investment necessary to comply with new federal regulations and (2) existing projects have been undergoing or are planning significant upgrades to their APC systems, as will be discussed in a later section.

### *Changing Regulations Affecting Project Financing*



As of 1999, the Tax Reform Act of 1986 and its various effects are "ancient history" for the MWC industry. As will be shown, the act caused severe downward pressure on the industry since it hampered the availability of low-cost capital and curtailed

the favorable tax treatment afforded the industry. In essence, with the removal of tax protection, MWC facilities had to rely more heavily on tip fees and revenues generated from energy sales. Since 1994, tip fees in general have faced tremendous downward pressure. The same has been true for revenues derived from the sale of electricity.

Since 1978, MWC facilities had enjoyed favorable pricing of electricity. As a result of the Arab oil embargoes of 1973 and 1978, Congress passed PURPA. This law, which is overseen by the Federal Energy Regulatory Commission (FERC), requires utilities to buy power from MWC projects. FERC does not set the purchase price, but states that utilities must purchase energy at a "fair and reasonable" price. In practice this has come to mean "avoided cost"—the utilities' marginal cost of the production or purchase of energy. In addition, individual states passed legislation to support this act, at times setting a rate or a minimum price to which utilities must adhere in the purchase of energy from these facilities. Long-term power sales contracts were signed that helped ensure the financial viability of these projects.



However, 20 years after the passage of PURPA, the picture has changed substantially, mainly as a result of falling energy prices worldwide and the flattening demand for energy because of widespread conservation and productivity gains. By the mid-1990s, FERC had substantially weakened the underpinnings of PURPA. It struck down various state laws requiring utilities to purchase electricity at prices in excess of avoided cost. FERC also overturned state initiatives requiring regulated utilities to purchase specific quantities of energy from renewable sources under the rationale that such purchases would lead to prices in excess of avoided cost.

As of 1999, state and proposed federal legislation to deregulate the retail electricity industry was poised to change the nature of the generation and transmission of electricity to industry and consumers. Deregulation is shattering the institutional structure upon which PURPA was built and will directly or indirectly impact most WTE facilities. While the federal government is still working on the final shape of a bill, at least 18 states have passed or are anticipating passage of some measure of deregulation. Under the proposed federal bill, all consumers would be able to choose their electricity provider by January 1, 2001. Major issues for WTE projects are the sanctity of existing power sales contracts and the requirement that power providers meet a renewable-energy standard. While all plans call for the protection of existing contracts, there is already pressure by utilities to buy out expensive contracts and renegotiate subsequent rates downward.



Furthermore, controversy continues to swirl around the renewable portfolio standard and the inclusion of WTE projects

under this rubric. Under proposed federal legislation, the renewable portfolio standard requires that each electric generator in a state generate renewables, or purchase renewable energy credits, equivalent to a certain percentage of their generation. This percentage has been proposed at 3% in 2005, rising to 4% in 2010. Renewables include power generated from such "green" energy sources as wind, solar, and biomass. Certain groups are arguing that energy from MWCs should be excluded from the biomass category because of the general inefficiency of these plants and the high level of air emissions associated with them. Energy deregulation legislation has introduced further uncertainty into the business environment of WTE facilities. While in the long run it might prove beneficial to those plants that can negotiate directly with an end user for electricity, the short-run impact of deregulation is uncertainty and downward pressure on rates.

### *Supreme Court Decisions*

In the mid-1990s there were two major US Supreme Court decisions that drastically changed the WTE industry: *Chicago* v. *Environmental Defense Fund* (*EDF*) and *Carbone* v. *Town of Clarkstown*. In the first case, the court held that ash residue from an MWC is subject to hazardous-waste rules. (Up to that point, there had been a lack of consensus within EPA regarding appropriate ash management practices.) Furthermore, EPA then stipulated that MWC operators sample and analyze their ash to determine whether it was hazardous according to RCRA, Subtitle C regulations. The agency ultimately issued a policy guidance requiring that all MWC ash be tested using the Toxicity Characteristic Leaching Procedure (TCLP) to determine if it is hazardous. Importantly, EPA also ruled that each plant could combine its ash streams into a single stream for testing, as long as the streams were generated within the confines of the plant enclosure.

The Supreme Court's decision in the *EDF* case and EPA's subsequent policy guidance caused concern among owners and operators of MWCs regarding the financial and environmental liabilities surrounding ash disposal. Owners and operators were particularly greatly concerned about potential Superfund liability. In a number of cases, the operating costs of MWCs increased significantly as a result of the new requirements for the treatment and disposal of ash.

The *EDF* court decision not only had a profound effect on the MWC industry, it also adversely affected providers of MWC ash-recycling services, such as Rolite. The ruling created substantial confusion and uncertainty with respect to the recycling of MWC ash because of the concern over potential liability issues. This uncertainty caused MWC owners and operators to be more favorably inclined to dispose of their ash in landfills rather than through recycling.

While the *EDF* decision forced MWC owners and operators to examine and, in some instances, change their methods of ash handling and disposal, they were able to adapt to new testing requirements and disposal methods, incorporating these upgrades into their costs. With proper combustion techniques, most of the incinerator ash passed the TCLP test. However, the second Supreme Court decision in the same month—May 1994—had a much more dramatic impact on the MSW combustion industry. In *Carbone* v. *Town of Clarkstown*, the Supreme Court held that mandatory solid waste–flow control ordinances constituted an impermissible restraint on interstate commerce and were in violation of the Commerce Clause of the US Constitution. Prior to this decision, local governments were able to direct the flow of waste within their jurisdiction's boundaries to a given facility or location. Haulers were forced to pay the tipping fees levied at the mandated facility, even if they could find a cheaper solid waste–disposal alternative elsewhere. As a result of the *Carbone* decision, haulers could take their waste to any licensed facility. Thus, many MWCs were suddenly forced to compete for the waste. With landfills aggressively seeking waste, MWC projects had to lower their tipping fees, causing a decline in their operating revenues. This created a fundamental change in the financial structure of MWCs, which had previously been dependent on noncompetitive tipping fees.

Since the Supreme Court decision, state and local governments have attempted to find ways around it, with only limited success. For example, New Jersey mandated waste-flow control to its state MWC facilities. As a result of a recent court decision that found New Jersey's flow-control law unconstitutional, the state's MWCs have lost captive control of their solid waste supply, and several of the bonds for New Jersey MWCs have been downrated.

Major policy and legislative initiatives have affected the WTE industry from the mid-1980s through the present. Stringent APC and combustion requirements, as well as mandated ash-handling and disposal practices, have added to the capital and operating costs of these facilities. The loss of the ability of local governments to dictate the flow of waste to particular projects has permitted waste to flow freely to the lowest-priced disposal option. More costly WTE facilities are finding it difficult to compete for waste. Finally, the power industry is in a state of flux, with energy prices at a low. Power sales revenues accruing to MWC tend to be dropping.

## Landfill Capacity and Disposal Prices

All the developments cited above might not have undermined the municipal WTE industry had landfilling not reemerged as the disposal option of choice. Concerns in the late 1980s about possible landfill-capacity shortages proved to be unfounded. In fact, for the past decade, while the number of landfills that accept

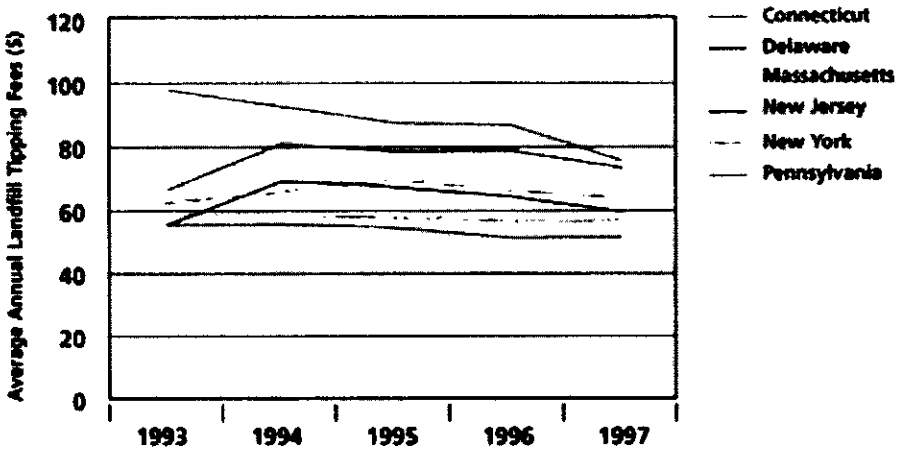
MSW has plunged by approximately 60% because of the closure of small, substandard landfill, available landfill capacity has increased. In fact, in a national survey undertaken by *BioCycle* magazine in April 1998, of the 37 states providing an estimate of their landfill capacity, 13 reported remaining capacity to be 20 years or more and another 16 estimated 10 years or more. Furthermore, they reported more landfill capacity available than at any other time over the past 10 years.

Federal and state regulations on landfill construction, leachate management, closure, and methane gas control helped mitigate the negatives associated with landfilling. In addition, landfill capacity has grown with the permitting of new "mega" regional landfills and the vertical and horizontal expansion of existing landfills. Because of the significantly lower capital and operating costs of a landfill compared to a WTE facility, the price of landfill disposal can often be cheaper than that of a waste combustor. With the lifting of flow control, landfills became aggressive competitors for waste, drawing it away from waste combustors. Because controlling waste flow is no longer legal, waste is traveling considerable distances—even across states—to landfills charging the cheapest prices.

Moreover, the average price of landfilling has declined nationally over the last five years. One of the most dramatic declines in landfill tipping fees has been in New Jersey, where the overturning of the state's flow-control law has allowed more solid waste haulers to use out-of-state landfills in Pennsylvania and farther south. As a result of this increased competition for solid waste, many New Jersey MWCs and landfills have dramatically dropped their tipping fees. For example, Union County, NJ, recently sold its MWC to Ogden Corporation because it could not afford to run the facility without flow control. Camden County, NJ, has had to reduce its tipping fees by half to remain competitive and has had to rely on reserve funds to pay expenses.

Figure 1 graphically illustrates the trend of declining landfill prices from 1993 to 1997 in six key northeastern and Mid-Atlantic states, where a significant number of MWCs are located. The data reveal a downward trend in landfill prices throughout the region during this time period.

## FIGURE 1. Average Landfill Tipping Fees in the Northeast



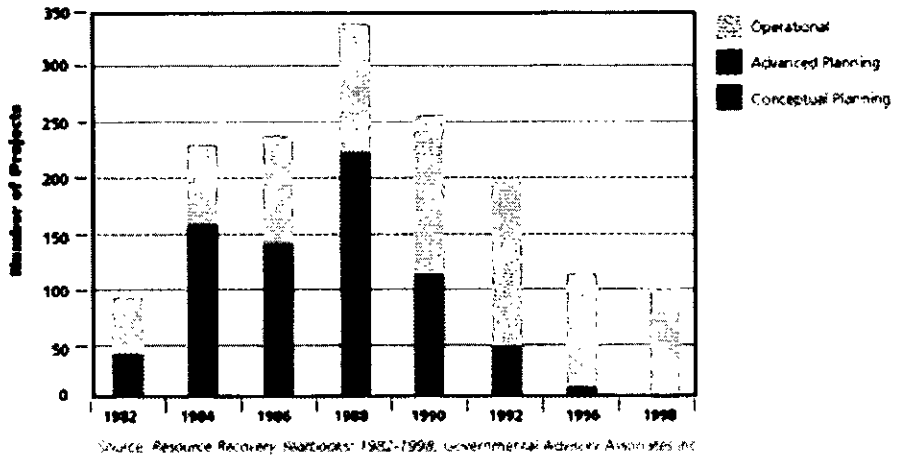

Source: Solid Waste Price Index, 1993-1997

### Status of MWC Facilities

***Number of Projects***

As is to be expected, the various factors outlined above have had a negative impact on the municipal WTE industry. These impacts are evident by the trends shown in Figure 2, which examines the number of facilities by status since 1982, when Governmental Advisory Associates Inc. first published its periodic survey of the industry. Total projects rose from 96 in 1982 to a high of 341 in 1988. After 1988, however, numbers started dropping to a total of 257 in 1990, 198 in 1992, 117 in 1996, and 101 in 1998. The peak in 1988 reflects the various governmental policies in place that drove the construction of MWC projects. Despite the fact that tax reform was passed in 1986, a large number of projects still in the pipeline were ultimately built.

## FIGURE 2. Status of MWC Facilities by Year

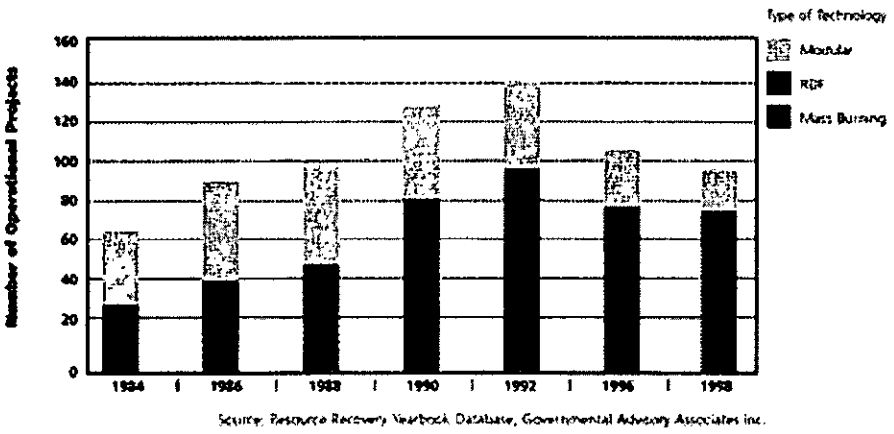



Source: Resource Recovery Yearbooks: 1982-1998, Governmental Advisory Associates Inc.

The status of the projects in Figure 2 indicate that through 1988 there was a sizable proportion of planned facilities. In fact, there were almost twice as many planned projects than operating facilities between 1984 until 1988. At that point, the number of projects in planning began to decline, dropping precipitously between 1992 and 1996 until 1998, when there were effectively no planned facilities. These findings denote a mature industry, with negligible growth after 1992.

The data on operational projects reveal another interesting finding. The number of projects coming on-line increased from 1982 through 1992. Thus, while fewer and fewer facilities were being planned, most projects that had been in the pipeline were built. However, since 1992, the industry has contracted. Operational facilities are closing, which has reduced the number of plants from 150 in 1992 to 100 in 1998. The number of operating projects is now at the same level as 1986, which is about the time the industry began its largest growth spurt. Between 1992 and 1996, 43 operational plants closed or stopped accepting municipal waste. Of these 43, 27 were still on-line as of 1994. Between 1996 and 1998, an additional 16 shut down from APC concerns or lack of economic viability. These closures came in the wake of the implementation of strict EPA air-emissions guidelines and the inability of some of these projects to compete with landfills for waste.

**FIGURE 3. Type of Technology Used in Operational Facilities by Year**




Source: Resource Recovery Yearbook Database, Governmental Advisory Associates Inc.

### *Type of Technology Used*

The type of technology employed at MWC facilities has also been undergoing a change. Three major categories of technology have been used. Mass burning is the most commonly used process. Raw MSW is taken "as is"—with little or no shredding or separation prior to combustion. Refuse is fed into individual furnaces, mostly of the waterwall type. The sides of the furnace contain closely spaced steel tubes through which water circulates. The refuse is burned, heating the water to produce steam, which is used as an energy product or as fuel for turbines

generating electricity. Modular facilities have one or more small-scale combustion units to process smaller amounts of waste, usually less than 200 tpd. The units are usually prefabricated and can be shipped fully assembled in modules to the site. Many have a two-chamber design, which in the years prior to the CAA Amendments provided an acceptable level of APC. Under new federal and state initiatives, this is no longer the case. The third type of technology is refuse-derived fuel (RDF). This approach employs a two-stage production system. Wastes are initially preprocessed to produce a homogeneous fuel product. The RDF can be sold to outside customers or burned on-site in a dedicated furnace.



In the early years of WTE, modular facilities were dominant. They were relatively simple to implement and did not require a high level of capital investment. However, as can be seen in Figure 3, the number of these projects had declined considerably by 1998. Their small size has made them unprofitable, particularly in areas with declining waste-disposal prices. Many of these facilities have been forced to upgrade their APC systems and have shut down rather than make the large capital investments necessary to meet current APC requirements. The majority of facilities that remain are using mass-burn, waterwall technology. Over the last two decades, this has proved to be the most efficient and effective in terms of combustion and energy generation. Nevertheless, many of these projects have undergone or will undergo significant upgrades to retrofit boilers and APC systems.

**New Developments in MWC**

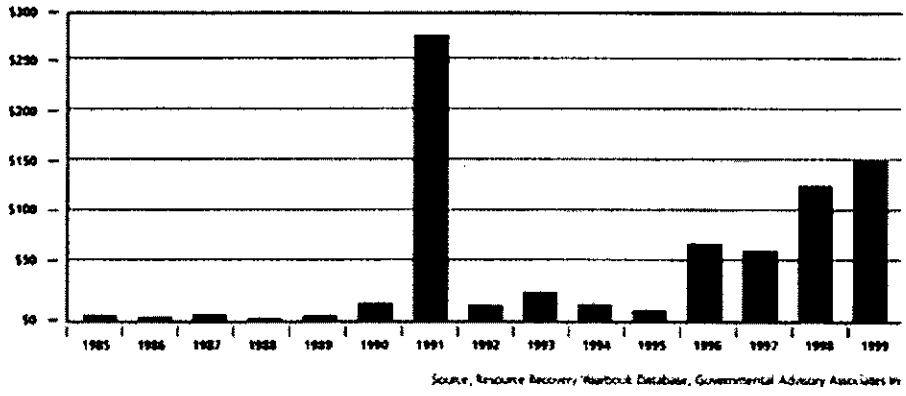
While the above discussion reflects an industry in contraction, there are two areas of projects in which there has been significant capital investment: (1) APC and boiler-system upgrades and (2) ash-handling methods. Both are direct results of federal and state regulations that are requiring system upgrades to incorporate state-of-the-art technology. As has been discussed above, these regulations are partially responsible for the increased rate of plant closures. Because of the competitive environment for waste and, thus, the need to keep tip fees low, facilities are unable to recoup the capital investment for the upgrade and, as a result, decide to close down.

