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TRACTATENBLAD

VAN HET

KONINKRIJK DER NEDERLANDEN

JAARGANG 1995 Nr. 200

A. TITEL

Protocol bij het Verdrag van 1979 betreffende grensoverschrijdende luchtverontreiniging over lange afstand inzake de beheersing van emissies van stikstofoxyden of van de grensoverschrijdende stromen van deze stikstofverbindingen, met bijlagen;
Sofia, 31 oktober 1988

B. TEKST

De Engelse en de Franse tekst van het Protocol zijn geplaatst in *Trb*. 1989, 59. Zie voor de ondertekeningen ook *Trb*. 1991, 71.

Voor wijziging van de Technische Bijlage bij het Protocol zie rubriek J van *Trb*. 1992, 84 en van *Trb*. 1994, 68 en rubriek J hieronder.

C. VERTALING

Zie *Trb*. 1991, 71 en rubriek J van *Trb*. 1992, 169 en van *Trb*. 1994, 138.

D. PARLEMENT

Zie *Trb*. 1991, 71.

E. BEKRACHTIGING

Zie *Trb*. 1991, 71, *Trb*. 1992, 84 en 169 en *Trb*. 1994, 68 en 138.

Behalve de aldaar genoemde Staten heeft nog de volgende Staat in overeenstemming met artikel 14, vierde lid, van het Protocol een akte van bekrachtiging, aanvaarding of goedkeuring nedergelegd bij de Secretaris-Generaal van de Verenigde Naties:

Ierland . . . . 17 oktober 1994

F. TOETREDING

Zie *Trb*. 1994, 68 en 138.

G. INWERKINGTREDING

Zie *Trb.* 1991, 71.

J. GEGEVENS

Zie *Trb.* 1989, 59, *Trb.* 1991, 71, *Trb.* 1992, 84 en 169 en *Trb.* 1994, 68 en 138.

Verwijzingen

Voor het op 26 juni 1945 te San Francisco tot stand gekomen Handvest van de Verenigde Naties zie ook *Trb.* 1994, 277.

Wijziging

Op 23 juni 1995 heeft de Uitvoerend Secretaris van de Economische Commissie voor Europa in overeenstemming met artikel 11, vijfde lid, van het Protocol de wijzigingen van de Technische Bijlage bij het Protocol, welke tijdens de van 28 november tot 1 december 1994 gehouden twaalfde vergadering van het Uitvoerend Orgaan werden aangenomen, medegedeeld aan de Partijen bij het Protocol.

De Engelse tekst van de gewijzigde Technische Bijlage bij het Protocol luidt als volgt:

TECHNICAL ANNEX

1. The purpose of this annex is to provide guidance to the Parties to the Convention in identifying NO_x control options and techniques in the implementation of their obligations under the Protocol.

2. It is based on information on options and techniques for NO_x emission reduction and their performance and costs contained in official documentation of the Executive Body and its subsidiary bodies; and in documentation of the ECE Inland Transport Committee and its subsidiary bodies; and on supplementary information provided by governmentally designated experts.

3. The annex addresses the control of NO_x emissions considered as the sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2) expressed as NO_2 and lists a number of NO_x reduction measures and techniques spanning a wide range of costs and efficiencies. Unless otherwise indicated these techniques are considered to be well established on the basis of substantial operating experience, which in most cases has been gained over five years or more. It cannot, however, be considered as an exhaustive statement of control options; its aim is to provide guidance to Parties in identifying best available technologies which are economically feasible as a basis for national emission standards and in the introduction of pollution control measures.

4. The choice of pollution control measures for any particular case will depend on a number of factors, including the relevant legislative

and regulatory provisions, primary energy pattern, industrial infrastructure and economic circumstances of the Party concerned and, in the case of stationary sources, the specific circumstances of the plant. It should be borne in mind also that sources of NO_x are often sources of other pollutants as well, such as sulphur oxides (SO_x), volatile organic compounds (VOCs), and particulates. In the design of control options for such sources, all polluting emissions should be considered together in order to maximize the overall abatement effect and minimize the impact of the source on the environment.

