## Publication for "Müll und Abfall"

# "Hot DeNO$_x$" (catalytic nitrogen removal) in the Würzburg waste-to-energy power station (WTEPS)

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## 1. Starting situation

Lines 1 and 2 (both built in 1984) of the Würzburg waste-to-energy power station (WTEPS) were equipped with fabric filters right from the outset, thus meeting not only the then valid TA – Air 1986, but - what is more - also very largely the clearly tighter requirements of the 17$^{th}$ BImSchV, which were stipulated as of 1996.

For reliable compliance of the 17th BImSchV limiting values for dioxins/furans and particularly mercury, the exhaust-gas clean-up was upgraded according to the system of single-stage dry sorption (System Würzburg).
To this end, an evaporation cooler was installed as conditioning stage and the subsequently separated dosage of hearth-type furnace coke and lime.

For reliable compliance of the 17th BImSchV limiting values for nitrogen oxides, low-dust $NO_2$ removal was realised at the end of the exhaust-gas clean-up in accordance with the SCR process.
In those days, a reaction temperature of approx. 300 $^{o}$C was required at the catalyst. The requisite reheating of the exhaust gases escaping from the fabric filter at approx. 140$^{o}$C occurred through waste heat recovery with a pure-gas economiser (ReGaVo) and with additional gas burners.

However, in the meantime, the catalysts are only still operated at a temperature of only 225$^{o}$ C.

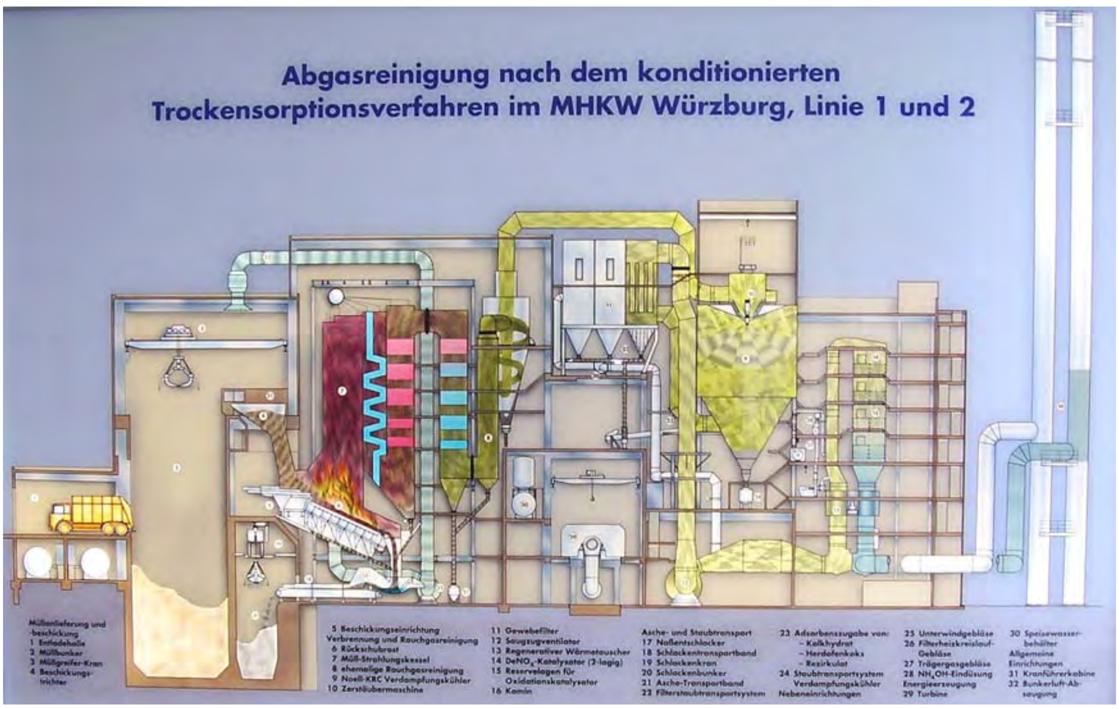


**Figure 1:** Facility diagram subsequent to upgrading of the exhaust-gas clean-up in 1994 and 1995

Figure 1 shows that the exhaust gases are conducted past the previously existing fabric filter into the evaporation cooler, then from the evaporation cooler back again to the fabric filter and from there into the reactor for $NO_2$ removal.