***Plant Retrofits***

The degree of plant retrofits is directly related to the age of a facility. A relatively new project will have taken into account proposed federal and state regulations and incorporated these technologies into its construction plans. However, as previously shown, most projects have come on-line between 1988 and 1992, prior to the implementation of EPA's most recent regulations in 1995. Many of these facilities have undertaken or plan to undertake substantial systems upgrades. Figure 4

summarizes the level of capital investment in APC systems and boiler upgrades by year.

**FIGURE 4. Total Dollars Spent on Air-Pollution Control and Boiler Retrofits by Year (in millions)**




From 1985 through 1990, there was minimal investment in APC systems. In 1991, total dollars spent spiked to about $284 million. This spending is a result of the 1990 CAA Amendments that mandated state-of-the-art APC systems on large MWC facilities. The facilities making the upgrades in 1991 were proactive, as final EPA regulations were not promulgated until 1995. The remaining projects clearly responded to these final guidelines as capital spending increases by year from 1996 through 1999. Of course, the 1999 amounts might be overstated. Not all facilities will decide to go ahead with their plans if there is no chance for long-term economic health.

### *Ash Reuse and Recycling*

Reuse of ash from waste incineration has been a desire of the industry since the early 1960s, when the first research studies into MWC ash's engineering properties were initiated by the Federal Highway Administration. Despite the efforts of—and the proof from—comprehensive studies by EPA, numerous public agencies, and the WTE industry that ash can be used safely without violating groundwater regulations or impacting human health and the environment, the status of ash reuse and recycling from MWCs has not improved dramatically. Almost 40 years later, based on the results of two comprehensive surveys by the Solid Waste Association of North America, ash reuse has been limited. If it is used at all, it is primarily as a soil substitute for daily or intermediate cover on sanitary landfills. Public opposition by intervenor groups and a patchwork of regulations in many states have kept the material from reaching its recycling potential. Invariably, ash-reuse and recycling proponents have been asked by state regulators to conduct ash-recycling research or demonstration projects time and time again while at the same time requiring them to meet conservative regulatory standards for cancer risk along with requirements of institutional controls for ash reuse.

Notwithstanding these impediments, in recent years several firms, such as American Ash Recycling Inc. (Jacksonville, FL), have been successful in receiving state regulatory approval in Massachusetts, Pennsylvania, and Tennessee for using MWC ash for such applications as base course in state roads and parking lots and structural fill in construction projects.

## Conclusions

Overall, the near-term picture is not good. MWC is not a competitive solid waste–disposal alternative in many areas, nor does federal, state, or local policy support it. The level of capital investment is high, and revenues from low tip fees and falling energy prices are frequently not enough to cover and recoup capital spending. However, in the long term, the prognosis might be different. There are now serious challenges to the unbridled exporting of waste. In particular, Pennsylvania and Virginia are considering the regulation of waste imports. If costs to send waste out of state to large landfills increase, other disposal options might begin to look attractive. Additionally, new technologies that might significantly reduce air emissions are being revisited. These include pyrolysis and waste-to-alcohol (ethanol or methanol) processes.

Finally, electricity deregulation might positively benefit independent power producers, of which MWCs are a subset. These projects may be able to negotiate directly with electricity consumers for a higher rate than they are now receiving from utilities. For example, under the newly deregulated electricity market, it might be feasible to wheel electricity from a community's MWC to its large-energy users (water and wastewater treatment plants, airports, administrative complexes, municipal lighting districts, or correctional facilities). In some instances, the cost savings realized might underscore the value of having an MWC as part of a community's public works structure.

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MSW Management
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Feature

# Waste-to-Energy Trends:


***A detailed analysis gives favorable marks to these WTE facilities for recycling rates, health protection, and reduced emissions. But has public opinion caught up yet?***

**WTE Trends**

By Raffaella Dunne

The use of waste-to-energy (WTE) as a mechanism for solid waste reduction has been the subject of debate for as many years as WTE facilities have been in operation. WTE facilities are often viewed as a source of pollution that can cause serious health and environmental effects. On the other hand, WTE facilities are also viewed as a viable recycling mechanism that reduces the volume of solid waste requiring ultimate disposal and reduces the impact of landfill leachate and gas on the environment while creating electricity. Over time, increasingly stringent regulations have been promulgated to reduce the air emissions from these facilities, including the federal performance standards 40 CFR 60 Subpart Eb and Subpart Cb. On December 19, 2000, all facilities with units designed to combust greater than 250 tpd were required to comply with these regulations. For this reason many facilities were obligated to retrofit to add air pollution control equipment to enable them to comply with the more stringent limits. To determine how

effectively WTE facilities are operating as the industry has evolved from an environmental performance standpoint, the Delaware Solid Waste Authority retained the services of HDR Engineering Inc., Cambridge Environmental Inc., and Eden Environmental Inc. This collective group, HDR team, evaluated 12 of the most recently constructed and/or permitted WTE facilities and the public health and environmental impacts associated with WTE facilities. The HDR team was also asked to identify concerns expressed by WTE opponents at the time of the permitting of these facilities and to provide a long-term assessment of those concerns.

The WTE evaluation involved obtaining information on specific performance criteria for 11 facilities in the United States and one facility in the Netherlands. Performance information was obtained through issuing Freedom of Information requests, interviewing state regulatory officials, visiting state regulatory agencies to conduct file reviews (where necessary and where day visits were possible), interviewing agencies that oversee operations of the WTE facilities, and interviewing facility operators.

The Delaware Solid Waste Authority requested that the 12 facilities evaluated include mass-burn and refuse-derived fuel (RDF) technologies (including fluidized-bed combustion). Therefore, of the 11 facilities evaluated in the US, eight are mass-burn waterwall combustors and three are RDF processing facilities. Two of the RDF facilities use spreader stokers and one uses a fluidized-bed combustor. The facility in the Netherlands is a mass-burn waterwall combustion facility. Data collected for each of the 12 WTE facilities included combustion technology; air pollution control technology; general facility design data; compliance with air, ash, and water discharge limits; community and facility recycling data; and area demographics.



The following 12 WTE facilities were evaluated:

- Robbins Resource Recovery Facility, Robbins, IL
- Montgomery County Resource Recovery Facility, Dickerson, MD
- Onondaga County Resource Recovery Facility, Jamesville, NY
- Wheelabrator Falls Energy Recovery Facility, Morrisville, PA
- Lee County Solid Waste Resource Recovery Facility, Fort Myers, FL
- Union County Resource Recovery Facility, Rahway, NJ
- AVI Amsterdam, Amsterdam, Holland
- Delaware County Resource Recovery Facility, Chester, PA
- Montgomery County Resource Recovery Facility, Conshohocken, PA
- Southeastern Connecticut Resource Recovery Facility, Preston, CT
- Palm Beach County Resource Recovery Facility, West

Palm Beach, FL
- Semass Facility, Rochester, MA

The data developed for each facility included utilization, demonstrated combustion technology, facility age, exceedances, maximum achievable control technology (MACT), location in a coastal zone, zero water discharge, use of an air-cooled condenser, ash reuse, front-end separation of waste received, recycling rates in excess of national average, bypass landfill, host community benefits, high-pressure design vs. low-pressure design, and demographics.

General information regarding the location, date of facility start-up, facility operator and owner, combustion system used, the number of boilers, facility rated capacity, location in a coastal zone, and host community zoning is included in Table 1.

> Tables 1 through 5 can be viewed as a pdf by clicking here. You will need Acrobat Reader in order to view this version. If you do not have Acrobat please download it now.

Table 2 contains facility operating data. The operating data include the facility rated capacity, the average utilization, the tip fee charged based upon the December 1998 issue of *Solid Waste Digest*, the rated steam production, the boiler exit temperature and pressure design values, and the turbine generator rated capacity. Facility capacity utilization ranges from 52.7% to 100% of facility rated capacity for each of the facilities surveyed. There are four low-pressure design facilities with pressures that range from 625 to 675 psig. The remaining eight facilities are high-pressure design facilities with pressures ranging from 750 to 900 psig.

Table 3 indicates the types of air pollution control equipment used at each of the facilities. Seven of the 12 facilities have air pollution control equipment considered MACT by the Environmental Protection Agency (EPA): carbon injection, selective noncatalytic reduction (SNCR), semidry reactor (SDA), and fabric filter (FF). These facilities are RRRF-Illinois, MCRRF-Maryland, ORRF-New York, WFERF-Pennsylvania, LCSWERF-Florida, UCRRF-New Jersey, and AVI-Holland. Of these facilities, RRRF-Illinois has exceeded the current permit limits and future enforceable Subpart Eb emission limits. Three additional facilities (DCRRF-Pennsylvania, MCRRF-Pennsylvania, and SCRRF-Connecticut) have an SDA and an FF. MCRRF-Pennsylvania and SCRRF-Connecticut have Hg stack emissions that exceed the future enforceable Subpart Cb emission limit. MCRRF-Pennsylvania has started using Sorbalit for control of mercury emissions. The most recent stack tests conducted indicate that this facility is operating well below the mercury emission limits. SCRRF-Connecticut also intended to use Sorbalit starting in December 2000 to control mercury emissions. SCRRF-Connecticut does not plan to install an

## Table 1. Facility Information

| Data | RRRF-Illinois | MCRRF-Maryland | ORRF-New York | WFERF-Pennsylvania | LCSWERF-Florida | UCRRF-New Jersey | AVI-Holland | DCRRF-Pennsylvania | MCRRF-Pennsylvania | SCRRF-Connecticut | PBCRRF-Florida | Semass-Massachusetts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| City and County | Robbins, Cook County | Dickerson, Montgomery County | Jamesville, Onondaga County | Morrisville, Bucks County | Fort Myers, Lee County | Rahway, Union County | Aziehaven Amsterdam | Chester, Delaware County | Conshohocken, Montgomery County | Preston, New London County | West Palm Beach, Palm Beach County | Rochester, Plymouth County |
| Start of Operations | December 1997 | August 1995 | February 1995 | August 1994 | December 1994 | February 1994 | 1993 | April 1992 | February 1992 | December 1991 | November 1989 | January 1989 |
| Operator | Foster Wheeler | Ogden Martin Systems | Ogden Martin Systems | Wheelabrator | Ogden Martin Systems | Ogden Martin Systems | Local Government | American Ref-Fuel Inc. | Montenay Energy Resources | American Ref-Fuel | Babcock and Wilcox | American Ref-Fuel Inc. |
| Owner | Foster Wheeler | Northeast Maryland Waste Disposal Authority | Ogden Martin Systems of Onondaga County | Wheelabrator Falls Inc. | Lee County | Union County Utilities Authority | Government | Fleet National Bank of Connecticut | Montenay Montgomery Ltd. Partnership | American Ref-Fuel | Palm Beach County Solid Waste Authority | Semass Partnership |
| Combustion System | Foster Wheeler | Martin Systems | Martin Systems | Von Roll | Martin Systems | Martin Systems | Martin Systems | O'Connor | L&C Steinmuller | Deutch, Babcock, Riley Stoker | Babcock and Wilcox | Riley Stoker |
| Number of Boilers | 2 | 3 | 3 | 2 | 2 | 3 | 2 | 6 | 2 | 2 | 2 | 3 |
| Facility Rated Capacity | 1,200 tpd | 1,800 tpd | 990 tpd | 1,500 tpd | 1,200 tpd | 1,440 tpd | 2,400 tpd | 2,688 tpd | 1,200 tpd | 690 tpd | 2,000 tpd | 2,700 tpd |
| Location in Coastal Zone | No | No | No | Yes | No | Yes | Yes | Yes | No | Yes | No | Yes |
| Host Community Zoning | Industrial | Rural, Agricultural | Rural/ Residential | Industrial | Rural, Mostly Farms | Commercial | Industrial | Urban/ Industrial/ Residential/ Commercial | Commercial/ Industrial | Rural | Rural | Rural/ Commercial/ Residential |

## Table 2. WTE Facility Operating Data

| Data | RRRF-IL | MCRRF-MD | ORRF-NY | WFERF-PA | LCSWERF-FL | UCRRF-NJ | AVI-Holland | DCRRF-PA | MCRRF-PA | SCRRF-CT | PBCRRF-FL | Semass-MA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility Rated Capacity (tpd) | 1,200 | 1,800 | 990 | 1,500 | 1,200 | 1,440 | 2,400 | 2,688 | 1,200 | 690 | 2,000 | 2,700 |
| Average Utilization (tpd) | 1,200 | 950 | 786 | 1,500 | 876 | 1,345 | 2,401 | 2,364 | 1,130 | 686 | 2,000 | 2,700 |
| Tip Fee ($/ton) | 59 | 44 | 84 | 56 | 62.43 | 50 | -95 | 45 | 68.50 | 79 | 23 | 50 |
| Rated Steam Production (lb./hr.) | 460,000 | 513,000 | 311,646 | 418,000 | 337,500 | 360,000 | -308,000 | 840,000 | 324,000 | 151,000 | 300,000 | 280,000 |
| Boiler Exit Temperature (°F) | 830 | 830 | 830 | 850 | 825 | 830 | 780 | 810 | 750 | 842 | 750 | ~500 |
| Pressure Design Value (psig) | 900 | 865 | 865 | 900 | 850 | 850 | 625 | 675 | 650 | 855 | 750 | 700[1] |
| TG (MW) | 55 | 67 | 39.5 | 53.1 | 50 | 45.1 | 80 | 75 | 34 | 18 | 61 | 75 |

*NOTE:*
1 Conversions with Semass facility operator indicated that the boiler exit temperature was ~500°F. The *Municipal Waste Combustion Industry in the United States, 1997-98 Resource Recovery Yearbook and Directory,* 7th Edition, reports 700°F.

## Table 3. Facility Air Pollution Control Equipment

| Pollutant Emission Controlled | RRRF-IL | MCRRF-MD | ORRF-NY | WFERF-PA | LCSWERF-FL | UCRRF-NJ | AVI-Holland | DCRRF-PA | MCRRF-PA | SCRRF-CT | PBCRRF-FL | Semass-MA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mercury | Carbon Injection | Carbon Injection | Carbon Injection | Carbon Injection | Carbon Injection | Carbon Injection | Carbon Injection | None | None | None | None | None |
| Nitrogen Oxide | SNCR | SNCR | SNCR | SNCR | SNCR | SNCR | SNCR | None | None | None | None | Unit 3 Only |
| Acid Gas | SDA | SDA | SDA | SDA | SDA | SDA | SDA | SDA | SDA | SDA | SDA | SDA |
| PM and Metals | FF | FF | FF | FF | FF | FF | FF and ESP | FF | FF | FF | ESP | FF on Unit 3/ ESP on Units 1&2 |

## Table 4. Recycling Quantities for WTE Communities

| Commodity | SSMMA, 1996 | Montgomery County, 1996 | Onondaga County, 1996 | Bucks County, 1996 | Lee County, 1996 | Union County, 1996 | AVI-Amsterdam Holland | Delaware County, 1996 | Montgomery County, 1996 | New London County, 1996 | Palm Beach County, 1996 | Plymouth County, 1996 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WTE Recycled Materials | N/R | Ferrous | Ferrous | Ferrous and Ash | Ferrous | Ferrous | Ferrous, Nonferrous, Yard, and Food | Ferrous and Ash | Ferrous and Ash | Ferrous | Ferrous | Ferrous, Non-ferrous, and Boiler Aggregate |
| Total Recycling | 51,100 | N/R | 468,952 | 86,090 | 220,979 | 384,809 | N/R | 73,237 | 208,596 | N/R | 1,017,334 | 67,961 |
| Recycling Rate | 19.9% | 30% | 64.9% | 18.8% | 37% | 40.1% | N/R | 33.3% | 27.2% | N/R | 31% | 33% |

SNCR system for $NO_x$ controls. Rather, the facility will continue to purchase emission credits to ensure compliance with the $NO_x$ limit.

The Semass-Massachusetts facility has two units with an SDA and an ESP (electrostatic precipitator) and one unit with an SDA, FF, and SNCR system. This facility also has added Compact Hybrid Particulate Collectors (COPAC) downstream of the ESPs on Units 1 and 2. The COPAC system acts as a final particulate-matter collection system and is expected to reduce mercury emissions by 90%. A carbon injection system was added to Unit 3 to control mercury emissions. PBCRRF-Florida has an SDA and an ESP. The $NO_x$ emissions based upon the stack test results exceed the future enforceable Subpart Cb emission limits. PBCRRF-Florida reported that recent test data indicates that both NOx and mercury emissions are below the respective limits and therefore there is no plan to add air pollution control equipment at this time.

Table 4 contains information on the total quantity of materials recycled and the recycling rates for each of the WTE host communities. Because various states allow different materials to be counted when calculating recycling rates, caution should be used in making comparisons with the recycling rates. The national average recycling rate published in the April 1999 issue of *Biocycle* is 30%. Based on the information provided in Table 4, seven of the 10 communities for which information could be gathered had recycling rates exceeding the national average. This is consistent with surveys conducted by various trade organizations that have concluded that communities with WTE facilities generally have higher recycling rates, showing that WTE and recycling work hand in hand.

Table 5 contains information related to nuisance issues reported for each of the 12 WTE facilities. This table also contains information on the issues raised by opponents to WTE during the siting, permitting, and construction phases of each of the 12 WTE facilities. The names of the opponents are also provided.

> Tables 1 through 5 can be viewed as a pdf by clicking here. You will need Acrobat Reader in order to view this version. If you do not have Acrobat please download it now.



The evaluation also included a review of information regarding the public health and environmental impacts both perceived and real in relation to WTE facilities. The major public health issues of concern include asthma and cancer, dioxin toxicity, metals toxicity, ash handling and disposal, and environmental justice.