5. The annex reflects the state of knowledge and experience of NO_x control measures, including retrofitting, which has been achieved by 1992, in the case of stationary sources, and by 1994 in the case of mobile sources. As this knowledge and this experience continuously expand, particularly with new vehicles incorporating low-emission technology and the development of alternative fuels, as well as with retrofitting and other strategies for existing vehicles, the annex needs to be updated and amended regularly.

1. CONTROL TECHNOLOGIES FOR NO_x EMISSIONS FROM STATIONARY SOURCES

6. Fossil fule combustion is the main source of anthropogenic NO_x emissions from stationary sources. In addition, some non-combustion processes may contribute considerably to the emissions. The major stationary source categories of NO_x emissions, based on EMEP/CORINAIR 90, include:

a) Public power, cogeneration and district heating plants:
(i) Boilers;
(ii) Stationary combustion turbines and internal combustion engines;
b) Commercial, institutional and residential combustion plants:
(i) Commercial boilers;
(ii) Domestic heaters;
c) Industrial combustion plants and processes with combustion:
(i) Boilers and process heaters (no direct contact between flue gas and products);
(ii) Processes (direct contact); (e.g. calcination processes in rotary kilns, production of cement, lime, etc., glass production, metallurgical operation, pulp production);
d) Non-combustion processes, e.g. nitric acid production;
e) Extraction, processing and distribution of fossil fuels;
f) Waste treatment and disposal, e.g. incineration of municipal and industrial waste.

7. For the ECE region, combustion processes (categories (a), (b), (c)), account for 85% of NO_x emissions from stationary sources. Non-combustion processes, e.q. production processes, account for 12%, and extraction, processing and distribution of fossil fuels for 3% of total NO_x emissions. Although in many ECE countries, power plants in category

(a) are the largest stationary contributor to NO_x emissions, road traffic is usually the largest single overall source of NO_x emissions, but the distribution does vary between Parties to the Convention. Furthermore, industrial sources should be kept in mind.

GENERAL OPTIONS FOR REDUCING NO_x EMISSIONS FROM COMBUSTION

8. General options for NO_x reduction are:
a) Energy management measures:[1])
i) Energy saving;
ii) Energy mix;
b) Technical options:
(i) Fuel switching/cleaning;
(ii) Other combustion technologies;
((iii) Process and combustion modifications;
(iv) Flue gas treatment.

9. To achieve the most efficient NO_x reduction programme, beyond the measures listed in (a), a combination of technical options identified in (b) should be considered. Furthermore, the combination of combustion modification and flue gas treatment needs site specific evaluation.

10. In some cases, options for reducing NO_x emissions may also result in the reduction of emissons of Co_2 and SO_2 and other pollutants.

Energy saving

11. The rational use of energy (improved energy efficiency/process operation, cogeneration and/or demand-side management) usually results in a reduction in NO_x emissions.

Energy mix

12. In general, NO_x emissions can be reduced by increasing the proportion of non-combustion energy sources (i.e. hydro, nuclear, wind, etc.) to the energy mix. However, further environmental impacts have to be considered.

Fuel switching/cleaning

13. Table 1 shows the uncontrolled NO_x emission levels to be expected during fossil fuel combustion for the different sectors.

14. Fuel switching (e.g. from high – to low-nitrogen fuels or from coal to gas) can lead to lower NO_x emissions but there may be certain restrictions, such as the availability of low NO_x emitting fuels (e.g. natural gas on plant level) and adaptability of existing furnaces to different

[1]) Options (a) (i) and (ii) are integrated in the energy structure/policy of a Party. Implementation status, efficiency and costs per sector are not considered here.

fuels. In many ECE countries, some coal or oil combustion plants are being replaced by gas-fired combustion plants.

15. Fuel cleaning for fuel nitrogen removal is not a commercial option. Increasing the application of cracking technology in refineries, however, also brings about a reduction in the nitrogen content of the end-product.

Other combustion technologies

16. These are combustion technologies with improved thermal efficiency and reduced NO_x emissions. They include:

a) Cogeneration using gas turbines and engines;

b) Fluidized bed combustion (FBC): bubbling (BFBC) and circulating (CFBC);

c) Integrated gasification combined cycle (IGCC);

d) Combined cycle gas turbines (CCGT).