The following diagrams show the % emission quotas of lines 1 and 2 compared to the requirements of the 17$^{th}$ BImSchV (100 %):

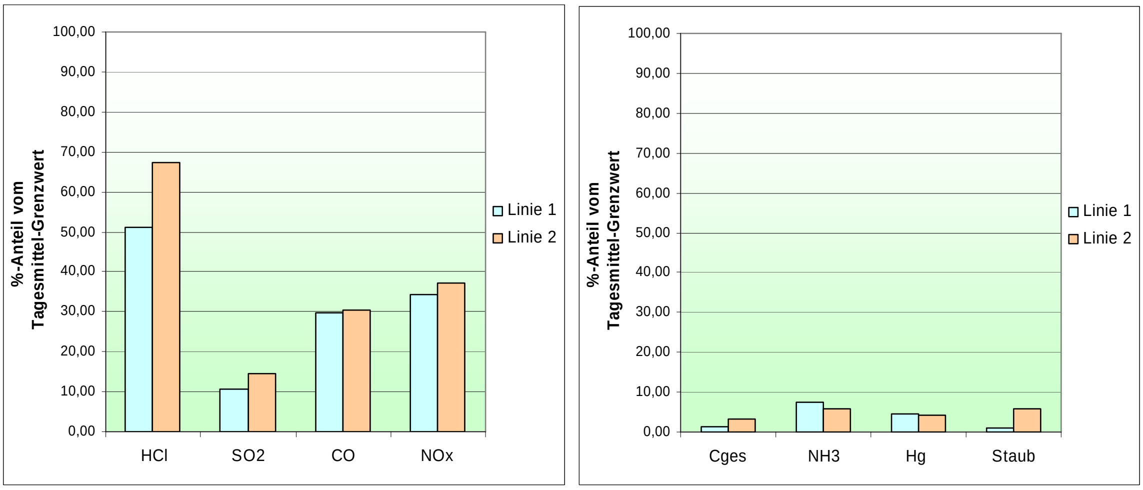


**Figure 2**: Emissions of Lines 1 and 2 and the requirements of the 17$^{th}$ BImSchV (100 %)

In these two lines, the emission figures for the significant contaminants dioxins/furans and mercury have now basically been falling well below the mandatory figures of the 17$^{th}$ BImSchV/European Waste Incineration Directive by over 90 % for 10 years.

As the daily mean value of up to 70 mg/m$^3$, the emission figure for $NO_x$ likewise clearly lies below the limiting value of 200 mg/m$^3$.

The facilities still conform with the best available technology. Currently, however, it has the drawback that valuable primary energy gas is being used for reheating the exhaust gases prior to $NO_x$ removal.

## 2. Line 3 at the Würzburg WFPW

Project planning of Line 3 was carried out after successful completion of the above-described upgrading in accordance with the same process of dry sorption in 1995 and 1996.

A concept from the company Noell – KRC was commissioned, in which, as a special feature, catalytic $NO_x$ removal is not configured as "low-dust" at the end of the exhaust-gas clean-up, but as "high-dust" in the zone of the boiler downstream from the third flue (hot SCR).
With a temperature of > 300$^o$ C at this point, reheating the exhaust gases was no longer necessary.

In this process, provision was initially made for preliminary dust removal with eight cyclones in order to remove as much coarse dust as possible and only to act upon the catalyst with exhaust gas and fine dust (cyclones = Item 13 in Fig. 3).