**Asthma and Cancer**

**Table 5.** Nuisance Issues and Opponents

| Facility | Nuisance Issues | Opposition Issues and Opponents |
|---|---|---|
| RRRF-IL | N/R; however, numerous Notices of Violation for litter and odors | Public health issues, including dioxins, sulfates, and PM. The facility was featured several times in Ellen and Paul Connett's *Waste Not*. |
| MCRRF-MD | Noise, odor, fugitive ash, lighting | Public health issues, including mercury and metals, traffic, and noise. Opponents include the Sugarloaf Citizens Association and the Dickerson-Beallsville Citizens. The facility was also featured in Ellen and Paul Connett's *Waste Not*. |
| OCRRF-NY | Odor | Public health issues, including dioxins and ash deposition. Opponents include Vicky Baker and Paul Connett. The facility was featured several times in Ellen and Paul Connett's *Waste Not*. |
| WFERRF-PA | Noise and traffic | N/R |
| LCSWERF-FL | N/R | Public health issues related to mercury. Opponents include Michael Katin, Joseph K. Isley, SFCARE, US Department of Interior, Fish and Wildlife Service |
| UCRRF-NJ | Ash deposition, traffic, noise, housekeeping, and health-related issues | Traffic and public health issues related to mercury. The local concerned citizens group was vocal against the facility. Opponents include Carrie Blanchard, Vincent Lahutzki, Bea Birdson, Reverend Brown, and Dan Carson. Neil Seldman wrote *Pitfalls and Promises* that rebutted the results of the Environmental Impact Statement information. The facility was featured several times in Ellen and Paul Connett's *Waste Not*. |
| AVI-Holland | N/R | Location. Opponents include Friends of the World and Greenpeace |
| DCRRF-PA | Odor, noise, traffic, and dust | Environmental and financial concerns. Issues include concerns regarding dioxins. Opponents include Andrew Saul, Clinton Johnson, Larry Jennings, and Ronald Mersky. The facility was also featured in Ellen and Paul Connett's *Waste Not*. |
| MCRRF-PA | N/R | N/R |
| SCRRF CT | N/R | Public health issues, including dioxin concerns. Specific opponents could not be recalled. |
| PBCRRF-FL | N/R | Property value concerns. Opponents hired Barry Commoner to provide expert testimony against the facility. |
| Semass-MA | Odors, noise, housekeeping | Public health issues related to heavy metals. Opposition was voiced by the Clean Water Action Group. |

Asthma is a disease that affects the immune system and therefore involves allergens, not simple chemical pollutants. Certain outdoor air pollutants exacerbate symptoms in those already afflicted with asthma. Because solid waste combustors are a source of criteria pollutants, such as fine particulate and sulfur dioxide, they will likely continue to be a focus of concern with respect to asthma and other respiratory diseases.



The American Cancer Society (ACS) has a pamphlet that provides a brief review of environmental health risk assessment. This pamphlet states that the cancer hazard depends on dose and observes that many risks that concern the public are unproven or negligible. The document also reviews mortality rates from various cancers and notes which cancers are increasing or decreasing in frequency. The International Agency for Research on Cancer (IARC) also has a list of chemicals evaluated for evidence of carcinogenicity to humans and provides a classification of those chemicals. Neither ACS nor IARC mentions WTE or solid waste combustion as a cancer risk.

**Dioxin**

In 1994, public concern about adverse health effects escalated through preliminary findings in EPA's draft, *Health Assessment of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) and Related Compounds.* This document found that (1) humans are most likely vulnerable to the same spectrum of biological effects that are induced in other animals by TCDD, (2) the evidence is fairly strong that TCDD is a human carcinogen, and (3) current exposures to polychlorinated dibenzo-dioxins/polychlorinated dibenzo-furans (PCDD/PCDF) could be causing adverse health effects in some people. In related work by EPA, solid waste combustion was incriminated as the major source of PCDD/PCDF emissions to air. Members of the public are often vehemently opposed to construction of new WTE facilities because of the concern that even slight increases in dioxin exposure, on top of unavoidable background exposure, might trigger toxic injury. Hence, they might consider such facilities to be dioxin factories.

The preliminary findings by EPA, described above, are highly controversial in the scientific community. Many scientists argue that studies do not show harmful effects in humans at environmental levels of PCDD/PCDF (as opposed to, perhaps, industrial or poisonous exposure levels), that TCDD carcinogenic action in laboratory animals may proceed by a threshold mechanism not triggered at low exposure levels, that TCDD is not a human carcinogen, and that population exposures to PCDD/PCDF have been decreasing. Other scientists consider the evidence of toxicity strong on all counts.

The most recent assessment of the contribution of solid waste combustion to current releases of PCDD/PCDF is the *Inventory of Sources of Dioxin in the US*, a draft prepared and released by

EPA in 1998. This reassessment is under continuing peer review and review by the Science Advisory Board. The inventory, however, is a significant update of the database on sources and emissions presented in EPA's 1994 draft *Estimating Exposure to Dioxin-Like Compounds*, which incorporates additional data and research. Important findings of EPA's research are the following: (1) Annual releases of PCDD/PCDF in the US from all quantified sources appear to have dropped significantly between 1987 and 1995 from an estimated 11,900 g of 2,3,7,8-TCDD toxic equivalents to an estimated 3,000 g, and (2) the decrease in emissions is largely the result of decreased emissions from solid waste and medical waste combustion. A third important conclusion of the inventory is that the relative importance of a particular source (such as solid waste combustion) to total *emissions* is not necessarily indicative of the relative importance of that source to the general populations *exposure* to PCDD/PCDF. Because most of our exposure to PCDD/PCDF comes from diet (more than 90%), only emission sources affecting what we eat will have a marked effect on our exposure to dioxins. Releases of dioxins into the air from local solid waste combustors generally have a very small incremental effect on exposure.

Scientists have sought changes in environmental levels of PCDD/PCDF because of the activities of particular solid waste combustors. The findings can be broadly interpreted as worst-case, as the combustors are of older designs and used (or might have used) air pollution control devices that did not hinder PCDD/PCDF formation. While impacts have sometimes been noted in environmental media or cows' milk, we know of no study finding increased levels of dioxins in the blood or fat of persons residing near (but not working at) solid waste combustors.

The main points, then, are as follows:

- Solid waste combustion technology has improved tremendously and emits far less PCDD/PCDF than in the past.
- New Source Performance Standards will reduce PCDD/PCDF emissions even further.
- Solid waste incinerators are rarely a significant source of PCDD/PCDF for the local population, as most exposure comes from food and not air, water, or soil.
- Much is suspected, but little is actually known, about the effects of PCDD/PCDF on people at the low doses received through environmental media.

**Metals**

Toxic metals in waste have been a potential concern to many critics of WTE technologies. Unlike organic compounds, metals are not destroyed by incineration but instead are distributed among ash and stack emissions. WTE ash is therefore more concentrated in metals than waste prior to combustion. As

described below, however, the mobility of metals in ash is quite low and not believed by most analysts to be of environmental concern.

Emissions of metals via stack gases for municipal waste combustors are strictly regulated. Federal regulations, 40 CFR 60 Subpart Cb and 40 CFR 60 Subpart Eb, strictly limit allowable concentrations of Cd, Pb, and Hg and indirectly limit the stack gas concentrations of other metals by regulating particulate matter in air emissions. Among these metals, mercury has been of greatest concern for combustors. Not only is it a vapor at normal operating conditions, making its capture inefficient by particulate control devices, but it can also accumulate in fish in the form of methyl mercury, which is a potent neurotoxin.

About 19% of anthropogenic emissions were attributed to solid waste combustors. EPA expects mercury emissions from solid waste combustors to decline to approximately 4.4 tpy as Subpart Cb and Subpart Eb emission limits are implemented. According to EPA, the recent decreasing trend in the amount of mercury in solid waste, if it persists, will also reduce emissions from solid waste combustors.

**Ash Residue**

Issues surrounding ash have changed substantially over the past decade. Data accumulated since the late 1980s have demonstrated that leachate from ash landfills, though concentrated in simple salts, is not concentrated in heavy metals. These data suggest that metals in ash are of limited mobility, at least in the environment of a landfill. Laboratory testing of ash, which can be treated to bind metals, has also shown only limited mobility of metals or other potentially toxic constituents. These data, from both field and laboratory tests, have led to a gradual acceptance of WTE ash as a material that could be used as daily cover in sanitary landfills. This is far different from the traditional thinking that ash was a material so dangerous that it had to be separately disposed of in ash monofills. Florida allows such ash reuse without any special approvals. Reuse as daily cover is allowed in other states with specific approvals. Reuse of ash, rather than landfilling of ash, has a potential economic benefit to a WTE facility. A recent legal review of the liabilities of reusing ash, sponsored by the US Conference of Mayors and conducted by the law firm of DeCotiis, Fitzpatrick and Gluck, is available on the SWANA Web site (www.swana.org, click on Technical Divisions).

**Environmental Justice**

Opposition to WTE facilities may be founded on concern for environmental justice. Environmental justice is the belief that frequently poorer, minority communities are targeted for many pollutant-generating projects that confer benefits on many and

risks on a few. Would-be developers of solid waste combustors should be mindful of the litigious aspects of this issue. While the authors of this report do not know of any successful lawsuits charging industrial facilities with miscarriage of environmental justice, a large amount of time, energy, and money has been spent in defense of these claims.

Other issues affecting the WTE business include economics, the Clean Air Act amendments, and flow control. The evaluation also included public health and monitoring studies and information on the operational responses to environmental issues. The findings have been that public outcry in some cases resulted in implementation of costly environmental monitoring programs such as soil and biota sampling that, contrary to public expectations, never found any contribution of contaminants from a single facility.

The historic public health issues of concern that have been used by opponents of WTE have not been confirmed through scientific study and environmental monitoring programs. Concern regarding these public health issues resulted in more stringent regulations, which ultimately result in more stringent emission controls and less emissions from WTE facilities.

In conclusion, WTE has made great strides by:

- reducing facility emissions such as NOx, acids gases, mercury, and dioxins;
- successfully adapting to changing regulations, such as the Clean Air Act Amendment of 1990;
- developing state-of-the-art facilities using either mass-burn or RDF technologies that can meet the current stringent air pollution control regulations, while producing a renewable energy that is cleaner than coal or oil power-generated energy;
- implementing recycling programs that enhance the technology in a synergistic process often referred to as integrated solid waste disposal;

- demonstrating a high level of reliability of mass-burn and RDF facilities to process waste and produce energy.

In addition, the US WTE industry needs to continue to work on the following areas:

- increasing public education to improve public opinion,
- increasing improvement or development of reliable alternate technologies that can improve WTE economics and still maintain a high level of environmental control,
- evaluating technology improvements achieved in other countries.

*Raffaella Dunne is operations director for HDR Engineering's*

# DUTCH NOTES ON BAT

# FOR THE INCINERATION OF WASTE

## MINISTRY OF HOUSING, SPATIAL PLANNING AND THE ENVIRONMENT

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Fax: +31 70 363 33 33
Internet: http://www.infomil.nl/

**ISBN-CODE:** 90.76323.062



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February 2002

## CONTENTS

# 2. PROCESS DESCRIPTION

## 2.1 Introduction

In the Dutch municipal waste incineration sector all (eleven) plants are based on grate technology, as described below.

There is one centralised plant for the incineration of hazardous wastes, with two (rotary kiln) incineration lines. Additionally, there are a number of smaller dedicated units for special hazardous waste categories. These units are owned and operated by various industries. The description of these units in this BAT-document is less detailed.
For specific clinical waste, one centralised plant is operational.
Sewage sludge is incinerated in two (formerly three) plants in the Netherlands.

This section gives an overview of these plants.

### 2.1.1 Dutch municipal waste incineration plants

*GEVUDO, Dordrecht:*
This plant, which has been in operation since the early 1970s, consisted originally of three lines (capacity 3 x 7,5 t/h). The applied grate system is the reciproking grate of Martin München. Two of the lines were connected with a multiple hearth sewage sludge incineration unit that was removed at the beginning of the 1990s. There were no facilities for electricity production. Flue gas treatment consisted of a wet scrubber system, for removal of fly ash and gaseous compounds.
By the end of the 1980s and beginning of the 1990s, the plant was adapted to current air emission standards by a complete adaptation of the wet scrubbing system and was expanded with a fourth line of comparable design and capacity. The new line (line no. 4) and one existing line (line no. 1) were equipped with boilers for electricity production.
After the introduction of the new air emission standards (BLA, see section 3.1.2), the plant's flue gas treatment system was adapted once again. In the present situation line 1 (with steam boiler) and line 2 (without energy recovery) have a combined flue gas treatment system, as well as line 3 (without energy recovery) and line 4 (with steam boiler). The configuration is as follows:
- (further) flue gas cooling by water evaporation (separate per line);
- reactor (combined for two lines) with injection of adsorbens (zeolite for dioxin removal and $Na_2S_4$ for heavy metals absorption;
- dust bag filters for removal of adsorbens and fly ash;
- two stage wet scrubbers (acid and neutral pH, including physical-chemical treatment of process waste water);
- two parallel wet electrostatic precipitators;
- SCR-DeNOx for removal of $NO_x$ and remaining dioxins.

The steam system of the plant is connected with the steam systems of the adjacent sludge incineration plant of DRSH (see section 2.1.4) and the specific clinical waste incineration plant of ZAVIN (see section 2.1.3);

*AVR Rotterdam:*
This plant has been in operation since 1962, with four incineration lines (capacity 4 x 13,4 t/h), with reciproking grate (Martin München), electricity production, and electrostatic precipitators for reduction of dust emission. In 1993, the plant was overhauled, including the installation of wet flue gas treatment system (including physical-chemical treatment of process waste water), activated carbon fixed bed flue gas polishing and SCR-DeNOx;

*AVR Botlek:*
AVR Botlek is in operation since 1972, with a capacity of 6 lines x 19.8 t/h, roller grate (system Düsseldorf), steam production for electricity production and production of distilled water by using low-temperature heat from the steam cycle. Flue gas treatment consisted of electrostatic precipitators for dust removal. In 1994, the existing lines were provided with wet flue gas treatment systems (including physical-chemical treatment of process waste water), activated carbon fixed bed flue gas polishing and SCR DeNOx. In the same period a seventh line (25 t/h) was realised. The environmental permit of the plant includes the incineration of 85.000 t/y of hazardous waste. The installation is equipped with nozzles for the injection and incineration of liquid (hazardous) waste;

*AVR AVIRA, Duiven:*
This plant is in operation since 1974, with 3 lines x 12 t/h, roller grate (system Düsseldorf), without energy recovery, with electrostatic precipitators for dust removal. In 1984, one of the lines was equipped with a hot water boiler for supply of heat to the local district heating system. In 1989, a wet flue gas treatment system (including physical-chemical treatment of process waste water) was installed on all three lines, followed by the application of SNCR-DeNOx and a DeDiox system. In the latter system, activated carbon is injected into the scrubbers. Subsequently the two other lines were equipped with steam boilers for electricity production as well as supply of heat to the district heating system (1991 and 1996). The installation of the boilers was combined with a capacity increase of the units from 12 till 15 t/h. The plant is equipped with provisions for the co-incineration of sewage sludge. The sludge can be spread over the waste in the bunker area; the sludge co-incineration system is however not in operation;

*AVI Roosendaal (SITA ReEnergy, formerly WATCO):*
The original municipal waste incineration plant dates from 1975, with 2 lines with a forward moving inclined grate system (Brun&Sorensen), supply of heat to a neighbouring nursery gardening centre and with electrostatic precipitators. In the 1980s, a sludge drying unit was added, using hot flue gases as its energy source. In 1995, the plant was completely overhauled, including new horizontal forward moving grate systems (Noell), capacity 2 lines x 4 t/h, hot water boilers for supply of heat to the nursery gardening centre, the possibility to use hot flue gases for sludge drying and electrostatic precipitators. Flue gas treatment consists of a combined unit for both lines with semi-dry flue gas treatment based on injection of lime slurry, with the option to dose soda-bicarbonate ($NaHC0_3$) at peak loads, injection of activated carbon, dust bag filters and SCR-DeNOx;

*ARN Beuningen:*
This incineration plant has been operational since 1987, with two mechanical sorting lines and one incineration line of 9 t/h, horizontal forward moving grate (Noell), electricity production and wet flue gas treatment. In 1995, the plant was expanded with additional mechanical sorting capacity and a second incineration line of 21 t/h of RDF, horizontal forward moving grate (Noell), electricity production, dust removal with electrostatic precipitators and wet flue gas treatment (waste water free by use of a spray dryer), SCR-DeNOx and entrained bed flue gas polishing (including dust bag filter). The grates of both lines were adapted from air cooling to water cooling;

*AVI Amsterdam (GDA):*
Operational since 1993, with 4 lines x 25 t/h, forward/backward moving horizontal grate (W+E, now ABB), electricity production, supply of heat to neighbouring industries, dust removal with electrostatic precipitators, wet flue gas treatment (waste water free) and SNCR-DeNOx. The plant is equipped with provisions for the co-incineration of sewage sludge by direct injection in the furnace in one of the four lines;

*AVI Alkmaar (Huisvuilcentrale):*
Operational since 1995, with 3 lines x 18.5 t/h, forward moving inclined grate (Von Roll), electricity production, dust removal with electrostatic precipitators, wet flue gas treatment (waste water free), SCR-DeNOx and entrained bed flue gas polishing;

*AVI Wijster (Essent Milieu):*
This incineration plant has been operational since 1995 with three mechanical sorting lines and an incineration capacity of 3 x 18 t/h, forward/backwards moving inclined grate (11°), electricity production, dust removal with electrostatic precipitators, wet flue gas treatment (waste water free) and SCR-DeNOx and DeDiox. The grates were adapted to water cooling in 1998 (Stiefel);

*AVI Moerdijk (AZN):*
Operational since 1996, with 3 lines x 28 t/h, forward moving inclined grate (Von Roll), steam production for a neighbouring combined cycle power plant, SNCR-DeNOx, dust removal with electrostatic precipitators, wet flue gas treatment (including physical-chemical treatment of process waste water) and entrained bed flue gas polishing;

*AVI Twente (Twence):*
Operational since 1997, with 2 lines x 18 t/h, reciproking grate (Martin München), electricity production, wet flue gas treatment (waste water free), SCR-DeNOx and entrained bed flue gas polishing.

*Summary of applied technologies*
Table 2.1 (next page) gives an overview of the applied technologies, including the amounts of incinerated municipal waste in 1999. In the years 2000 and 2001 there have been no substantial changes in incinerated amounts of waste. More detailed descriptions of the applied technologies are found in sections 2.2 – 2.6 and Chapter 4.