17. The emission levels for these techniques are summarized in table 1.

18. Stationary combustion turbines can also be integrated into existing conventional power plants (known as topping). The overall efficiency can increase by 5% tot 6%, but achievable NO_x reduction will depend on site and fuel specific conditions. Gas turbines and gas engines are widely applied in cogeneration applications. Typically some 30% energy saving can be attained. Both have made significant progress in reducing NO_x emissions through new concepts in combustion and system technology. However, major alterations to the existing boiler system become necessary.

19. FBC is a combustion technology for burning hard coal and brown coal but it can burn other solid fuels such as petroleum coke and low-grade fuels such as waste, peat and wood. In addition, emissions can be reduced by integrated combustion control in the system. A newer concept of FBC is pressurized fluidized bed combustion (PFBC) presently being commercialized for the generation of electricity and heat. The total installed capacity of FBC has approached approximately 30.000 MW_{th} (250 to 350 plants), including 8,000 MW_{th} in the capacity range of > 50 MW_{th}.

20. The IGCC process incorporates coal gasification and combined cycle power generation, in a gas and steam turbine. The gasified coal is burned in the combustion chamber of the gas turbine. The technology also exists for heavy oil residue and bitumen emulsion. The installed capacity is presently about 1,000 MW_{el} (5 plants).

21. Combined cycle gas power stations using advanced gas turbines with an energy efficiency of 48%–52% and with reduced NO_x emissions are currently being planned.

Process and combustion modifications

22. These are measures applied during combustion to reduce the formation of NO_x. They include the control of combustion air ratio, flame temperature, fuel to air ratio, etc. The following combustion techniques, either singly or in combination, are available for new and existing installations. They are widely implemented in the power plant sector and in some areas of the industrial sector:

a) Low excess air combustion (LEA);[1])
b) Reduced air preheat (RAP);[1])
c) Burner-out-of-service (BOOS);[1])
d) Biased-burner-firing (BBF);[1])
e) Low NO_x burners (LNB);[1]) and[2])
f) Flue gas recirculation (FGR);[3])
g) Over fire air combustion (OFA);[1]) and[2])
h) In-furnace-NO_x-reduction reburning (IFNR);[3])
i) Water/steam injection and lean/premixed combination.[4])

23. The emission levels due to the application of these techniques are summarized in table 1 (based mainly on experience in power plants).

24. Combustion modifications have been under continuous development and optimization. In-furnace-NO_x-reduction is being tested in some large-scale demonstration plants, whereas basic combustion modifications are incorporated mainly into boiler and burner design. For example, modern furnace designs incorporate OFA parts, and gas/oil burners are equipped for flue gas recirculation. The latest generation of LNBs combines both air-staging and fuel-staging. A remarkable increase in full-scale retrofit of combustion modifications in ECE member countries has been recorded in the last years. By 1992 a total of about 150,000 MW was installed.

Flue gas treatment processes

25. Flue gas treatment processes aim at removing already formed NO_x and are also referred to as secondary measures. Wherever possible it is usual to apply primary measures as a first stage of NO_x reduction before applying flue gas treatment processes. The state-of-the-art flue gas treatment processes are all based on the removal of NO_x by dry chemical processes.

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[1]) Typical retrofit measures, with limited efficiency and applicability.
[2]) State-of-the-art in new plants.
[3]) Implemented in single large commercial plants; operational experience still limited.
[4]) For combustion turbines.

26. They are the following:
a) Selective Catalytic Reduction (SCR);
b) Selective Non-catalytic Reduction (SNCR);
c) Combined NO_x/SO_x removal processes:
(i) Activated Carbon Process (AC);
(ii) Combined catalytic NO_x/SO_x removal.

27. The emission levels for SCR and SNCR are summarized in table 1. Data are based on the practical experience gathered from a large number of implemented plants. By 1991 in the European part of the ECE about 130 SCR plants corresponding to 50,000 MW_{el}, 12 SNCR installations (2,000 MW_{el}), 1 AC plant (250 MW_{el} and 2 combined catalytic processes (400 MW_{el}) were erected. The NO_x removal efficiency of AC and combined catalytic processes are similar to SCR.