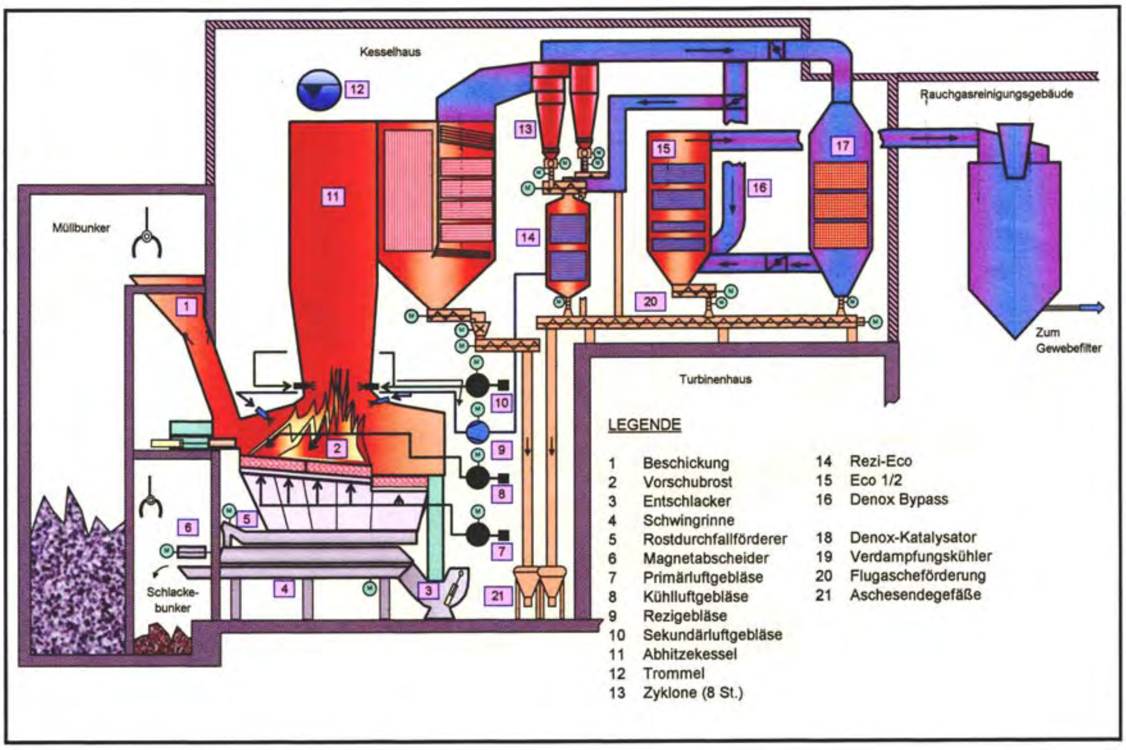


**Figure 3:** Line 3 with preliminary dust removal

An electrostatic filter was deliberately dispensed with at that time due to the existing know-how on the DeNovo synthesis of dioxins and furans.

Experiments were to be made to run the temperature range down to 200$^{o}$ C as quickly as possible.

In such a pilot project, it was naturally an absolute must to ensure compliance of the NO$_x$ limiting value of 200 mg/m$^3$ even without catalytic NO$_x$ removal.
This was done by additional installation of non-catalytic NO$_x$ removal in the furnace (SNCR).
As far as legal requirements were concerned, it was thus even possible to circumscribe hot SCR NO$_x$ removal and nevertheless to maintain the limiting value reliably.

Simultaneous with this concept, the possibility was also opened of operating non-NO$_x$ removal in the furnace (SNCR) combined with downstream hot catalytic NO$_x$ removal (SCR).

Initial hot start-up of Line 3 was initiated in December 1998.

As early as immediately after start-up, dust deposits were to be found at the inflow of the catalyst honeycombs that very quickly (several attempts, each in the double-digit hourly range) led to complete blinding of the catalyst.

All rectifications that could be executed relatively easily and at short notice to eliminate this blinding with superimposed grids, etc. failed.
The honeycombs of the catalyst with a pitch of 6 mm constantly clogged up again.

## 3. Approaches to a solution

### 3.1 Elimination of preliminary dust removal

The station manager of the Würzburg Stadtwerke (Public Utility Company) AG at that time (operator of the Würzburg WFPW for the Administration Union), Dipl.-Ing. Gerhard Kerber, proposed decommissioning preliminary dust removal in an experiment.
The idea was that the coarse dust existing in the raw gas would prevent any dust deposits on the catalyst through a "cleaning effect".

Despite all misgivings that the coarse dust might negatively affect or even destroy the catalyst's surface, the experiments were conducted.
Decommissioning preliminary dust removal was realised by the cyclones being run to full capacity.

The experiments showed an unequivocally smaller dust deposit in the catalyst.

### 3.2 Lowering the catalyst temperature

During the above-mentioned experiments (capacity-running cyclones, raw gas with coarse dust) it was demonstrated that the catalyst no longer possessed any reactivity.

Analysis of the catalyst material revealed, inter alia, conspicuous proportions of lead, which blinded the catalyst surface almost completely and thus destroyed activity.

Extensive research in comparable and similar facilities finally led to the perception that the lead agglomeration is greatly temperature-dependent.
By changing the temperature window for the catalyst, it should therefore be possible to counter this lead agglomeration.

It was planned to lower the temperature from a previous approx. $330^{o}$ C to a then approx. $250^{o}$ C.