Lower Heating Value (LHV) of the waste, treated in the various municipal waste incineration plants varies from 8.4 MJ/kg (AVI Roosendaal) until 12 – 13 MJ/kg (ARN and AVI Wijster, after mechanical sorting). A typical average value is just below 10 MJ/kg (AVI Twente 9 MJ/kg, AVI Amsterdam 9.5 MJ/kg, GEVUDO Dordrecht 9.8 MJ/kg).

## Table 2.1:Municipal waste incineration plants in the Netherlands

| Municipal waste incineration plant | Incineration | Energy/cooling | Flue gas treatment | Incinerated amount (1999): in t/y |
|---|---|---|---|---|
| GEVUDO | rg | sb.ep.ss.ec | bfa.ws.wesp.scr | 171,000 |
| AVR Rotterdam | rg | sb.ep.hs.wc | esp.ws.fxbac.scr | 385,000 |
| AVR Botlek | rolg | sb.ep.ssdiw.wc | esp.ws.fxbac.scr | 1,105,000 |
| AVR AVIRA | rolg | sb/hwb.ep.hsdh.ec/ac | sncr.esp.wsa | 300,000 |
| AVI Roosendaal | fhg | hwb.hsgar.hssd.ac | esp.sda.scr | 55,000 |
| ARN Beuningen | fhg/wc | sb.ep.ec.lths | esp.sd.esp.ws.scr.bfa | 250,000 |
| AVI Amsterdam | fbhg | sb.ep.ss.wc | sncr.esp.sda.esp.wsa.edv | 790,000 |
| AVI Alkmaar | fig | sb.ep.ac | esp.sd.esp.ws.bfa.scr | 450,000 |
| AVI Wijster | fig/wc | sb.ep.ac | esp.sd.esp.ws.scrd | 435,000 |
| AVI Moerdijk | fig | sb.sswkc | sncr.esp.ws.bfa | 600,000 |
| AVI Twente | rg | sb.ep.ac | esp.sd.esp.ws.scr.bfa | 285,000 |
| Total | | | | 4,830,000 |

ac : air cooling
bfa : adsorbent injection, followed by bag house filter
ec : evaporative cooling
ec/ac : evaporative cooling and air cooling
edv : electro dynamic venturi
ep : electricity production
esp : electrostatic precipitation
fbhg : forwards/backwards moving horizontal grate
fhg: forward moving horizontal grate
fhg/wc: forward moving horizontal grate, water cooled
fig : forward moving inclined grate
fig/wc : forward moving inclined grate, water cooled
fxbac : fixed bed reactor with activated carbon

hs : heat supply
hsdh : heat supply for district heating
hsgar : heat supply for gardening centre
hssd : heat supply for sludge drying
hwb : hot water boiler
lths : low-temperature heat supply
rg : reciproking grate

rolg : roller grate
sb : steam boiler
sb/hwb: steam boiler, hot water boiler
scr : scr-denox
scdr : scr-denox and dediox
sd : spray dryer
sda : spray dryer with adsorbens injection
sncr : sncr-denox
ss : steam supply
ssdiw : steam supply for destilled water production
sswkc : steam supply to a combined cycle power plant
wc : water cooling
wesp : wet electrostatic precipitation
ws : wet scrubber
wsa : wet scrubber with adsorbens injection

**Washing of bottom ash in deslaggers**
As will be indicated in section 3.3.2, bottom ash has problems to comply with the Dutch Building Materials Decree for use as secondary civil construction materials. As indicated there, critical aspects are the too high leachability of copper and molybdene.

Leachability of bottom ash can be reduced by washing the bottom ash in the deslagger. In this case the deslagger cannot operate waste water free. The waste water from the deslagger can be treated in combination with the waste water of a wet flue gas treatment system (see section 4.5.2).

Bottom ash quality may additionally be improved by addition of specific chemicals (phosphate, sulphides etc.). Though various experiments have been executed in this field, practical experience and evaluation of results is limited.

For treatment techniques for bottom ash we further refer to section 4.6.2.

**Dry deslagging systems**
The bottom ash from the normally applied wet deslaggers is drenched with water. This has following disadvantages:
- an increase of weight;
- reduced possibilities for further bottom ash treatment. Separation of iron scrap and non-ferrous metals from the bottom ash is more difficult.

Additionally, it can be noted, that the pH of the bottom ash increases, due to the presence of quick lime (CaO) in the bottom ash after incineration. This results in the formation of (hydr-)oxides of elementary metals (iron, aluminium), reducing the possibilities of recovery and in a sintering process, reducing the possibilities of sieving out glass, stone, ceramic materials etc.

For these reasons there is an increasing interest in dry deslagging systems. However, experiments on practical scale have not yet been executed in the Netherlands.

**Water (or steam) cooled grates**
In the past few decades, the LHV levels in municipal waste have substantially increased. This is partly due to an increased consumption of paper and plastic materials, etc. Also, the wide-spread introduction of seggregated collection of organic waste, with its relatively low LHV has resulted in an increase of the LHV of the remaining waste. Especially incineration plants with preceding mechanical separation of organic wet material must cope with relatively high LHV's of the combustible fraction.

In common grate types, the grate material is cooled by primary combustion air. Normally, the grate blocks are designed to facilitate sufficient contact between air and block. In roller grates, the cooling of the grate material is improved by intermittent exposure to the burning waste material.

Nevertheless, the lifetime of the grate material is limited, especially for the grate material in the incineration zone. Moreover, the lifetime of the grate material is reduced

considerably by higher LHV's in the waste, even if specific alloys are used as grate block materials.

This has resulted in the development of water cooled grates. With these grates, grate block temperatures are kept significantly lower. An additional advantage is that there is more flexibility in selecting the optimal amount and distribution of primary air.

Although warm cooling water can be applied for heating purposes, water cooling results in a slight reduction of energy efficiency. Approx. 3 - 5% of thermal capacity is lost and therefore is not available for steam (and electricity) production. This results in a reduction of electrical efficiency of less than 1%. Plant capacity, however, is slightly increased by reduction of the thermal load of the flue gas stream.

Practical experience with water cooled grates is limited in comparison with air cooled grates, but operational experience is reported to be good.

A new, comparable development is the use of steam as a cooling medium. With this concept, grate material temperatures are higher than with water cooling, but can be kept at sufficiently low levels. An advantage of steam cooling is a better overall energy efficiency and a higher temperature of the grate material, which can improve combustion behaviour. There is however no practical experience with steam cooled grates in the Netherlands.

**Special secondary air distribution systems**
As indicated in section 2.2.3, an adequate secondary air system is of prime importance for an optimal incineration process in the furnace. Secondary air is introduced from both sides (front and rear) of the furnace.

In modern incineration plants with high capacities, furnace dimensions are so large, that an equal distribution of secondary air is difficult to realise, as the distance over which the air must be blown in is too large. For this reason, cooled beams with additional air nozzles, located across the furnace can be applied.

**Recirculation of flue gases**
To achieve an adequate homogeneity of flue gases, a certain amount of secondary air is required. However, more secondary air results in a higher flue gas amount. This has a negative influence on the energy efficiency of the plant, leading to larger flue gas treatment units and, therefore, higher costs.

A current development is to use part of the cooled flue gases, after the dust has been removed, instead of (part of) the required secondary air. The technical configuration for the recirculation of flue gas is shown in figure 2.5.

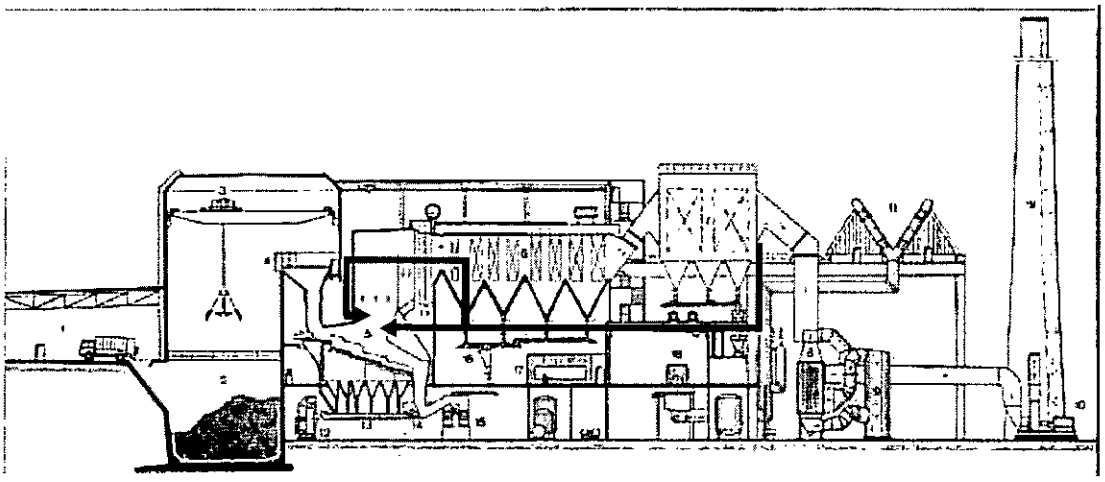

Figure 2.5. Recirculation of flue gases (in combination with secondary air)

Greater efficiency with FGR counteracts loss of W.C.

Approximately 50% of the required amount of secondary air can be replaced by recirculating flue gases. This results in a 10 - 15% reduction of the total amount of incineration air and flue gases. The load of the flue gas treatment system is reduced proportionally (resulting also in a reduction of emission loads) and the thermal efficiency of the plant increases by approximately 2 - 3%. This increase has however a limitation, as oxygen content of the flue gas cannot be reduced without restrictions (<6%).

Recirculation of flue gas as a replacement for primary air is not used in existing municipal waste incineration plants. In the past, plants have used this system, but the acid gases which remain in the flue gases after dust removal led to serious corrosion problems in the relatively cool installation parts under the grate.

AVI Amsterdam will research and test this system in future, as indicated in figure 2.6. The primary air for the first one or two zones will (partially) be replaced by recirculating flue gases. Expected advantages are a better drying behaviour, resulting from the higher temperatures, and a slower ignition of the waste, resulting from the lower oxygen content. This will result in a better positioning of the incineration process on the grate. Additionally, the energy efficiency is improved.

Corrosion problems will be solved by using special materials or by keeping the system on a higher temperature level.

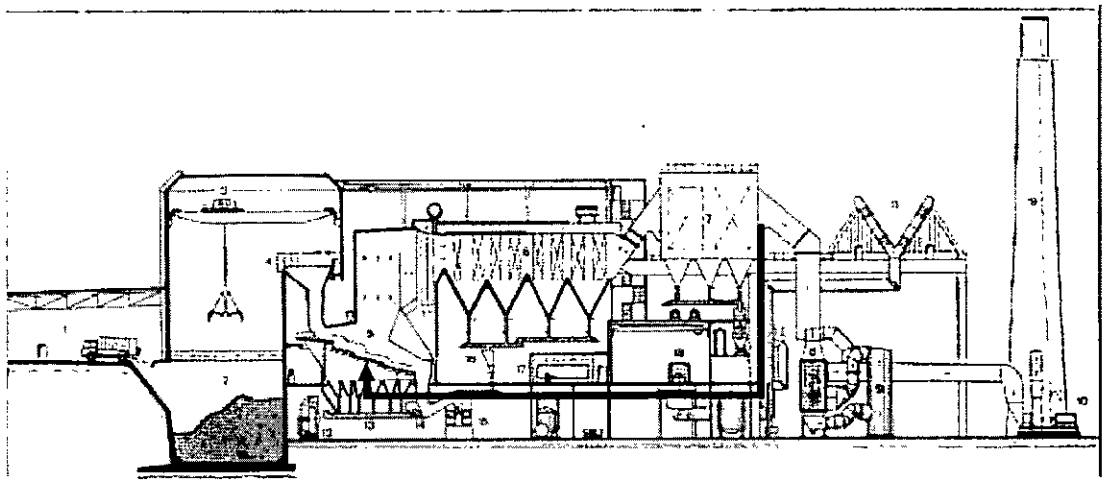

Figure 2.6: Recirculation of flue gases (as part of the primary air)

**Application of oxygen-enriched air**

The effectiveness of the incineration process can be improved by enriching the incineration air with (technically) pure oxygen. In this way, the amount of incineration air can be reduced. This results in an increase in thermal efficiency (higher incineration temperatures, less flue gas losses) and a reduction of the flue gas amount that requires treatment. Test results have shown, that an adequate control of the incineration process is facilitated by application of oxygen enriched air.

Energy consumption for oxygen production is however substantial, compensating the increase of thermal efficiency, and cost effectiveness is low. There has been executed a theoretical study on the effects on a Dutch grate incineration plant, including some laboratory tests. Results show that the application of enriched air can be connected with locally increased temperatures and increased concentrations of damaging compounds, resulting in increased risks on corrosion.

The system is not applied in existing Dutch municipal waste incineration plants. Based on the results of the indicated study, the application of oxygen-enriched air will most likely be limited to very specific cases.

**Application of higher incineration temperatures**

By adaptation of the furnace design, it is possible to achieve higher incineration temperatures of up to 1100 – 1200 °C. To achieve these higher temperatures, the following (combinations of) measures are required:

- preheating the incineration air;
- reducing the amount of incineration air;
- adaptation of the furnace design (no membrane boiler walls, but isolated refractory).

The purpose of this design is to improve the incineration process, thereby reducing the formation of components like CO, $C_xH_y$ and other organic compounds, such as dioxin(-precursors). $NO_x$-concentration levels, however, could be substantially higher.

Achieving higher incineration temperatures requires substantially higher investment costs, and plant availability may be reduced.

There is no practical experience with this type of municipal waste system in the Netherlands. A demonstration plant has been realised in Bremerhaven (Germany). In the Netherlands, higher incineration temperatures are used when incinerating hazardous waste.

**Short summary**
*new developments on incineration technology*
- all existing Dutch municipal waste incineration plants use modern incine-ration control techniques in order to improve the incineration processes. Although there are differences in set-up, this option is considered to be an important improvement (a.o. application of fuzzy logic).
- possibilities to improve bottom ash quality by washing bottom ash in the des-laggers are in an experimental stage.
- there is an increasing interest in application of dry deslaggers.
- most of the existing Dutch plants use traditional air cooled grates. Under the influence of increasing LHV's, there is a clear preference/tendency for water cooled grates.
- also improvement of secondary air systems is actually an important develop-ment.
- recirculation of flue gases is used as a replacement for part of the secondary air in several cases. The advantages are a reduction of flue gas volume, of $NO_x$-concentrations and an improvement of energy efficiency.
- recirculation of flue gases as primary air has not yet been applied, but will be researched.
- there is no application of oxygen-enriched air in the Netherlands. Application will probably be limited to very specific cases
- there is also no application of extra high incineration temperatures (> 1100°C) for municipal waste incineration in the Netherlands.

For a description of incineration systems, other than the grate incineration type see section 2.2.7.

**For reference literature on sections 2.1 – 2.2.4, see chapter 7, references [1] – [25].**

2.2.5 Related boiler technology

This section provides a description of the boiler technology used for the incineration of municipal waste. The description is based on the use of grate incineration technol-ogy. It should be mentioned however, that boiler designs of other incineration systems are comparable.

The hot flue gases that are emitted from the furnace are cooled down in the boiler. Boiler design must be adapted to the special characteristics of the waste incineration flue gases:
- the flue gas contains solid particles and fly ash, which are polluted with a wide variety of heavy metals, salts and other compounds;
- the flue gas also contains high concentrations of gaseous polluting components, such as hydrochloric acid, hydrofluoric acid, sulphur dioxide and nitrogen oxides.

These compounds can cause boiler clogging, erosion and/or corrosion. Special at-tention must be paid to the high temperature corrosion of the boiler tube material, due to the presence of chlorine. Normal boiler tube material suffers corrosion at tempera-

Table 3.1: Flue gas concentrations and Dutch and European emission standards to air for waste incineration plants

| | Unit | Typical composition of raw flue gas (mun. waste) | Dutch municipal waste standard (BLA) | Dutch hazardous waste standard (RVGA) | Typical values realised in the Netherlands | Old EU-standard | EU-standard per 4.12.2000 |
|---|---|---|---|---|---|---|---|
| Dust | $mg/m_b^3$ | 3000 | 5 | 10 | 0.5 - 3 | 30 | 10 |
| Acid gases | | | | | | | |
| HCl | $mg/m_b^3$ | 750 | 10 | 10 | 0.5 - 5 | 50 | 10 |
| HF | $mg/m_b^3$ | 5 | 1 | 1 | 0.1 - 0.5 | 2 | 1 |
| $SO_2$ | $mg/m_b^3$ | 300 | 40 | 50 | 2 – 30 | 300 | 50 |
| $NO_x$ | $mg/m_b^3$ | 350 | 70 | - | 40 – 70 | - | 200/400 |
| $NH_3$ | $mg/m_b^3$ | - | - | - | 0 – 3 | - | - |
| Heavy metals | | | | | | | |
| Hg | $mg/m_b^3$ | 0.25 | 0.05 | 0.05 | 0.005 – 0.02 | 0.2 | 0.05 |
| Cd+Tl | $mg/m_b^3$ | 1.0 | 0.05 | 0.05 | 0.001 – 0.01 | | 0.05 |
| Others[1] | $mg/m_b^3$ | 35 | 1 | 0.5 | 0.01 – 0.1 | 5 | 0.5 |
| Non combusted carbon/organics | | | | | | | |
| CO | $mg/m_b^3$ | 25 | 50 | 50 | 5 – 50 | - | 50 |
| $C_xH_y$ | $mg/m_b^3$ | 5 | 10 | 10 | 0 – 10 | - | 10 |
| PCDD/F's as TEQ | $ng/m_b^3$ | 1 – 5 | 0.1 | 0.1 | 0.01 –0.05 | - | 0.1 |

1) for municipal waste incineration
2) Sb, Pb, Cr, Cu, Mn, V, Co, Ni, Se en Te

Following remarks can be made on the typical composition of untreated flue gases (column 1):

- the indicated concentrations of 'raw' flue gas are related to municipal waste incineration with grate technology. For other waste types and/or incineration technologies figures may differ;
- dust concentrations depend on the character of the waste as well as on the design of grate and furnace;
- HCl, HF and $SO_2$ concentrations depend on waste composition. Design of the incineration part of the plant has little influence on this value;
- $NO_x$-concentration mainly depends on process conditions (temperature, homogeneity, $O_2$-concentrations, division between primary and secondary air);
- concentrations of heavy metals strongly depend on waste composition. Solid components are attached to dust particles. Heavy metals with a relatively low boiling point (Hg, Cd, Pb) cause (also) emissions in gaseous form. This is especially the case for mercury (Hg);
- concentrations of CO and $C_xH_y$ mainly depend on grate and furnace design. Especially the optimal division of incineration air, control of temperature, residence time and homogeneity is important;

- concentrations of PCDD and PCDF depend on boiler design ("de-novo-synthesis"), but also on grate and furnace design and on the use of an electro-static precipitator.