28. Table 1 also summarizes the costs of applying the NO_x abatement technologies.

CONTROL TECHNIQUES FOR OTHER SECTORS

29. Unlike most combustion processes, the application of combustion and/or process modifications in the industrial sector has many process specific limitations. In cement kilns or glass melting furnaces, for example, certain high temperatures are necessary to ensure the product quality. Typical combustion modifications being used are staged combustion/low NO_x burners, flue gas recirculation and process optimization (e.g. precalcination in cement kilns).

30. Some examples are given in table 1.

SIDE-EFFECTS/BY-PRODUCTS

31. The following side-effects will not prevent the implementation of any technology or method, but should be considered when several NO_x abatement options are possible. However, in general, these side-effects can be limited by proper design and operation:
a) Combustion modifications:
– Possible decrease in overall efficiency;
– Increased CO formation and hydrocarbon emissions;
– Corrosion due to reducing atmosphere;
– Possible N_20 formation in FBC systems;
– Possible increase of carbon fly ash;
b) SCR:
– NH_3 in the fly ash;
– Formation of ammonium salts on downstream facilities;
– Deactivation of catalyst;
– Increased conversion of SO_2 to SO_3;

c) SNCR:
- NH_3 in the fly ash;
- Formation of ammonium salts on downstream facilities;
- Possible formation of N_20.

32. In terms of by-products, deactivated catalysts from the SCR process are the only relevant products. Due to the classification as waste, a simple disposal is not possible, however recycling options exist.

33. The reagent production of ammonia and urea for flue gas treatment processes involves a number of separate steps which require energy and reactants. The storage systems for ammonia are subject to the relevant safety legislation and such systems are designed to operate as totally closed systems, with a resultant minimum of ammonia emissions. The use of NH_3 is, however, not jeopardized even when taking into account the indirect emissions related to the production and transportation of NH_3.

MONITORING AND REPORTING

34. The measures taken to carry out national strategies and policies for the abatement of air pollution include legislation and regulatory provisions, economic incentives and disincentives, as well as technological requirements (best available technology).

35. In general emission limiting standards may be set per emission source according to plant size, operating mode, combustion technology, fuel type and whether it is a new or existing plant. An alternative approach also used is to set a target for the reduction of total NO_x emissions from a group of existing sources and to allow the Parties to choose where to take action to reach this target (bubble concept).

36. The limiting of the NO_x emissions to the levels set out in the national framework legislation has to be controlled by a permanent monitoring and reporting system and reported to the supervising authorities.

37. Several monitoring systems, using both continuous and discontinuous measurement methods, are available. However quality requirements vary among Parties. Measurements are to be carried out by qualified instititutes and approved measuring/monitoring systems. To this end a certification system would provide the best assurance.

38. In the framework of modern automated monitoring systems and process control equipment, reporting creates no problems. The collection of data for further use is a state-of-the-art technique. However, data to be reported to competent authorities differ from Party to Party. To obtain better comparability, data sets and prescribing regulations should be har-

monized. Harmonization is also desirable for quality assurance of measuring/monitoring systems. This should be taken into account when comparing data from different Parties.

39. To avoid discrepancies and inconsistencies, key issues and parameters including the following, must be well-defined:

– Definition of the standards expressed as ppmv, mg/m^3, g/GJ, kg/h or hg/t of products. Most of these units need to be calculated and need specification in terms of gas temperature, humidity, pressure, oxygen content or heat input value;

– Definition of time over which standards may be averaged, expressed as hours, months or a year;

– Definition of failure times and corresponding emergency regulations regarding bypass of monitoring systems or shut-down of the installation;

– Definition of methods for backfilling or data missed or lost as a result of equipment failure;

– Definition of the parameter set to be measured. Depending on the type of industrial process, the necessary information may differ. This also involves the location of the measurement point within the system.

40. Quality control of measurements must be ensured.

II. CONTROL TECHNOLOGIES FOR NO_x EMISSIONS FROM MOBILE SOURCES MAJOR NO_x EMITTERS FROM MOBILE SOURCES

41. Primary mobile sources of anthropogenic NO_x emissions include:

Road vehicles:

– Petrol-fuelled and diesel-fuelled passenger cars;
– Light commercial vehicles;
– Heavy-duty vehicles (HDV);
– Motor cycles and mopeds;
– Tractors (agricultural and forestry).