To this end, an economiser (Eco 3 = Item 11 in Fig. 4) was installed downstream from the third furnace flue and upstream from the SCR reactor instead of the previously existing preliminary dust removal (cyclone = Item 13 in Fig. 3).
A reaction temperature of $250^{o}$ C can thus be realised at the catalyst with a deviation of ± 10 degrees.

The catalyst itself was renewed, now with a greater pitch of 10 mm.

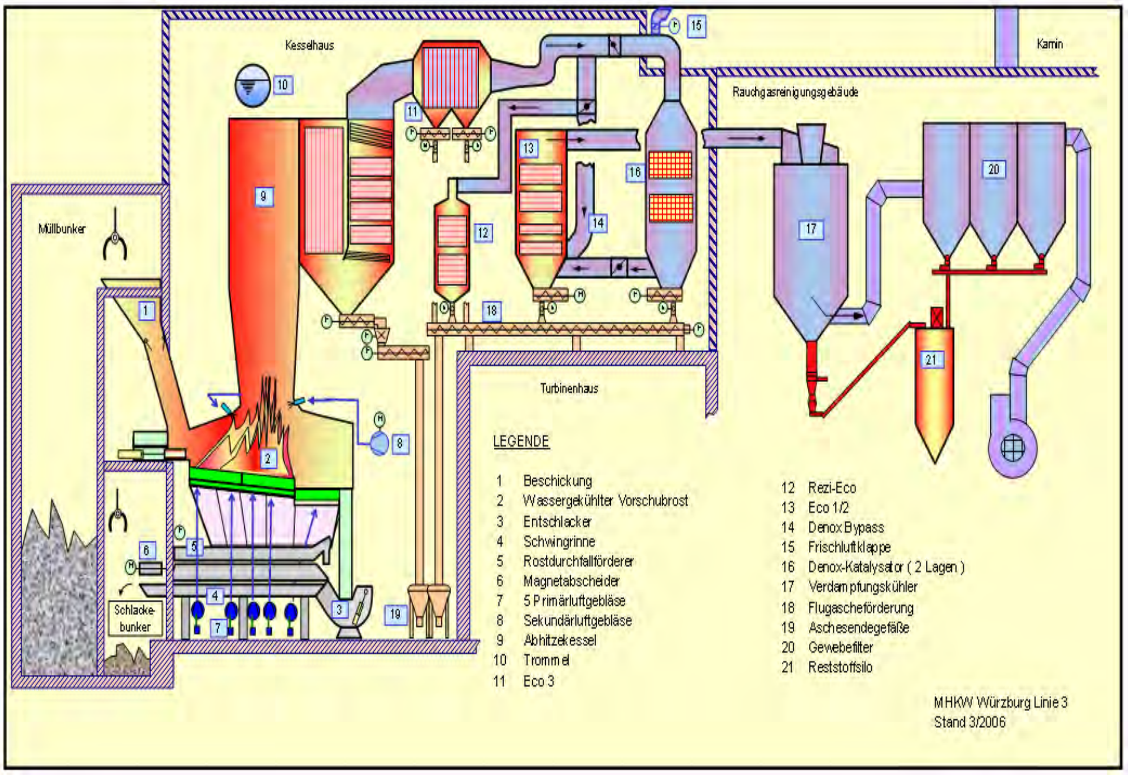


**Figure 4:** Line 3 with Eco 3, already with 2 catalyst layers (Item 16)

After this conversion, lead covering on the catalyst surface could no longer be detected, further dust deposits, however, necessitating additional installation of deflectors in the reactor.

This constellation enabled over 8,000 hours of trouble-free operation to be realised for the first time.

Addition of ammonia water in the SCR plant was kept relatively low to minimise $NH_3$ slip.

Subsequent to non-catalytic reduction (SNCR), the pure gas figures for $NO_x$ were again lowered to some 150 mg/m$^3$ in this mode of operation from approx. 180 mg/m$^3$.