In Table 3.2 a survey is given of the emissions of the waste incineration plants in the Netherlands (for the year 1999). In section 4.4 the various flue gas treatment systems are presented.

**Specific note for table 3.2**
The data in table 3.2 are not collected specifically for this BAT-document but are based on figures, collected out of the various Environmental Annual Reports. In some cases, figures are influenced by specific circumstances (start-up, technical problems etc.) or by factors, such as other (waste treatment or industrial) activities, executed by the incineration companies, such as:
- mechanical sorting and landfill activities (ARN Beuningen and AVI Wijster);
- waste type and composition. As an example, specific emissions to air per ton of waste are influenced by the LHV of the waste proportionally
- combinations of the incineration of municipal waste with hazardous waste (AVR Botlek), sludge and specific hospital waste (GEVUDO, ZAVIN, DRSH);
- additional sludge drying (by AVI Roosendaal) etc.

The figures should therefore not be considered as absolute values but as indications.

**Emission standards for co-incineration**
Emission standards for co-incineration of biomass and waste together with fossil fuels are still in development in the Netherlands. According to the present proposals, following principles will apply:
- The emission standards will be comparable with the emission limit values of the EU-directive
- Emission standards of heavy metals, HF and HCl will be more strict.

Table 3.2
**DUTCH WASTE INCINERATION PLANTS**

**1999 EMISSIONS TO AIR**

Tabel 3.2 : Specific emission loads to air of the Dutch waste incineration plants (see section 2.1.1);
Calculated out of the yearly emission loads and the incinerated amounts of wastes in 1999 [176]-[190] and [201].

| Company (*) | Incinerated (kton/year) | CO2 (ton/ton) | Dust (kg/ton) | HCl (kg/ton) | HF (g/ton) | NH3 (kg/ton) | SO2 (kg/ton) | NOx (kg/ton) | Hg [g/ton) | Cd (g/ton) | heavy metals (g/ton) | CO (kg/ton) | CxHy (kg/ton) | Diox/Fur [10E-6 g/ton) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Municipal Waste Incineration** | | | | | | | | | | | | | | |
| Gevudo | 171 | 1,090 | 0,007 | 0,003 | 1,558 | 0,001 | 0,028 | 0,402 | 0,088 | 0,043 | 0,48 | 0,134 | 0,013 | 0,13 |
| AVR R'dam | 386 | 0,885 | 0,001 | 0,013 | 0,371 | n.a. | 0,008 | 0,278 | 0,005 | 0,002 | 1,04 | 0,086 | 0,004 | 0,11 |
| AVR-Botlek | 1.106 | 0,898 | 0,002 | 0,005 | 0,127 | 0,025 | 0,003 | 0,320 | 0,011 | 0,003 | 0,16 | 0,188 | 0,007 | 0,39 |
| AVR AVIRA | 301 | 1,170 | 0,001 | 0,019 | 1,311 | 5,4 | 0,058 | 0,219 | 0,015 | 0,004 | 0,35 | 0,098 | 0,003 | 0,52 |
| AVI Roosendaal | 55 | 0,805 | 0,001 | 0,039 | 0,603 | 0,008 | 0,063 | 0,381 | 0,007 | 0,004 | 0,37 | 0,116 | 0,037 | 0,09 |
| ARN | 250 | 1,069 | 0,004 | 0,004 | 1,495 | 0,002 | 0,004 | 0,432 | 0,006 | 0,047 | 0,05 | 0,100 | 0,005 | 0,08 |
| AVI Amsterdam | 789 | 0,891 | 0,003 | 0,001 | 0,020 | 0,000 | 0,015 | 0,324 | 0,010 | 0,002 | 0,13 | 0,058 | 0,002 | 0,25 |
| AVI Noord-Holland | 452 | 0,918 | 0,008 | 0,006 | 0,252 | 0,008 | 0,013 | 0,303 | 0,006 | 0,023 | 0,02 | 0,062 | 0,002 | 0,12 |
| AVI Wijster | 433 | 1,164 | 0,006 | 0,001 | 1,335 | 0,001 | 0,025 | 0,231 | 0,074 | 0,005 | 0,32 | 0,042 | 0,006 | 0,06 |
| AZN | 603 | 1,000 | 0,003 | 0,015 | 0,332 | 0,017 | 0,008 | 0,342 | 0,006 | 0,000 | 0,11 | 0,046 | 0,001 | 0,33 |
| AVI Twente | 285 | 1,053 | 0,006 | 0,009 | 0,674 | 0,002 | 0,012 | 0,324 | 0,007 | 0,007 | 0,54 | 0,055 | 0,015 | 0,00 |
| **Hazardous Waste Incineration** | | | | | | | | | | | | | | |
| AVR-Chemie DT-08 | 44 | 1,182 | 0,016 | 0,041 | 0,913 | n.a. | 0,012 | 1,629 | 0,020 | 0,004 | 0,64 | 0,455 | 0,012 | 0,11 |
| AVR-Chemie DT-09 | 51 | 1,181 | 0,006 | 0,006 | 0,392 | n.a. | 0,005 | 1,666 | 0,030 | 0,003 | 0,19 | 0,360 | 0,011 | 0,61 |
| **Clinical Waste Incinera-tion** | | | | | | | | | | | | | | |
| ZAVIN | 7 | n.a | 0,002 | 0,003 | 4,750 | n.a. | 0,101 | 0,870 | 0,042 | 0,048 | 0,09 | 0,047 | 0,009 | 0,23 |
| **Sewage Sludge Incineration** | | | | | | | | | | | | | | |
| DRSH | 371 | 0,291 | 0,001 | 0,001 | 0,094 | 0,000 | 0,004 | 0,089 | 0,003 | 0,003 | 0,01 | 0,009 | 0,002 | 0,01 |
| V.I.T. | 89 | 0,293 | 0,003 | 0,002 | 0,005 | 0,002 | 0,008 | 0,065 | 0,007 | 0,003 | 0,05 | 0,108 | 0,004 | 0,01 |
| SNB | 406 | 0,301 | 0,002 | 0,002 | 0,000 | 0,028 | 0,012 | 0,085 | 0,010 | 0,002 | 0,02 | 0,017 | 0,001 | 0,02 |

lee

1.29



$= \frac{310 \text{ tons } NO_x}{240,000 \text{ tons waste}} \times \frac{2000 \text{ lb } NO_x}{\text{ton } NO_x} \times \frac{1 \text{ kg/ton}}{2 \text{ lb/metric ton}} = 1.29 \frac{\text{kg}}{\text{metric ton}}$

### 3.1.3 Other emissions to air

**Air emissions due to traffic**
These emissions are caused by the heavy transport trucks or other means of transport. Main bulk truck emissions are dust, CO, $C_xH_y$, $NO_x$ and $SO_2$. Typical figures for transport emissions per ton of material for trucks with a capacity of 30 tons are indicated in table 3.3.

Table 3.3:Emission factors of diesel driven lorries

| Compound | Emission factor (gram/km) |
|---|---|
| Dust | 1,0 |
| CO | 3,3 |
| CxHy | 2,2 |
| NOx | 14 |
| $SO_2$ | 0,95 |

It can be calculated that the contribution of these emissions to the total emission load, related to waste incineration is relatively very limited, as long as transport distances are not over 100 – 200 km, with $NO_x$ as an exception.

**Air emissions of acceptance and storage of waste**
Acceptance and storage of municipal waste takes place in a closed bunker. So no significant direct air emissions take place. Ventilation air is used as incineration air. Polluting components are therefore incinerated and included in the stack emissions.

Only in special cases, air emissions (including odour emission) may occur:
- if plants are equipped with only one line. There will be periods for maintenance and other stops, during which no incineration air is required. This situation should be taken into account in the design of the plant, depending also on environmental conditions;
- in case of accidents (fire in the bunker). Adequate fire detection, prevention and abatement measures in the bunker area are required.

**Air emissions due to arrival, storage and use of chemicals**
Normally chemicals are arriving in closed systems and stored under comparable conditions. Exhaust air of silos or tanks can be lead to the incineration or flue gas treatment process or treated in small treatment units, according to valid regulations.

**Air emissions of pre-treatment of waste**
The potential air emissions of (mechanical) pre-treatment of waste are dust and odour. Dust emission can be prevented by application of cyclones or bag filters. Odour nuisance normally can be prevented by an adequate ventilation system. Only in specific cases (e.g sludge incineration plants), additional odour reduction provisions (biofilters, scrubbers) are required. An interesting option, in case of mechanical pre-treatment and

Table 4.5 gives an overview of Dutch plants that use semi-dry flue gas treatment. As indicated, most plants use the system as an intermediate system for the evaporation of process waste water, i.e. as spray dryer and not as spray adsorber.

Dry systems are not applied in Dutch waste incineration plants

Table 4.5. : Dutch plants equipped with semi-dry flue gas treatment

| Name/place | Reagent | Location of spray dryer/absorber in flue gas line | Fluoride emission [g/ton-waste] | Chloride emission [g/t-waste] | SOx emission [g/t-waste] |
|---|---|---|---|---|---|
| ARN Beuningen | Slaked lime | Intermediate | 1.5 | 4 | 4 |
| AVI Alkmaar | Lime / Active carbon | Intermediate | 0.3 | 6 | 13 |
| AVI Amsterdam | Slaked lime / Blast-furnace cokes | Intermediate | 0.02 | 1 | 15 |
| AVI Roosendaal (incl sludge drying) | Lime / active carbon / soda ash | End-step | 0.6 | 39 | 63 |
| AVI Twente | Slaked lime | Intermediate | 0.7 | 9 | 12 |
| AVI Wijster | Slaked lime | Intermediate | 1.3 | 2 | 28 |

Table 4.6 gives a summarised comparison between dry and semi-dry flue gas treatment systems.

Table 4.6: Comparison of dry and semi-dry flue gas treatment systems

| Process type | Emission concentrations | Advantages | Disadvantages |
|---|---|---|---|
| Dry | HF: <1 mg/$m_b^3$.<br>HC: <10 mg/$m_b^3$.<br>$SO_x$: <40 mg/$m_b^3$. | most simple design | - lower efficiency (compared to semi dry) difficult to comply with emission standards,<br>- high consumption of chemicals and large amounts of residue,<br>- dust bag filter required |
| Semi-dry | HF: <1 mg/$m_b^3$.<br>HCl: <10 mg/$m_b^3$.<br>$SO_x$: <40 mg/$m_b^3$. | relatively simple design, less complicated than wet scrubbers | - lower efficiency (compared to wet scrubbers),<br>- higher consum-ption of chemicals than wet scrubbing, more residues,<br>- dust filter recommended |

**Short summary**

*dry and semi-dry flue gas treatment systems*

- main advantage of dry and semi-dry flue gas treatment systems is, that there is no polluted process waste water stream which needs treatment before discharge;
- investment costs are lower than for wet flue gas treatment systems, especially for relatively small capacities;
- it is not possible to reach the same very low emission concentrations as with wet flue gas treatment;
- consumption of chemicals is larger, especially for dry flue gas treatment;
- also production of residues is larger than with wet flue gas treatment.
- dry flue gas treatment is not used in the Netherlands. Its application is mainly restricted to units with small incineration capacities.
- semi-dry flue gas treatment alone is used in one relatively small incineration plant.
- various municipal waste plants in the Netherlands use semi-dry spray dryer technique in combination with wet scrubbing, in order to avoid discharge of waste water (see section 4.5.3)

4.4.4 Wet flue gas treatment

**Description**

There exists a wide variety of elements and designs for wet flue gas treatment systems. The basic principle of wet scrubbing is an intensive contact between flue gas and liquid (water) during which pollutants are absorbed in the liquid.

Wet flue gas treatment is technically applicable in waste incineration. However, set-up in of wet systems with waste incineration is normally a two or three stage process.
In the first stage, part of the water used for scrubbing is evaporated, under simultaneously cooling of the flue gases until saturation temperature. In the first one or two stages, an acid pH (approx. 1) is maintained. At this process condition, removal of strong acids, such as HCl is possible. $SO_2$ is hardly or not removed, as it forms a weak acid. Additionally, the removal of (volatile) heavy metals is here effective, as they are in ionic state.
In the last stage, a more neutral pH is maintained, by dosing of alkaline chemicals (soda or sometimes lime), in order to realise sufficient removal of $SO_2$. Part of the remaining dust (after the preceding dust removal) is absorbed by the scrubber liquid.
It is noted that $NO_x$ is hardly or not removed in wet scrubber systems.

There is a wide variety of elements and designs for wet flue gas treatment systems, showing large differences in costs, reliability, availability, removal efficiency etc. The application of a wet scrubber system is a dedicated study in itself.

Table 4.9 gives an overview of the application of SNCR with Dutch municipal waste and sludge incineration plants.

Table 4.9:Dutch plants equipped with SNCR

| Name/place | Reagent | Location | Distribution | NOx-emission [g/ton-waste] |
|---|---|---|---|---|
| **Municipal Waste Incineration** | | | | |
| AVI Amsterdam | 25% ammonia | In furnace | 1 level<br>12 nozzles/level<br>3 boiler sides | 324 |
| AVI Moerdijk | 25% ammonia | In furnace | 3 levels<br>2 x 8 nozzles/level<br>2 boiler sides | 342 |
| AVR AVIRA | 10 - 25% ammonia | In furnace | 3 levels<br>12 nozzles/level<br>2 boiler sides | 319 |
| **Sewage Sludge Incineration** | | | | |
| DRSH Dordrecht | 25% ammonia | | | 89 |
| SNB Moerdijk | (*) ammonia | | 1 injection point (**) | 84 |

* concentration unknown as (partly) a waste stream is used ** in the furnace.

### 4.4.6 Selective Catalytic Reduction (SCR)

**General**

Selective Catalytic Reduction (SCR) is a commercially available process for the reduction of $NO_x$-emissions. In the SCR-method the $NO_x$ concentration in the flue gas is reduced through injection of ammonia ($NH_3$) in the presence of a catalyst. For the ammonia injection methods see the description in section 4.4.5 (SNCR). The most common SCR reactions, which are catalysed, are:

$$4\,NO + 4\,NH_3 + O_2 \rightarrow 4\,N_2 + 6\,H_2O$$
$$NO + NO_2 + 2\,NH_3 \rightarrow 2\,N_2 + 3\,H_2O$$
$$2\,NO_2 + 4\,NH_3 + O_2 \rightarrow 3\,N_2 + 6\,H_2O$$
$$6\,NO_2 + 8\,NH_3 \rightarrow 7\,N_2 + 12\,H_2O$$

The temperature at the catalyst has an important effect on the (relative speed of) the reactions. The optimum temperature range for catalytic reduction is usually between 300°C and 400°C; however, use of other, new types of catalysts has extended the temperature range downwards in some applications.

Generally spoken, a lower temperature results in a slower reaction rate and possible ammonia slippage. A higher temperature results in a shortened catalyst lifetime and can lead to the oxidation of $NH_3$, actually forming additional $NO_2$.

Present experience with SCR in the Dutch waste incineration sector is limited to application of SCR as a tail-end system, because flue gases before flue gas treatment contain too much pollutants which would poison the catalyst.

As in tail-end applications the temperature of the flue gases is below the optimum temperature window, heating of the flue gases is required. For this reason a heat exchanger is installed, followed by additional heating by an outside source (i.e. high pressure steam or natural gas). The ammonia is injected in a stoichiometric amount, just before the catalyst.

**Catalysts**
The catalyst material generally consists of the carrier ($TiO_2$) with added active substances ($V_2O_5$ and $WO_3$). It has been reported too, that activated carbon or cokes can act as a catalyst, but there is no experience with this system in the Netherlands

Criteria for determining the type of catalyst to be used are: flue gas temperature, NOx reduction required, permissible ammonia slip, and permissible oxidation of sulphur dioxide, concentration of pollutants and lifetime of the catalyst.

The following types of degradation limit the lifetime of catalysts:
- Poisoning: the active site of the catalyst is blocked by a strongly bound compound;
- Deposition: pores are blocked by small particles or condensed salts, such as ammonium bisulphate ($NH_4HSO_4$);
- Sintering: at too high temperatures the microstructure of the catalyst is destroyed;. Furthermore it is noted here that CO is converted to $CO_2$ and this exothermic reaction can cause additional sintering;
- Erosion, due to physical damage caused by solids and particles.

Guaranteed lifetimes of 3 to 4 years are reported for catalysts.

Furthermore, it can be remarked that there is no experience available in the Netherlands about formation of $N_2O$ with SCR-systems, due to a bad condition of the catalyst, as has been reported from the nitric acid production industry.

**Comparison with SNCR**
In the first half of the 1990-ies, the majority of the Dutch waste incineration plants have decided to use SCR to reduce $NO_x$-emissions (see table 4.10). An important argument for that decision was the fact that chemical process conditions within SCR-systems are better controlled than with SNCR, so there was more certainty that emission standards could be met. Also side effects such as ammonia slippage and $N_2O$ formation are less.

On the other hand SCR requires additional consumption of natural gas (or high-pressure steam) and relatively high additional investment costs. Price-effectiveness is therefore lower than with SNCR.

### High-dust SCR

As indicated above, in the Dutch waste incineration sector SCR is applied as a tail-end solution. In coal power plants, SCR is also applied as an intermediate process step. In such cases, the SCR-unit is located in the boiler area, before the economiser and without a preceding dedusting-step. At that position flue gasses have still sufficient temperature level. A similar configuration is under development with waste incineration. It is however expected that in that case a prededusting step will be required, as the fly ash of waste incineration is more polluted than the fly ash from coal incineration.