Non-road engine applications:

– Agricultural, mobile industrial and construction machinery.

Other mobile sources:

– Rail transport;
– Ships and other marine craft;
– Aircraft.

42. Road transport is a major source of anthropogenic NO_x emission in many ECE countries, contributing up to two thirds of the total national emissions. Current petrol-fuelled vehicles contribute up to two thirds of total national road NO_x emissions. In a few cases, however, the NO_x emissions from HDV traffic will exceed the decreasing emissions from passenger cars.

43. Many countries have enacted regulations that limit the emission of pollutants from road vehicles. For non-road applications, emission

standards including NO_x have been enacted by some ECE countries and are under preparation in the ECE itself. NO_x emissions from these other sources may be substantial.

44. Until other data become available this annex concentrates on road vehicles only.

GENERAL ASPECTS OF CONTROL TECHNOLOGY FOR NO_x EMISSIONS FROM ON-ROAD VEHICLES

45. The road vehicles considered in this annex are passenger cars, light commercial vehicles, motor cycles, mopeds and heavy-duty vehicles.

46. This annex deals with both new and in-use vehicles, with the attention primarily focused on NO_x emission control for new vehicle types.

47. Cost figures for the various technologies given are expected production costs rather than retail prices.

48. It is important to ensure that new-vehicle emission standards are maintained in service. This can be done through inspection and maintenance programmes, ensuring conformity of production, full useful-life durability, warranty of emission-control components, and recall of defective vehicles.

49. Fiscal incentives can encourage the accelerated introduction of desirable technology. Retrofit is of limited benefit for NO_x reduction, and may be difficult to apply to more than a small percentage of the vehicle fleet.

50. Technologies that incorporate catalytic converters with spark-ignited petrol engines require the use of unleaded fuel, which should be made generally available. The use of after-treatment technologies in diesel engines like oxidation catalysts or particulate traps requires the use of low-sulphur fuels (maximum 0,05% S content).

51. The management of urban and loog-distance traffic, though not elaborated in this annex, is important as an efficient additional approach to reducing emissions including NO_x. Measures to reduce NO_x emission and other air pollutants may include enforcement of speed limits and efficient traffic management. Key measures for traffic management aim at changing the modal split of public and long-range transport especially in sensitive areas like cities or the Alps by transferring transport from road to rail through tactical, structural, financial and restrictive elements and also by optimizing the logistics of the delivery systems. They will also be beneficial for other harmful effects of traffic expansion such as noise, congestion, etc.

52. A variety of technologies and design options are available making simultaneous control of different pollutants possible. For some appli-

cations reverse effects have been experienced when reducing NO_x emissions (e.g. non-catalyst petrol or diesel engines). This may change with the employment of new technologies (e.g. after-treatment cleaning devices and electronics). Reformulated diesel fuel and fuel containing post-combustion NO_x reducing additives may also have a role in a strategy to combat diesel vehicle NO_x.

CONTROL TECHNOLOGIES FOR NO_x EMISSIONS FROM ROAD VEHICLES

Petrol- and diesel-fuelled passenger cars and light commercial vehicles

53. The main technologies for controlling NO_x emissions are listed in table 2.

54. The basis for comparison in table 2 is technology option B, representing non-catalytic technology designed in response to the requirements of the United States for 1973/74 or of ECE Regulation 15-04[1]) pursuant to the 1958 Agreement concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts. The table also presents typical emission levels for open- and closed-loop catalytic control as well as their cost.

55. The ''uncontrolled'' level (A) in table 2 refers to the 1970 situation in the ECE region, but may still prevail in certain areas.

56. The emission level in table 2 reflects emissions measured with standard test procedures. Emissions from vehicles on the road may differ because of the effect of, inter alia, ambient temperature, operating conditions (especially at higher speed), fuel properties, and maintenance. However, the reduction potential indicated in table 2 is considered representative of reductions achievable in use.

57. The most efficient currently available technology for NO_x reduction is option E. This technology achieves large reductions of NO_x, volatile organic compounds (VOC), and CO emissions.