**Figure 5:** Installation of the first catalyst layer – July 2003

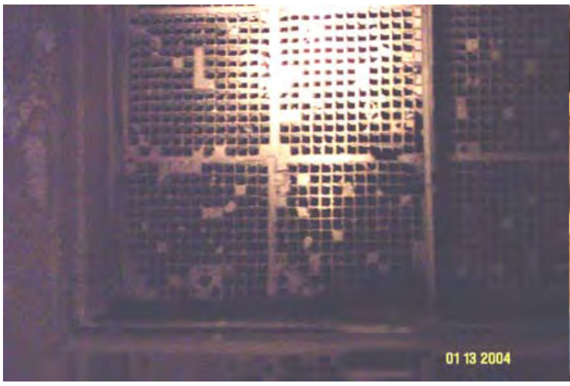


**Figure 6:** after approx. 2,500 operating hours (90 % of the surface free)

**Figure 7:** after approx. 12,000 operating hours (cleaning with water)

## 3.3 Other alterations / Installation of a second layer

Installation of a second catalyst plant was to represent a further step towards optimisation.

With $NO_x$ emissions being well and reliably maintained unchanged, the emission figure for $NH_3$ was to be lowered still further.

To keep the increase of Δp (= delta p = pressure loss via the SCR reactor) as low as possible, a pitch of 12 mm was selected.

Nevertheless, dust deposits again occurring more intensely necessitated installation of further deflectors, tapering of the free reactor cross section and concomitant increase in passage velocity.

Since these measures have been realised, $NO_x$ removal with two catalyst plants has been running without any essential problems.

Over and above this, changes to Δp and the reaction temperature on the catalyst are sensitively monitored in current operation.
Any irregularities occurring are swiftly countered by suitable specific-plant measures.

According to the present status, blinding or obstructions are only still encountered, when the installed soot blowers malfunction.

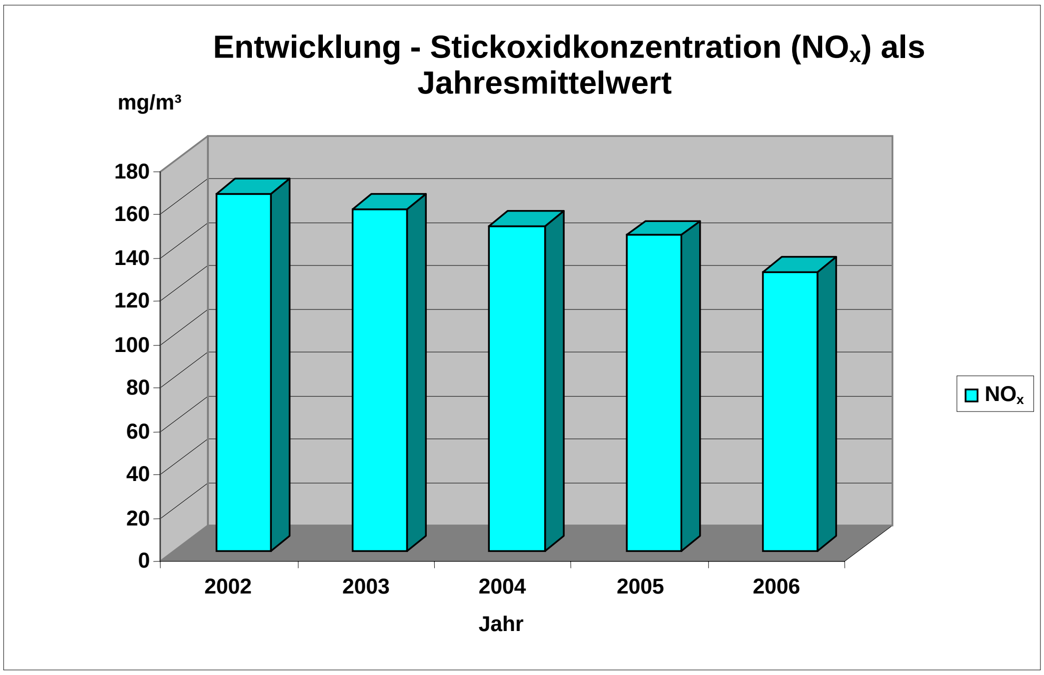


**Figure 8:** Development of $NO_x$ concentrations in the pure gas of Line 3

The plant is operated, so that the pure gas emission figures for $NO_x$ satisfactorily lie clearly and reliably below the limiting values of the 17th BImSchV/European Waste Incineration Directive.

The mean value currently lies at approx. 145 $mg/m^3$ and depending on the mode of operation (waste throughput, ammonia dosage, temperature) fluctuates between 85 $mg/m^3$ and 170 $mg/m^3$.

Installation of a third layer is not planned for procedural reasons due to the then even greater $\Delta p$ and problems thus to be expected.
Nonetheless the staff responsible see on the whole further possibilities and also further demand for optimisation.