Table 4.10: Dutch reference plants equipped with SCR.

| Name/place | Reagent | Catalyst | $NO_x$-emission [g/ton waste] |
|---|---|---|---|
| **Municipal waste incineration** | | | |
| ARN Beuningen | 25% ammonia | | 432 |
| AVI Alkmaar | 25% ammonia | | 303 |
| AVI Roosendaal (incl sludge drying) | 25% ammonia | $V_2O_5/TiO_2$ | 381 |
| AVI Twente | 25% ammonia | | 324 |
| AVI Wijster | 25% ammonia | | 218 |
| AVR Botlek | liquefied $NH_3$ | $V_2O_5/WO_3$ | 320 |
| AVR Rotterdam | 25% ammonia | $V_2O_5/WO_3$ | 278 |
| GEVUDO | 25% ammonia | | 402 |
| **Specific clinical waste incineration** | | | |
| ZAVIN Dordrecht | 25% ammonia | | 870 |

### Economics:

The operating costs of removing 1 ton of NOx ranges between € 3,500 and € 4,500. If this cost is allocated to the processing costs per ton of waste, this corresponds to € 5 to € 7.7 [1]. Originally it was reported that removal cost for SNCR and SCR were on the same level. More recent experience shows that removal cost of SNCR can be substantially lower than those of SCR.

**Short summary (DeNOx-systems)**

*Selective non-catalytic reduction (SNCR)*

- With application of SNCR $NO_x$-emission concentrations of 70 mg/$m_o^3$ are feasible;
- SNCR requires less capital costs compared to SCR (no specific reactor and catalyst are required).
- SNCR is associated with a certain amount of ammonia slip. However, the ammonia emission concentration will be low, due to downstream gasscrubbing. General practice shows that under steady conditions, this slip can be kept below 5 mg/$m_o^3$;
- Below 280°C and in presence of $SO_x$, ammonia slip can form deposits of ammonium bisulphate ($NH_4HSO_4$) and/or ammonium sulphate ($(NH_4)_2SO_4$) on the downstream equipment (can cause operational problems);
- In case of application of SNCR, nitrous oxide ($N_2O$) can be formed as a side effect. $N_2O$ has a very high Global Warming Potential. To keep formation of $N_2O$ on a low level it is important to adequately control process conditions (temperature, amount of injected ammonia)
- The handling, storage and use of gaseous or liquefied ammonia implies an increased safety risk. The complication and costs involved with handling and storing according to safety rules that exist in most countries, makes it favourable to use aqueous ammonia solutions or other chemicals, such as urea solutions. However, the use of urea may lead to the formation of nitrous oxide ($N_2O$) as a by-product. Therefore most waste incineration plants with SNCR use ammonia solutions

*Selective catalytic reduction (SCR)*

- With SCR $NO_x$ emission concentrations of 30 to 50 mg/Nm³ are realised. However, actual $NO_x$ reduction depends on the initial $NO_x$ concentration, the temperature and the number of catalyst layers, the minimum level of residue $NO_x$ obtainable being limited in practice by the risk of unreacted ammonia and allowed ammonia emission concentrations.
- As additional pre-treatment (dust removal) is needed to avoid excessive deposition of particulate on the catalyst bed, SCR can only be applied in a tail-end position in the flue gas treatment;
- SCR requires additional consumption of natural gas (or high pressure steam) and relatively high additional investment costs. Price-effectiveness is therefore lower than with SNCR;
- SCR is associated with some ammonia slip. General practice shows that under steady conditions, this slip can be kept below 5 mg/ $m_o^3$;
- As for SNCR, handling of gaseous or liquefied ammonia, implies an increased safety risk. The complication and costs involved with handling and storing according to prevailing safety rules, make it favourable to use ammonia solutions. Therefore all Dutch waste incineration plants, equipped with SCR use ammonia solutions.

## 5.2 General criteria for selection of Best Available Techniques

General criteria for the selection of BAT, related to the various environmental aspects can be summarised as follows.

### 5.2.1 Emissions to air

1. Selection of flue gas treatment technology should be based on an optimal reduction of air emissions, but also other environmental (cross-media) aspects are to be considered, such as:
   - minimisation of emissions to water,
   - acceptability of discharging of soluble salts to local surface water,
   - production of residues,
   - consumption of chemicals and energy
   - maximum energy recovery.

2. The following table gives an overview of emission concentrations to air for various polluting compounds, as normally reached for waste incineration in the Netherlands.

Table 5.1: Typical flue gas concentrations for Dutch waste incineration plants

| | Unity[2] | Typical values, realised in the Netherlands |
|---|---|---|
| Dust | $mg/m_b^3$ | 0.5 – 3 |
| HCl | $mg/m_b^3$ | 0.5 – 5 |
| HF | $mg/m_b^3$ | 0.1 - 0.5 |
| $SO_2$ | $mg/m_b^3$ | 2 – 30 |
| $NO_x$ | $mg/m_b^3$ | 40 – 70 |
| $NH_3$ | $mg/m_b^3$ | 0 – 3 |
| Hg | $mg/m_b^3$ | 0.005 – 0.02 |
| Cd+Tl | $mg/m_b^3$ | 0.001 – 0.01 |
| Others[1] | $mg/m_b^3$ | 0.01 – 0.1 |
| CO | $mg/m_b^3$ | 5 – 50 |
| $C_xH_y$ | $mg/m_b^3$ | 0 – 10 |
| PCDD/F's as TEQ | $ng/m_b^3$ | 0.01 – 0.05 |

1) As, Sb, Pb, Cr, Cu, Mn, V, Co, Ni, Se, Sn and Te
2) dry flue gas, at 273K, 101.3 kPa, 11% $O_2$, hourly average values based on standardised (inter)national sampling and analysis methods.

3. Other emissions to air (dust, odour) should be prevented by an adequate design of the plant (adequate storage and ventilation provisions etc.).

### 5.2.2 Emissions to water

1 Process waste water, resulting from a wet flue gas treatment system is to be adequately treated before discharge, in order to substantially reduce levels of pollutants (solid particles, heavy metals, organic micro-pollutants).

2 The following table gives an overview of emission concentrations to water for various polluting compounds, as normally reached for waste incineration in the Netherlands.

Table 5.2: Indication of emission standards for discharge of wet flue gas treatment waste water (direct and indirect discharges)

| Compound | Unity | Typical value for discharge to surface water | Normally applied range, depending on circumstances |
|---|---|---|---|
| As | µg/l | 10 | 3-200 |
| Cd | µg/l | 50 | 5-100 |
| Cr | µg/l | 30 | 30-500 |
| Cu | µg/l | 20 | 10-100 |
| Hg | µg/l | 5 | 1-20 |
| Pb | µg/l | 100 | 50-500 |
| Ni | µg/l | 30 | 15-100 |
| Sn | µg/l | 50 | 25-100 |
| Mo | µg/l | 1000 | 100-1000 |
| Zn | µg/l | 200 | 50-500 |
| Suspended solids | mg/l | 10 | 10-45 |
| PCDD/F (TEQ) | ng/l | 0.1 | <0.1 |

3 In case discharge of treated waste water, containing dissolved salts is not environmentally acceptable (depending on local circumstances), a waste water free flue gas treatment system (evaporation) should be applied.

4 Waste water, resulting from bottom-ash collection and storage should not be discharged without adequate treatment.

5 For other non-specific waste water streams an adequate set-up of provisions for storage, treatment and discharge is to be applied.

### 5.2.3 Residue treatment and disposal

1. The re-use of incineration residues (bottom-ash, fly ash etc.) is to be maintained on a high level.

2. Re-use of bottom-ash as civil construction material should preferably take place in large scale applications.

3. Improvement of the quality of the bottom-ash (reduction of leachability) is to be promoted in order to comply with category 2 of the Dutch Building Materials Decree (DBMD, "Bouwstoffenbesluit", see sections 1.6 and 3.3.2).

4. Increased re-use of fly ash is recommended, if required after using immobilisation techniques.

5. Further development of (on site) technologies for re-use of part of flue gas treatment residues (gypsum, salts) requires attention. Disposal of flue gas treatment residues should take place by controlled landfill (see European Directive for landfills).

### 5.2.4 Energy aspects

1. Use of recovered energy for production of electricity, based on maximum steam temperatures of approx. 400°C is a minimum requirement for BAT.

2. If the local situation offers this opportunity, use of heat by neighbouring activities, under application of co-generation technology is to be applied.

3. For the selection of a new site, possibilities for use of heat by neighbouring activities should be taken into account. For existing sites, possibilities for (increase of) use of heat should be investigated.

4. Possibilities to increase energy efficiency are to be investigated and if possible be applied. This includes options to reduce the own energy consumption, to increase thermal efficiency (recirculation of flue gas, improvement of incineration control systems etc.) as well as opportunities to improve thermodynamic efficiency, such as application of higher steam temperatures and/or better cooling.

## 5.3 BAT for municipal waste incineration

In this section, BAT for municipal waste incineration is defined. BAT-aspects of pre-treatment, acceptance and storage of municipal waste plants are discussed in section 5.3.1. BAT for grate, furnace, boiler and energy recovery is discussed in section 5.3.2. Subsequently, BAT for flue gas treatment is discussed in section 5.3.3.

### 5.3.1 BAT for pre-treatment, acceptance and storage of municipal waste

Based on the criteria, as discussed in the section 5.2, following aspects of municipal waste pre-treatment, acceptance and storage are included in BAT for incineration of municipal waste:

- an acceptance policy with maximal attention for segregated collection (at source) of specific waste categories such as organic household waste, paper and board, glass, metals, textiles, used household equipment, small amounts of hazardous wastes, industrial wastes, demolition and construction wastes etc.;

- adequate waste acceptance provisions and procedures, such as weighing bridges, administrative systems, possibilities to check contents of waste trucks etc.;
- a closed reception hall with adequate ventilation;
- a waste storage bunker of sufficient size (minimum approx. four days storage capacity), with sufficient dumping positions and with adequate fire protection provisions;
- a bunker crane system with at least two cranes. Crane personnel should have an adequate view in the bunker. Crane movements are to be controlled semi-automatically and with adequate safety provisions;
- size reduction of bulky wastes by means of guillotine and/or rotary shears;
- adequate provisions for storage and mixing of waste in the waste bunker.

### 5.3.2 BAT for grate, furnace, boiler and energy recovery

BAT for municipal waste incineration includes following aspects of grate incineration:

- a grate system which ensures an adequate incineration process with a low percentage of unburned material in the bottom ash;
- the distribution of primary air under the grate should be controlled;
- depending on the waste quality there should be provisions to pre-heat (part of) the primary incineration air;
- a deslagger system, which prevents the introduction of false air at the end of the grate. The deslagger should be able to operate waste-water free or with controlled discharge of waste water;
- the furnace should have a relatively low specific heat load, in order to reduce flue gas velocities and enable sufficient residence time of flue gases on a temperature level above 850 °C;
- secondary incineration air should be effective over the total cross-section of the furnace, if required by extra beams, in order to realise sufficient homogeneous presence of oxygen (a minimum of 6% is only indicative);
- part of the secondary air can be replaced by recirculated flue gases (after pre-removal of dust);
- flue-gas flow patterns in the furnace should be tested in computer models or on laboratory scale;
- protection of the lower part of the furnace by refractory lining;
- application of an incineration control system. Design of the system may vary, depending on design of the grate system and experience of equipment supplier and operating company;
- water cooled grate systems are considered as BAT for waste with a relatively high LHV (above 10 MJ/kg);

BAT for the related boiler and energy recovery system includes following elements:

- a maximum flue gas temperature before the first superheater convection bundles of 650°C;
- application of additional empty boiler passes is optional;
- a first convection bundle with a relatively low temperature and with large distances between tubes;

- application of moderate steam conditions (steam temperature <400°C) in combination with concurrent flow in the last superheater;
- application of special boiler cleaning devices;
- application of a steam turbine with electrical generator for electricity production;
- (if applicable) heat supply to neighbouring customers and if possible with co-generation technology;
- application of special configurations for the water/steam cycle, in case local conditions enable this;
- improving of energy efficiency by application of low cooling temperatures, if possible in combination with the supply of low-temperature heat to neighbouring customers;
- application of special tube materials (inconel) for furnace walls (evaporator).

Furthermore following conditions are to be taken into account on selection of BAT for municipal waste incineration:
- the grate, furnace and boiler system should have a well-proven availability;
- a sufficient economy of scale of the plant should be realised, preferably with minimal three lines and capacities per line of minimal 15 t/h, preferably approx. 25 t/h;
- the design of the plant should prevent the risk of local soil pollution by soil protection measures, such as watertight floors;

### 5.3.3 BAT for flue gas treatment of municipal waste incineration plants

BAT for flue gas treatment can be described as follows:

For large municipal waste incineration plants wet flue gas treatment is considered as BAT. For municipal waste incineration plants with relatively small capacities, semi-dry flue gas treatment (including pre-removal of fly-ash) can be considered as an alternative.

In detail BAT for flue gas treatment is assessed as follows:
- application of pre-removal of dust. The resulting fly ash is to be collected separately and can be applied usefully;
- application of wet flue gas treatment. The treatment of the resulting waste water depends on local circumstances;
- if local surface water can accept the resulting load of soluble salts (mainly chloride), physical/chemical waste water treatment is considered as BAT;
- physical/chemical treatment consists of following process steps: neutralisation of acid waste water (in two stages), sedimentation, sand and/or activated carbon filtration and dewatering of sludge. The emission levels to water, as indicated in table 5.2 are to be achieved;
- the waste water treatment unit should be dimensioned sufficiently large in capacity, in order to be able to cope with process variations. Additionally provisions for storage of waste water variations should be available and operational personnel should pay attention to process control. Discharge of effluent should preferably take place on a communal waste water treatment plant;
- if local surface water cannot accept the resulting load of dissolved salts, a waste water free design of wet flue gas treatment is applicable, by evapora-

tion of the produced waste water in a spray dryer/absorber, including bag house filter or ESP, located between pre-removal of dust and wet scrubber;
- SNCR-DeNOx for removal of $NO_x$, for new plants (less energy consumption, better cost-effectivity). For existing plants a retrofit with SNCR may not be applicable. In that case SCR-DeNOx is more appropriate.
- flue gas polishing by means of an entrained bed system, consisting of injection of adsorbens and dust bag filters;

The indicated technology is fully capable of reaching the emission levels to air of table 5.1 and if applicable the emission levels to water of table 5.2, with safe margins.

### 5.3.4 BAT for solid residues

BAT for bottom-ash treatment consists of:
- treatment by sieving, breaking, removal of iron scrap (magnetic separation) and non-ferrous metals (eddy-current);
- natural ageing of the material;

Although re-use of bottom-ash, fly ash and flue gas treatment residues takes place outside the boundaries of the incineration plant and therefore is formally out of the scope of this document, the best environmental solutions for these residues are:
- for bottom ash: controlled re-use as civil construction material in large projects (for embankments >10,000, preferably >100,000 tons per project, for road foundations >1,000 tons per project);
- for fly ash: re-use as a filler in bound applications (asphalt, mortars) and re-use after solidification;
- for flue gas treatment residues: controlled landfill after solidification

These routes are according to the LAP (version January 2002).

Sector Guidance Note

**IPPC S5.01**

# Integrated Pollution Prevention and Control (IPPC)
# &
# Integrated Pollution Control (IPC)

# Interim Sector Guidance for the incineration of waste and fuel manufactured from or including waste

ENVIRONMENT AND HERITAGE SERVICE


ENVIRONMENT AGENCY

WID provides mandatory environmental performance criteria for all installation in these sectors. Only at installations that have very large waste throughputs (and consequent potential impacts) is it possible that improvements beyond WID may be achieved within BAT. Further improvements may also be appropriate at installations where the process or abatement design in place for the primary fuel is such that its operation with a refuse derived fuel may already allow for standards better than the directive standards to be achieved.

***Individual Situations:***

1. ***Municipal RDF*** – some plants burning RDF are undergoing upgrade at the time of writing to meet new emission standards. The fact that these have been financed would appear to indicate that sector economics are adequate. The role of recycling credits and energy generation subsidies may be significant in supporting such schemes.
2. ***Poultry litter*** – whilst a number of plant upgrades have taken place, there have been few new plants developed in this sub-sector in recent years.
3. ***MBM Combustion*** – significant new projects have been financed. The quantity of MBM requiring disposal may lead to further proposals (this would also be true of animal remains and carcass incinerators)
4. ***Tyre Combustion*** – tyres offer a significant disposal problem but at an average CV of 32Mj/kg represent a significant energy recovery opportunity. Preparing the tyres to allow incineration has proved problematic in some instances. Opportunities for co-incineration in power stations and cement kilns offer a means of recovering energy and may even reduce emissions at those installations compared with the primary fuel. The relatively low level of exploitation of these opportunities may reflect technical difficulties, problems gaining permission or the public relations aspects of waste burning. Pyrolysis and gasification may be suited to this sector as they may be able to capitalise on the high volatile content of the tyres to produce a fuel rich off gas.
5. ***Secondary Liquid Fuels*** – the relatively widespread use of SLF and compliance with the existing HWID would indicate that the use of SLF remains economically viable.

## 1.8.2 Generic cost information required

Capital, revenue and annualised cost data for a variety of abatement and monitoring techniques are provided in the BAT report - Review of IPC Technical Guidance for Chapter 5 and 1.3c Vol1 March 2000 (Ref. 29).

Operators will be expected to justify their selected techniques using the H1 methodology (Ref. 5) (E1 for IPC) – thus comparing the costs of different techniques against the environmental gains. The key cost related aspects outlined below are of particular interest in this sector, and will require justification in the application. This section is intended as a guide. It should not be considered to be all encompassing.

Where it is not possible for uncertain (but potentially significant) factors such as "reliability" or "operational experience" to be quantified, these may still be included in any accompanying qualitative discussion that justifies the final BAT selection. In many cases such factors will be the dominant indicators of environmental performance:

1. ***Waste pre-treatment:***

Waste is often of a highly heterogeneous nature. This can create problems during its incineration including short-term exceedences of emissions limits and unnecessary waste production through the over-dosing with reagents to control peak emission rates.