58. In response to regulatory programmes for further NO_x emission reductions (e.g. low-emission vehicles in California), advanced closed-loop three-way catalyst systems are being developed (option F). These improvements will focus on engine management, very precise control of air-fuel ratio, heavier catalysts loading, on-board diagnostic systems (OBD) and other advanced control measures.

Motor cycles and mopeds

59. Although actual NO_x emissions of motor cycles and mopeds are very low (e.g. with two-stroke engines), their NO_x emissions should be considered. While VOC emissions of the vehicles are going to be lim-

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[1]) Replaced by Regulation No. 83.

ited by many Parties to the Convention, their NO_x emissions may increase (e.g. with four-stroke engines). Generally the same technology options as described for petrol-fuelled passenger cars are applicable. In Austria and Switzerland strict NO_x emission standards are already implemented.

Heavy-duty diesel-fuelled vehicles

60. In table 3 three technology options are summarized. The baseline engine configuration is the turbocharged diesel engine. The trend is towards turbocharged engines with intercooling, advanced fuel injection systems and electronic control. This trend may have the potential to improve baseline fuel consumption performance. Comparative etimates of fuel consumption are not included.

CONTROL TECHNIQUES FOR IN-USE VEHICLES

Full useful life, recall and warranties

61. To promote durable emission-control systems, consideration should be given to emission standards that may not be exceeded for the ‘‘full useful life’’ of the vehicle. Surveillance programmes are needed to enforce this requirement. Under such programmes, manufacturers are responsible for recalling vehicles that fail to meet the required standards. To ensure that the owner has no production-related problems, manufacturers should provide warranties for emission-control components.

62. There should not be any devices to reduce the efficiency or switch off the emission control systems during any operating conditions except conditions which are indispensable for trouble-free running (e.g. cold start).

Inspection and maintenance

63. The inspection and maintenance programme has an important secondary function. It may encourage regular maintenance and discourage vehicle owners from tampering with or disabling the emission controls, both through direct enforcement and public information. Inspection should verify that emission controls are in their original working order. It should also ensure that emission control systems have not been removed.

64. Improved monitoring of emission control performance can be achieved by on-board diagnostic systems (OBD) which monitor the functioning of emission control components, store fault codes for futher interrogation and call the attention of the driver to ensure the repair in case of malfunction.

65. Inspection and maintenance programmes can be beneficial for all types of control technology by ensuring that new-vehicle emission lev-

els are maintained. For catalyst-controlled vehicles it is essential to ensure that the new-vehicle specifications and settings are maintained to avoid deterioration of all major pollutants, including NO_x.

Table 1

Source category (i): Public power, cogeneration and district heating

Energy source	Uncontrolled Emissions		Process and Combustion Modifications			Flue Gas Treatment: (a) Non-catalytic			Flue Gas Treatment: (b) Catalytic (after primary measures)		
	mg/m^3 [1]	g/GJ[1]	mg/m^3 [1]	g/GJ[1]	ECU/kW_{el} [2]	mg/m^3 [3) 1)]	g/GJ[1]	ECU/KW_{el} [2]	mg/m^3 [1]	g/GJ[1]	ECU/kW_{el} [2]
Boilers:											
– Coal, WBB[4]	1 500–2 200	530–770	1 000–1 800	350–630	3–25	no data		no data	< 200	< 70	50–100 (125–200)[12]
– Coal, DBB[5]	800–1 500	280–530	300–850	100–300	3–25	200–400	70–140	9–11	< 200	< 70	50–100 (115–200)[12]
Brown coal[5]	450–750	189–315	190–300	80–126	30–40	< 200	< 84		< 200	< 85	80–100
– Heavy oil[6]	700–1 400	140–400	150–500	40–140	up to 20	175–250	50–70	6–8	< 150	< 40	50 –70
– Light oil[6]	350–1 200	100–332	100–350	30–100	up to 20	no data		6–8	< 150	< 40	50–70
– BE[14]	800		no data		no data	no data					no data
– Natural gas[6]	150–600	40–170	50–200	15–60	3–20	no data		5–7	< 100	< 30	
FBC	200–700		180–400		1 400–1 600[7]	< 130			no data		
PFBC	150–200	50–70			1 100[7]	60		< 140	< 50		
IGCC [13]	<600		<100						no data		
Gas turbines + CCGT:[13)18)]					Investment Cost:						
– natural gas	165–310	140–270	30–150	26–130	Dry: 50–100 ECU/kW_{el}	N/A			20	17	
– diesel oil	225–430	200–370	50–200	45–175	Wet: 10–50 ECU/kW_{el}	N/A			120–180	70	
IC Engines[4] (natural gas < 1 MW_{el})	4 800–6 300	1 500–2 000	320–640	100–200							