## 4. Summary

Most newly built waste-to-energy power stations are today equipped with non-catalytic $NO_x$ removal (SNCR).

Data for thus attainable $NO_x$ pure gas figures are, in the meantime, stated with up to 100 $mg/m^3$.

For this reason, it seems virtually paradoxical that operators of thermal waste management plants are constantly attempting to undercut this low pure-gas limiting value for $NO_x$ of 200 $mg/m^3$ even more.
At the same time, cement works are officially permitted to emit up to 500 $mg/m^3$ of $NO_x$ (and in reality they do emit for all intents and purposes about 400 $mg/m^3$ of $NO_x$).

In view of the comparatively low mass flows of thermal waste management plants, the limiting value of 200 mg/m³ of $NO_x$ is assessed much too low and the corresponding outlay to maintain it much too high.

On the other hand, modern thermal waste management plants have increasingly adopted the pioneering role in emission protection in the last few years and in the meantime have become the cleanest facilities for generating energy from fossil fuels.
Emissions of dioxins / furans are comparable with those of natural gas heating systems (cf. Figure 9).

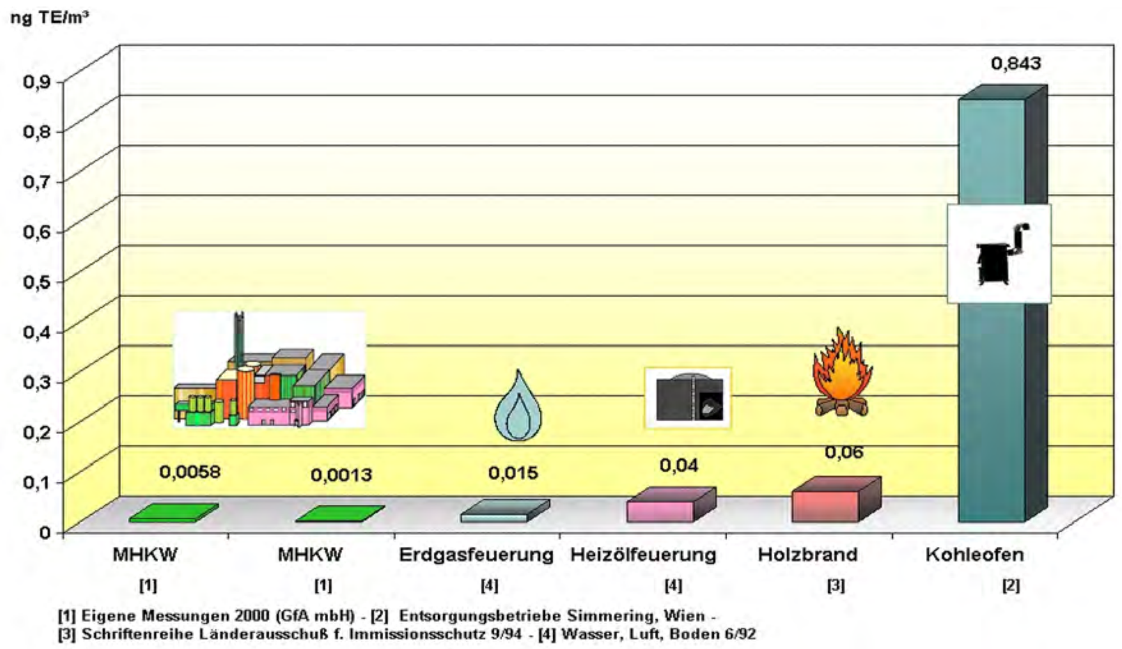


**Figure 9:** Dioxin emissions of the Würzburg WTEPS compared to other furnaces

Even if with considerable development outlay (6 years - from 1999 to 2005), Line 3 at the Würzburg WTEPS has ultimately – with, in the meantime, 15,000 hours of trouble-free operation – provided the evidence that hot catalytic $NO_x$ removal is possible.

However, an absolute prerequisite for this is plant-specific co-ordination of exhaust-gas velocity, catalyst pitch, reaction temperature and the possibility of effective cleaning during operation.
Further experiments regarding this are currently being conducted in the Brescia facility (Italy).

Incidentally, both plants are also members in the European *CEWEP* through their national umbrella organisations *Federambiente* and *ITAD.*

In this respect, further permanent improvements are being made in thermal waste treatment and "waste-to-energy plants" within the scope of a host of minor or – as here – major steps.

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