The degree of pre-incineration waste treatment will therefore require justification and should take into account the following:

- What are the benefits to be accrued from pre-treatment?
- Additional capital and revenue costs of the pre-treatment options?
- Costs and consequences associated with not implementing pre-treatment? e.g. waste disposal costs for additional reagent waste arising?

See also Section 2.3.1 (incoming waste management) and section 2.3.8 (abatement of point source emissions to air).

2. ***NOx control techniques:***

There are a variety of approaches available for the prevention and control of NOx, (see Sections 2.3.3 - furnace types, 2.3.4 - furnace requirements and Section 2.3.8 - abatement for details).

Operators will in particular be required to provide cost arguments comparing the NOx control techniques selected and take into account the following:

- Could waste pre-treatment reduce NOx production?
- Could a lower NOx furnace be used? e.g. fluidised bed
- Could staged combustion be used?
- Can FGR be used to reduce the need for reagent injection?
- Could SCR be used instead of or as well as SNCR?

Note: Recent cost comparisons for SCR and SNCR appear to have shown some conversion. Figures quoted in a recent application (year 2001) of £1,181/te NOx avoided with SNCR and £3,513/te of NOx avoided with SCR. Further reductions in SCR cost could lead to it becoming BAT in some situations and its possible use should be examined (see Section 2.3.8 for further comment on secondary NOx abatement and NOx cost benefit study requirements).

3. ***Acid Gas Treatment:***

There are a variety of approaches to acid gas control. The techniques are outlined in Section 2.3.8 - abatement of point source emissions to air.

The key cost related elements that must be considered in order to demonstrate that the selection chosen is the BAT are:

- Can waste elimination / pre-treatment be used to control inputs?
- What are the costs and benefits of waste pre-treatment? e.g. reduction in reagent and APC residue disposal costs? Capital and revenue costs of pre-treatment plant?
- Can reagent dosing be linked to acid gas load using fast response monitoring and adjustment?
- Would an alternative reagent assist?
- Justify why wet scrubbing is not employed?

4. ***Stack height***

Stack height increases will result in reduced ground level impacts but there are restrictions on this.

- Could the stack height be increased to reduce ground level impacts?

See Section 2.3.5 - Chimneys and vents, and Section 4 - Impact.

5. ***Energy recovery***

The primary purpose of the installations in this sector is the safe disposal of waste. The recovery of energy from the waste is an important, but secondary consideration. Nonetheless, installations should be designed and operated such that *"the heat generated ....is recovered as far as practicable"* (ref WID). See also Section 2.3.7 - Boiler design and Section 2.7 - Energy.

Operators must therefore justify how the degree of energy recovered is the BAT. This will require consideration of:

- How much energy is produced per tonnes of waste incinerated? What is the "net" energy production / consumption (i.e. less parasitic loads) of the installation per unit of waste incinerated?
- Will increased energy recovery result in increased emissions from the installation?
- What are the costs (capex / opex) of the options for increasing the energy recovered?
- Justify why combined heat and power and / or district heating cannot be used?
- Can waste heat be used to heat primary / secondary air? Or to heat the final gas discharge (to reduce plume visibility, improve dispersion, allow for SCR?)

**Furnace requirements**

### *2.3.4.8 Flue gas recirculation (FGR)*

Application Form Question 2.3 (cont.)

BAT for NOx prevention is as follows:

***With the Application the Operator should:***

1. supply the general Application requirements for Section 2.3 on page 39 for this aspect of the activities.

***Indicative BAT Requirements***

***BAT for flue gas recirculation***

1. All incineration plants are expected to include FGR or provide a clearly made site specific justification why FGR is not used (addressing each of the points below).
2. More secondary air is required to provide turbulence than is needed simply for supplying oxygen. The resulting excess oxygen encourages both $NO_x$ and dioxin formation. ***FGR*** replaces 10-20% of secondary air (with $N_2$ and $CO_2$) reducing oxygen and peak temperatures thereby reducing $NO_x$ generation.
3. FGR gives around 20% $NO_x$ reduction, but it has, in combination with repositioning air inlets (using CFD to optimise locations) and improved control, given 25-35% reduction.
4. Higher re-circulation rates may give rise to corrosion owing to elevated CO concentrations. At the lower levels this is not expected to be significant enough to prevent the routine use of this emission prevention technique.
5. The thermal efficiency of the installation may be increased by the re-circulation of the already warmed stack gases. This additional heat retention will need dissipation to prevent increased furnace temperatures altering the thermal profile of the operational plant. In new plant this may be addressed at the design stage (e.g. by providing a larger heat capacity boiler). Existing plants may find increasing heat removal rates highly capital intensive – although this may be recovered through increased heat recovery. Reductions in waste throughput could also reduce thermal load, but this will also be expensive and may be impractical in some situations.
6. The costs of retrofitting FGR may be prohibitive for existing plant owing to the space required for the ducting and other (heat removal and throughput) factors detailed in 5 above. Such situations will be assessed on a site specific basis.
7. The injection of ammonia or urea (***SNCR***), which converts both NO and $NO_2$ to nitrogen and water, can further reduce $NO_x$ levels (typically by 35-45%). Its use in conjunction with FGR has shown total reductions of up to 80% and may represent the BAT in many situations. The use of the two techniques in combination also reduces reagent consumption for SNCR. The abatement of NOx using SNCR and other techniques (e.g. SCR) is discussed further in Section 2.3.8.

Chimneys & vents

## 2.3.5 Chimneys and vents

### *2.3.5.1 General*

Requirements in respect of the assessment of environmental impact of releases to air are outlined in Section 4.1.

With other factors the same (e.g. plume temperature, efflux velocity) higher release points result in lower ground level pollutant concentrations. Operators should justify the selected release height selected and include their assessment in the application.

The assessment should include graphs showing:

- The change in unit ground level pollution concentration against stack height
- stack height against additional cost
- the change in unit ground level pollution against cost

The assessment should also take account of other factors such as the need to further reduce a particular pollutant concentration below a specific significance threshold or planning restrictions. The costs associated with increasing stack height should generally be restricted to construction and maintenance costs. Costs associated with gaining or amending planning permission should be detailed separately but may be taken into account (but should not be over weighted) when justifying the selected stack height.

### *2.3.5.2 Wet plumes*

Wet plumes may not disperse well and can ground easily. Additionally there can be local visual amenity issues and, in severe cases, loss of light issues. Therefore, unless it is agreed that these issues are not locally significant, the gas should be discharged at conditions of temperature and moisture content that avoid saturation under a wide range of weather conditions. The requirement could be specified as a maximum permissible length of plume or as no visible plume for a given percentage of the year.

The normal option to reduce plume visibility is to add heat, but **the use of energy should be balanced against the benefits gained**. Plumes must be abated sufficiently to ensure good pollutant dispersion but a limited visible plume may be acceptable in some conditions. Eliminating plume visibility under all meteorological conditions may not be possible and could result in excessive energy use, to a point that it would not be considered to represent BAT.

Alternatively, moisture can be removed by cooling and condensation, followed by reheat. However, where this is not an inherent part of a wet scrubbing process (where temperature is typically reduced to around 70 °C for scrubbing purposes), the disadvantage would be the generation of a significant liquid effluent stream.

As a further option, to minimise expense and energy use, Operators may wish to guarantee to reduce load under extreme weather conditions rather than to over-design a plume abatement system.

### *2.3.5.3 Dump stacks and bypasses*

Dump stacks should only be included where they are essential for safety reasons. In general in should be possible for dump stacks to be ducted to the main stack, thus forming a bypass and improving dispersion with the additional height and allowing monitoring equipment to quantify the release.

Systems must be designed so that the dump stack is not normally expected to operate. Operational frequencies greater than once per year are unlikely to acceptable. When a dump stacks or emergency bypass operates this will be considered to be a period of "abnormal operation" and the process should be reduced or closed down (Ref. WID Article 13).

Start-up and shutdown should normally be achieved without any releases from the dump stack. An abatement system bypass, linking to the main stack may be operated on start-up where this has been authorised and is necessary to prevent damage to abatement systems.

Electric heating is an available option for new bag filters to avoid the need for bypass on start-up. Failure of the flue gas cleaning plant should not normally lead to operation of the dump stack. The reliability of heat removal systems, in particular feed pumps and dump condensers, should be demonstrated to be adequate.

Further guidance in respect of ***abnormal operating conditions*** may be found in Section 2.8 - Accidents and their consequences.

**Abatement to air**

***BAT for particulate matter (cont.)***

8. **Electrostatic precipitators (EPs)**, either wet or dry, are not capable of abating particulate to the same extent as fabric filters and are not considered adequate on their own. EPs do however have the advantage of low pressure gradients which may result in lower parasitic energy loads derived from induced draft fans. They may therefore provide a means of reducing particulate loading on bag filters and hence reduced energy consumption. However, this energy saving will be minimal where reagents are dosed onto barrier filters as the contribution of the particulate load to the overall pressure drop is itself relatively minor in comparison to that created by the filters themselves and the reagent cake layer formed.

9. **Wet scrubbers** are not considered to be BAT for particulate abatement on their own, as they are not capable of meeting the same emission levels as other techniques. They can however offer advantages in respect of the control of other substances (e.g. soluble acid gases) and may represent the BAT in combination with barrier filtration techniques as mentioned above. They give rise to liquid effluent, which, if not recycled into the process, requires treatment and disposal. This has implications when considering the BPEO.

   Plume visibility is likely to be increased where wet scrubbers are employed unless plume reheat is employed – the source of this heat will have implications in relation to the overall energy efficiency of the installation with other waste heat being an acceptable source, but with the use of additional imported energy sources unlikely to represent the BAT.

## *Oxides of nitrogen*

***BAT for NOx***

The following techniques may represent the BAT for the reduction of oxides of nitrogen discharges to the atmosphere.

### *Primary $NO_x$ measures*

10. ***Fuel Selection*** There are not likely to be opportunities to reduce fuel NOx in this sector. Wastes which are nitrogen rich (e.g. sewage sludge) will need to pay particular attention to the techniques for NOx reduction outlined below.

11. ***Combustion Chamber Design*** - Fluidised bed combustors (FBC) operate at relatively lower combustion temperatures than other systems. They can therefore produce less thermal NOx than other designs and are commonly used for sewage sludge incineration. They are well suited to wastes of a consistent and small particle size but are not suited to large or heterogeneous waste feeds (e.g. raw municipal waste) if they are not pre-treated. Waste feed preparation stages have proved problematic for some waste streams (e.g. mixed raw municipal waste) with breakdowns and fires occurring. The potential NOx reductions of combining FBC and feed preparation must therefore be weighed against these potential difficulties for heterogeneous waste types.

    Where the emission limit values stated in European Directives can be guaranteed without the need for secondary abatement (e.g. reagent injection), and the waste is suitable, FBC with limited (or no) reagent injection may represent the BAT. However, such guarantees are not generally being given. This, and the ability of other non-FBC techniques to meet the required emission levels, and provide optimal reagent reaction conditions (see SNCR below) at slightly higher furnace temperatures means that there is currently little to choose between these technologies. The primary consideration should therefore remain that of waste characteristics.

12. ***Air Control – primary and secondary*** - High excess air at the combustion stage can increase NOx production. All equipment should therefore be sealed to prevent fugitive air ingress and maintained under slight negative pressure to allow control of air input (and to prevent combustion gas releases).

    Primary and secondary air feed should be optimised so that conditions in the combustion chamber secure oxidative combustion of gases (and hence destruction of organic specie), while not being excessive which would result in higher NOx production.

    At new plant, or those undertaking upgrade of the combustion chamber,

    - CFD should be used to select optimal primary and secondary air input regimes;
    - alternative (multiple) air injection ports and directional injection nozzles should be provided to allow for in service optimisation.

Cont.

**Abatement to air**

***BAT for NOx (cont.)***

Existing municipal and hazardous waste incinerators are required (respectively) to comply with MWID/HWID requirements that oxygen should be present in at least 6% excess until 28 December 2005. After this date these plants (and other existing incinerators) will be required to meet the standards of the new Directive (200/76/EC). This new Directive does not specify a minimum excess oxygen concentration. This being the case operators will be required to state the level of excess oxygen they intend to operate at, and justify how this will meet the requirements of achieving oxidative combustion whilst minimising NOx production. It would be appropriate to include in the application data to show how emissions would change were the oxygen concentration to vary either side of the selected optimal point.

***Pyrolysis and gasification*** plants are a special case in that they are specifically designed to operate the initial waste destruction stage at reduced oxygen levels. Pyrolysis itself requires the exclusion of oxygen and semi-pyrolytic and gasification plant use sub-stoichiometric levels to promote gas evolution. It is important that these "reaction" stages are sealed, and that air flows are well controlled to prevent gas escape and to create optimal conditions. The considerations stated in this section regarding balancing the need for oxidative combustion and NOx prevention are relevant to the *subsequent combustion* of the products that result from the earlier "reaction" stages.

Technical guidance for the combustion of products of these processes in internal combustion engines or gas turbines is provided in other Agency guidance. However, it is important to note that their subsequent combustion will be required to comply with WID standards

13. ***Temperature Control*** Temperatures must meet the requirements of the relevant Directives i.e. greater than 850 °C or 1100 °C where hazardous waste contains greater than 1% w/w halogenated organics (as chlorine). The location at which this temperature should be met should be that which relates to achieving the required residence time of 2 seconds. These requirements must be met at all times when waste is being burned including start up and shut down.

    Excessive or uneven temperatures should however be avoided as this may lead to higher NOx. Water cooled grates may assist with temperature control.

    As with 12 above, for pyrolysis and gasification plants these consideration relate to the subsequent combustion of the products of the reaction stage, rather than to the initial reaction stage itself.

14. ***Flue Gas Recirculation*** provides an effective means of NOx prevention by replacing 10 to 20% of secondary air with re-circulated flue gases. It has the additional benefit of reducing the consumption of reagents used for secondary NOx control (see below) and may increase overall energy recovery by retaining heat from stack gases. The commercial use of this technique and its inclusion in recent applications indicates that concerns regarding additional corrosion arising from higher CO levels are not as significant as had been expected. Furthermore the removal of the strict requirement to achieve 6% excess oxygen may facilitate this technique. It is therefore considered likely that FGR represents BAT for all new plant in this sector. Retrofits at existing plants may prove expensive or impractical due primarily to the space required for ducting. It will be necessary for existing plants to include consideration of FGR when assessing BAT for NOx reduction – revenue cost savings from reduced reagent use should be considered along with other factors when determining the site specific BAT. Re-circulation rates grater than 20% may give rise to excessively reducing conditions, incomplete combustion, elevated CO and VOC emissions and corrosion – they should therefore be regarded with caution.

### *Secondary $NO_X$ measures*

Secondary measures should be considered ***after*** the application of primary NOx reduction measures outlined above. The use of secondary measures without applying the primary measures outlined above (including FGR) is unlikely to represent BAT as the primary techniques will serve to reduce the production of NOx, which in turn will reduce reagent consumption during secondary treatment stages.

15. ***Selective non catalytic reduction (SNCR)***

    Injection of **$NH_2$ -X compounds** into the furnace reduces $NO_X$ emissions by chemically reducing it to nitrogen and water. Ammonia and urea injection are suitable and either may represent the BAT. When dosing is optimised ammonia tends to give rise to lower nitrous oxide formation (a potent greenhouse gas) however urea may be effective over a slightly wider temperature window and is easier to handle. SNCR relies on an optimum temperature around 900 °C, and sufficient retention time must be provided for the injected agents to react with NO. Port injection locations must therefore be optimised (CFD modelling may be useful and is likely to be essential for all new plant). (Cont.)

**Abatement to air**

***BAT for NOx (cont.)***

Poorly optimised reagent injection may give rise to elevated emissions of ammonia. $NO_X$ levels should be monitored and the addition of reagent closely controlled to minimise the possibility of ammonia slippage.

SNCR should be used where $NO_X$ emissions are above WID release levels. It is probable that SNCR will be required to ensure WID standards are met. In order to comply with WID daily average NOx standards reagent injection rate set points are usually set such that longer term average releases are typically in the range of 150 to 180mg/m$^3$. At higher reagent dosing rates further NOx reductions can be achieved but only with increasing cost – reductions significantly beyond WID compliance therefore appear unlikely to represent BAT. This may not be the case at large plant (over 250K te/yr. waste throughput) or where local environmental conditions justify additional NOx reduction.

16. ***Selective catalytic reduction (SCR)***

SCR reduces NO and $NO_2$ to $N_2$ with the addition of $NH_3$ and a catalyst at a temperature range of about 300-400°C. SCR technology can also reduce VOCs, CO and dioxin emissions

SCR is a proven technology in the waste incineration sector, particularly in continental Europe where NOx emissions of below 70mg/m$^3$ are achieved. The costs of this technique (and lower UK disposal gate fees) currently make this technique unlikely to be BAT for the UK. However, it is possible that this situation will change.

The additional costs of SCR are derived mainly from the energy requirements of achieving the required temperature range. To avoid catalyst poisoning the SCR unit is requires combustion gases to be relatively clean. This means that the SCR unit must be positioned down stream of the particulate and acid gas filtration plant. With the exit temperature from the filtration unit being significantly below that required for SCR, the combustion gases must be reheated.

All applications must therefore include in their cost benefit assessment consideration of the use of SCR and justify if it is not employed. Similarly the adoption of the technique must also be justified against the alternatives (e.g. SNCR) focussing particularly upon the potential for reduced energy efficiency with SCR owing to gas re-heat.

17. ***NOx control: cost/benefit study***

Operators should provide a cost benefit study using the methodology in H1 (Ref. 5), to demonstrate the relative merits of primary measures, SNCR and SCR for the installation. The comparison will show the cost per tonne of $NO_X$ abated over the projected life of the plant using the asset lives and typical discount rates given in that document.

## *Acid gases and halogens*

***BAT for acid gases and halogens***

Techniques that may represent BAT to minimise acid gas and halogen releases are summarised below. The technique that represents BAT in one incineration sub-sector may be different to that which provides a solution for another. This will generally relate to the potential of the particular waste stream to give rise to acid gas emissions, their quantity and variability.

### *Primary acid gas measures*

18. ***Fuel Selection***

Start up and support fuels should be low in sulphur. Sulphur contents of below 0.2%w/w are commonly available. The waste incineration directive prevents the use of fuels at start up, shut down or as support fuels which can cause higher emissions than those of gas oil (as defined by Art 1(1) of Directive 75/716/EEC), liquefied gas or natural gas. In requiring the relevant combustion temperature to be maintained at all times when waste is being burned, WID also effectively prevents the use of wastes as a start up fuel – regardless of specification.

Owing to the primary purpose of incineration being the disposal of waste, there may, in many cases be few opportunities to influence releases through waste selection. It is fundamental that the installation should be designed to cope with the type of waste it is to receive (see abatement design envelope below). However, it may be the case that a particular waste stream is known to create particular difficulties at the installation or that the waste stream has changed. An example of this is large quantities of PVC plastics or plaster board where they are not well mixed with other waste at municipal waste incinerators. Where such problems occur, the Operator will be expected to take whatever steps are necessary to ensure compliance.

Cont.

**Abatement to air**

***BAT for acid gases and halogens (cont.)***

***Secondary acid gas measures***

21. ***Abatement Type – wet / dry / semi dry***

There are three main techniques for the control of acid gases, wet scrubbing, semi-dry scrubbing and dry scrubbing. Each has advantages and disadvantages, and each may represent the BAT in different circumstances dependent mainly upon the type of waste being incinerated, but also depending upon other decisions taken in respect of overall process design.

Generally wet scrubbing will provide the greatest security in terms of meeting air emission limit values, particularly where wastes are of very varied composition. This is because the wet conditions and low operating temperatures, enhances the capture of the water soluble acid gas species. Wet scrubbing is therefore well suited to plant with exceptionally high or variable acid gas loading e.g.HWIs. Wet scrubbing does however have disadvantages regarding the production of an effluent stream and of a wet plume which may require energy input to reheat it. Dry and semi-dry systems are available. The advantages and disadvantages of these are outlined in Table 2-6 below. Operators will be required to justify their selected technology by referring to the factors indicated.

**Table 2 6- Abatement type - advantages and disadvantages for acid gas control**

| Abatement Type | Advantages | Disadvantages |
|---|---|---|
| **Wet** | • High reaction rates<br>• Good performance over range of loadings<br>• Low reagent consumption<br>• Low solid residues production<br>• Reagent delivery may bevaried by concentration and flow rate<br>• Condensation effect may assist with metals abatement | • Large effluent disposal and water consumption if not fully treated for re-cycle<br>• Effluent treatment plant required<br>• May result in wet plume<br>• Energy required for effluent treatment and plume reheat<br>• Wet systems may experience higher corrosion<br>• Pre-scrubbing particulate removal may be required |
| **Dry** | • Low water use<br>• Reagent consumption may be reduced by recycling in plant | • Reaction rates low therefore larger residence time required<br>• Higher solid residue production<br>• Reagent delivery only by input rate |
| **Semi-dry** | • Medium reaction rates<br>• Medium water use<br>Reagent delivery may be varied by concentration and input rate | • Higher solid waste residues<br>• In process reagent recycle not proven |

Guidance on the general suitability of each of these systems to different incineration sub-sectors is given in Section 2.3.9 below.

22. ***Alkaline Reagent Selection***

***Consistent low acid waste streams:***

It may be possible for some waste streams of very consistent composition, that can be demonstrated to be reliably very low in halogens (e.g. well segregated non-halogenated waste solvent streams incinerated on the site of production) to be incinerated without alkaline scrubbing. Indeed, to do so where clearly not necessary is itself unlikely to be BAT owing to the unnecessary consumption of reagent. Water scrubbing only may be acceptable in these circumstances.

However, in general, provision for alkaline reagent injection will need to be made wherever the concentration of acid gases or acid gas forming materials in raw flue gases exceed the standardised flue gas emission limit concentrations outlined in Section 3.3.

Cont.

**Abatement to air**

***BAT for acid gases and halogens (cont.)***

***Other waste streams:***

For the vast majority of waste streams the injection of alkaline reagents will be required to absorb acid gases and meet the required emission limit values. The most commonly used reagents are:

- Sodium Bicarbonate (NaHCO);
- Lime($Ca(OH)_2$);
- Sodium Hydroxide (NaOH).

Although the basic stoichiometry of these reagents would indicate that lime, with two hydroxyl molecules per molecule of reagent would provide for more efficient removal of acid gases, sodium hydroxide is, in practice, the most efficient and lime the least. This is explained by the relative reaction rates achieved i.e. the lime / acid reaction takes longer to reach completion.

All of these reagents can be effectively used to secure the emission limit values outlined in Section 3.3, and may represent BAT in an individual situation. The advantages and disadvantages of these are outlined in Table 2-7 below. Operators will be required to justify their selected technology by referring to the factors indicated.

**Table 2 7- Reagent selection - advantages and disadvantages for acid gas control**

| Reagent | Advantages | Disadvantages | Comments |
|---|---|---|---|
| **Sodium Hydroxide** | Highest removal rates<br>Copes well with high acid load<br>Low solid waste production | Effluent requires treatment<br>Corrosive material<br>ETP sludge for disposal | Suitable for HWIs and DIs |
| **Lime** | Very good removal rates<br>Low leaching solid residue<br>Copes well with medium acid loads<br>Temperature of reaction well suited to use with bag filters<br>Wet, dry and semi dry systems available | Corrosive material<br>Some handling / pumping difficulties<br>May give greater residue volume if no in-plant recycle | Wide range of uses |
| **Sodium Bicarbonate** | Good removal rates<br>Easiest to handle<br>Dry recycle systems proven | Effient temperature range may be at upper end for use with bag filters – ceramics required?<br>Leachable solid residues<br>Bicarbonate more expensive | Often used at CWIs<br>Not proven at large plant |

Guidance on the general suitability of each of these systems to different incineration sub-sectors is given in Section 2.3.9 below.

23. ***Alkaline Reagent Dosing Control***

Optimisation of the alkaline reagent dosing system is the BAT. This is because a well optimised reagent doing control system will:

- Control acid gas emissions within emission limit values;
- Reduce consumption of reagent;
- Reduce production of alkaline residues.

Optimisation in this context means delivering the right amount of reagent to absorb acid gases to meet emission limit values, without wasting reagent and producing excessive residues. The techniques that are considered BAT for securing this optimisation are:

- Trimming reagent dosing to acid load using fast response upstream HCl monitoring as a trigger;
- Ensuring reagent concentration can be rapidly changed through use of variable speed pumps / screw feeders and / or low volume intermediate silos (which will allow for more rapid concentration changes);
- Small silo load cell systems provide close control on reagent delivery rates in dry systems;

Cont.

Abatement to air

## 2.3.9 Review of commonly proposed techniques for control of releases to air – by plant type

This section provides a review of those techniques recently proposed or currently employed in each sub-sector of the incineration industry. They may represent BAT where emissions limits and other criteria are being achieved.

They are **provided as a guide only and DO NOT cover all aspects of each plant type**, only some particularly areas where they differ from one another or there are particular, sub-sector specific issues. **They should not be relied upon without referring to the rest of this guidance.**

Individual installations are still required to demonstrate:

- Site specific selection of BAT – taking into account, for example, local environmental factors
- Ability to meet the minimum standards required by Directives, including emission limit values

***Candidate BAT for abatement of point sources to air by plant type***

### *2.3.9.1 Municipal waste incinerators*

In order to prevent releases to air new UK plants are adopting:

- Waste selection by upstream removal of recyclable or provision of a waste treatment stage;
- Staged combustion with close combustion control techniques;
- Temperatures in the range 900 to 1000 °C and residence times of greater than 2 seconds;
- Flue gas re-circulation; Should add water-cooled grates + structures in empty pass.
- Selective non-catalytic reduction (with either urea or ammonia injection);
- Rapid temperature reduction from 450 to 200 °C (for dioxin control);
- Feed forward control systems for alkaline reagent injection;
- Semi-dry lime injection systems;
- Carbon injection for Hg and dioxin absorption;
- Bag filters;
- Sufficient burnout techniques (including time) to maintain total organic carbon levels below 3% in bottom ash;
- Electricity generation using steam turbines – with options for developing waste heat use.

### *2.3.9.2 Clinical waste incinerators*

Modern CWIs although much smaller, are similar in design to MWIs. The common differences are:

- Waste pre-treatment is less used;
- Waste management procedures must take account of potentially greater health and safety hazards;
- Combustion temperatures are higher and will be in excess of 1100 °C for hazardous waste;
- Dry acid scrubbing systems are sometimes adopted;
- Steam generation only may be favoured over electricity plus steam (usually where there is a high and dependable local steam demand).

### *2.3.9.3 Chemical waste incinerators*

- Waste pre-treatment and blending is often carried out;
- Waste management procedures, including handling and charging operations are often elaborate – reflecting the hazardous nature of the waste;
- On site QA and laboratory operations are often provided;
- Combustion temperatures in excess of 1100 °C are used;
- Multi-stage wet or combined wet and dry scrubbing is the norm;
- Waste water treatment and re-circulation may not be maximised;
- Heat recovery is often limited to internal heat exchange and does not extend to full recovery.

### *2.3.9.4 Sewage sludge incinerators*

- Fluidised beds are being adopted to assist in reducing NOx production – additional techniques may be required to achieve WID emission limit values owing to high waste feed nitrogen levels;

## 3.3 Releases to Air

The incineration of waste is subject to a number of European Directives. This section outlines the standards required by those directives in respect of releases to air. In addition to the legislative standards, the use of BAT may result in additional emission reductions.

### 3.3.1 Introduction to the European Directive Emission Limits

Where an installation falls within the scope of a particular Directive, the standards set by that Directive apply ***as a minimum***. In some circumstances the use of BAT may result in tighter controls.

Each of the Directives contains sections which define the scope of the directive and its provisions. The interpretation of the scope of a particular directive will depend upon legal interpretation of the Directive.

National governments have the responsibility for implementing the enabling legislation that brings European Directives into force, and for appointing an appropriate Regulator. The enabling legislation generally takes the form of Regulations or Direction by the Secretary of State. Once the enabling legislation has been passed the appointed Regulator is required to enforce the requirements of the Directive as advised by Government.

At the time of writing this guidance, the "new" waste incineration directive or WID (2000/76/EC), whilst in force at a European level, remains to be implemented by means of national legislation. For the purposes of this guidance the requirements of the Directive itself have therefore been considered. Any subsequent implementing legislation will need to be taken into account in due course.

The WID is of particular relevance because it will repeal earlier directives on municipal and hazardous waste incineration, and in replacing them, substantially broaden the scope of installations that will be effected by European Legislation. **There will be very few installations that burn waste that do not fall within the scope of WID.** The Agency intends to produce separate "Regulatory Guidance" which will outline the scope and application of WID in more detail.

It is **important** that Operators of existing installations and those who propose any new installation **contact the Agency at an early stage** to discuss this matter if:

- They intend to burn any waste
- They intend to burn any fuel derived from waste

### 3.3.2 Waste Incineration Directive 2000/76/EC

The Waste Incineration Directive has been developed to fill the gaps between existing Directives on municipal waste incineration and hazardous waste incineration. The existing Directives dealing with municipal and hazardous waste incineration will be repealed on 28 December 2005, five years after the Waste Incineration Directive comes into force. The Agency intends to issue detailed regulatory guidance on the Directive to assist in interpretation, and provide links as appropriate to this guidance.

Implementation provisions are:

- for new plant: shall comply with this Directive from 28 December 2002;
- for existing plant: shall comply with this Directive no later than 28 December 2005.

Co-incineration plants which start co-incinerating waste not later than 28 December 2004, are to be regarded as existing co-incineration plants. The emission limit values for co-incineration plants are not included here – readers should refer to the Directive and to the sector specific guidance.

The emission limit values for incineration plants falling within WID are summarised in Table 3-1. Readers should consult the Directive for full details.

**Table 3-1 - Waste Incineration Directive Annex V: air emission limit values (ELV)**

| Pollutant | Directive Requirement | | |
|---|---|---|---|
| | ELV (mg/m$^3$ unless stated)* | Averaging / Monitoring Period | Monitoring Frequency |
| Total Dust | 10 | Daily average | Continuous |
| Total Dust | 30 | 100% ½ hourly averages | |
| Total Dust | 10 | 97% ½ hourly averages | |
| VOCs (as TOC) | 10 | Daily average | Continuous |
| VOCs (as TOC) | 20 | 100% ½ hourly averages | |
| VOCs (as TOC) | 10 | 97% ½ hourly averages | |
| HCl | 10 | Daily average | Continuous (periodic may be used where emission *cannot* exceed ELV) |
| HCl | 60 | 100% ½ hourly averages | |
| HCl | 10 | 97% ½ hourly averages | |
| HF | 1 | Daily average | Continuous (periodic may be used where emission cannot exceed ELV or where HCl ELVs complied with) |
| HF | 4 | 100% ½ hourly averages | |
| HF | 2 | 97% ½ hourly averages | |
| $SO_2$ | 50 | Daily average | Continuous (periodic may be used where emission cannot exceed ELV) |
| $SO_2$ | 200 | 100% ½ hourly averages | |
| $SO_2$ | 50 | 97% ½ hourly averages | |
| NOx (nitrogen monoxide and nitrogen dioxide expressed as nitrogen dioxide) | 200 | Daily average | Continuous |
| NOx (as above) | 400 | 100% ½ hourly averages | |
| NOx (as above) | 200 | 97% ½ hourly averages | |
| CO | 50 | Daily average | Continuous |
| CO | 150 | 95% of 10min averages | |
| CO | 100 | 100% of ½ hourly averages | |
| Cd and Tl | total 0.05 | All average values over the sample period (30 minutes to 8 hours) to be less than these limits | Periodic – 2 per year but one every 3 months during the first year of operation. |
| Hg | 0.05 | | |
| Sb, As, Pb, Cr, Co, Cu, Mn, Ni and V | total 0.5 | | |
| Dioxins and furans | 0.1 ng/m$^3$ TEQ | CEN method (EN 1948, parts 1, 2 and 3) sample period 6 to 8 hours | Periodic – 2 per year but one every 3 months during the first year of operation. |

This causes emissions to be lower on daily basis.

**Notes:**

1. * reference conditions: 273 K, 101.3 kPa, 11% $O_2$, dry gas.
2. ELVs apply at all times when waste is being burned (except for CO during start-up and shut down)
3. The ELVs for metals include solid, gaseous and vapour forms as well as their compounds.
4. TEQ should be calculated as described in annexe I of the Directive
5. The Directive provides for certain derogations in respect of NOx and particulate emissions from existing plants. These are not generally expected to be applicable in the UK as BAT will achieve the required ELV.
6. The Agency will generally apply the 100%ile limits for both daily and ½ hourly ELVs.
7. Derogation from the above CO ELVs is available for fluidised beds up to 100mg/m$^3$ as an hourly average.
8. The Waste Incineration Directive goes beyond emission limit values. Permits will also be required to include an extensive range of conditions to ensure high operational standards.
9. Monitoring techniques should be CEN or where not available, national or international standards. Further guidance is given in Section 2.10.

### 3.3.4 Municipal waste incinerators

#### *Standards and obligations for MWIs*

- Existing installations must meet the requirements of the *current* municipal waste incineration directives (the 1989 directives) as an absolute minimum. It is unlikely that operation to this standard will be acceptable, as the use of BAT will result in improved environmental performance.
- All existing installations must comply with WID standards as a minimum from 28 December 2005 at the latest.
- All new plants must comply with WID standards as a minimum with immediate effect.
- Although compliance with WID standards will be taken to indicate that BAT is in use, Operators will be required to demonstrate why further emission reductions cannot be achieved through the use of BAT. This will be particularly the case at larger throughput plant, or where local environmental conditions require installation pollutant contributions to background levels are further reduced.

#### *Benchmark emission values*

| Substance(s) | Currently reported (mg/m$^3$ unless stated) | Benchmark ELV | Comments |
|---|---|---|---|
| Total particulate | 1 - 28 | WID | Bag filters are capable of meeting WID standard.<br>Wet scrubbing or EP are not adequate on their own |
| VOCs (as TOC) | <1 - <8 | WID | Combustor design and combustion control important. |
| HCl | 1 - 98 | WID | Optimisation of alkaline dosing by upstream HCl monitoring and feed forward dosing control or extensive waste selection/ pre-treatment required to control short term peaks<br>avoid excessive alkaline reagent dosing<br>wet systems may meet standard but effluent treatment required.<br>Waste pre-treatment may be required to prevent peaks |
| HF | 0.1 – 2.8 | WID | See measures under HCl |
| $SO_2$ | <3 - 479 | WID | See measures under HCl |
| NOx (NO and $NO_2$ as $NO_2$) | 276 - 479 | WID | Some existing plant will require upgrade.<br>Combustor and grate design and combustion control important. (like under cooling)<br>FGR likely to be BAT for all new plant and existing plant except where high retrofit costs.<br>Fluid bed may offer advantages with treated waste feeds<br>SNCR (urea or ammonia) required to guarantee ELVs.<br>All (particularly new) plant must justify why SCR and ELV of 100mg/m3 is not BAT. |
| $NH_3$ | | 10 mg/m$^3$ daily avg.<br>20 mg/m$^3$ 1/2hr avg. | Not covered by European legislation.<br>Limits to be applied to control slip from NOx control systems |
| $N_20$ | | 30 mg/m$^3$ avg. over 8 hr sample period | Not covered by European legislation.<br>Limits to be applied to control slip from NOx control systems |
| CO | 3 - 198 | WID | Combustor design and combustion control important.<br>Charging systems need control |
| Cd and Tl | 0.02 – 0.12 | WID | Avoid excessive furnace temperatures<br>Barrier filtration required to control particulate bound metals. |
| Hg | 0.005 – 0.08 | WID | Carbon injection required. |
| Sb, As, Pb, Cr, Co, Cu, Mn, Ni and V | 0.04 – 0.53 | WID | Avoid excessive furnace temperatures<br>Barrier filtration required to control particulate bound metals |
| Dioxins and furans | 0.01 – 0.14 ng/m3 | WID | Combustor design and combustion control important.<br>FGR likely to be BAT for all new plant and existing plant except where high retrofit costs.<br>Carbon injection required.<br>Use of SCR to be considered in BAT assessment.<br>Use of catalytic filter bags to be considered in BAT assessment |

***Note:*** 1. Quoted performance figures may not be directly comparable owing to different averaging periods.