Source category (ii): Commercial, institutional and residential combustion plants

Energy source	Uncontrolled Emissions		Process and Combustion Modifications			Flue Gas Treatment: (a) Non-catalytic			Flue Gas Treatment: (b) Catalytic (after primary measures)		
	mg/m^3 [1]	g/GJ[1]	mg/m^3 [1]	g/GJ[1]	ECU/kW_{el} [2]	mg/m^3 [3]	g/GJ[1]	ECU/KW_{el} [2]	mg/m^3 [1]	g/GJ[1]	ECU/kW_{el} [2]
Coal	110–500	40–175									
Brown coal	70–400	30–160									
Light oil	180–440	50–120	130–250	35–70							
Gas	140–290	40–80	60–150	16–40	2–10						
Wood[15]	85–200	50–120	70–140	40–80							

Source category (iii): Industrial combustion plants and processes with combustion

Energy source	Uncontrolled Emissions		Process Modifications			Flue Gas Treatment: (a) Non-catalytic			Flue Gas Treatment: (b) Catalytic (after primary measures)		
	mg/m^3 [1]	g/GJ[1]	mg/m^3 [1]	g/GJ[1]	ECU/kW_{el} [2]	mg/m^3 [3]	g/GJ[1]	ECU/KW_{el} [2]	mg/m^3 [1]	g/GJ[1]	ECU/kW_{el} [2]
Industrial combustion plants:											
– Coal, PF[8]	600–2 200	200–770	up to 700	up to 245							
– Coal, grates[3]	150–600	50–200	up to 500	up to 175							
– Brown coal	200–800	80–340									
– Heavy oil[6]	400–1 000	110–280	up to 650	up to 180							
– Light oil[6]	150–400	40–110	up to 250	up to 70							
– Natural gas[6]	100–300	30–80	up to 150	up to 42	2–10						
Gas turbines + CCGT:[13) 18]					Investments Cost:						
– natural gas	165–310	140–270	30–150	26–130	Dry: 50–100 ECU/kW_{el}	N/A			20	17	
diesel oil	235–430	200–370	50–200	45–175	Wet: 10–50 ECU/kW_{el}	N/A			120–180	70	
FBC[8]	100–700		100–600								

Energy source	Uncontrolled Emissions mg/m[3 1)]	Uncontrolled Emissions g/GJ[1)]	Process Modifications mg/m[3 1)]	Process Modifications g/GJ[1)]	Process Modifications ECU/kW_{el}[2)]	Flue Gas Treatment: (a) Non-catalytic mg/m[3)]	(a) Non-catalytic g/GJ[1)]	(a) Non-catalytic ECU/KW_{el}[2)]	(b) Catalytic (after primary measures) mg/m[3 1)]	(b) Catalytic g/GJ[1)]	(b) Catalytic ECU/kW_{el}[2)]
IC Engines (natural gas <IMW_{el})[4)]	4 800–6 300	1 500–2 000	320–640	100–200							
Industrial processes:											
– Calcination	1 000–2 000		500–800								
Glass:											
– Plate glass		6 kg/t	500–2 000						<500		
– Containers		2,5 kg/t									
– Fibreglass		0,5 kg/t									
– Industrial		4.2 kg/t									
Metals:											
– Sintering	300–500[16)]	1,5 kg/t							<500		
– Coke ovens	1 000	1 kg/t									
– Baked carbon fuels	< 3000										
Electric arc furnaces	50–200										
Paper and pulp:											
– Black liquor	170[17)]	(50–80 g/GJ)		(20–40 g/GJ)		60					13–20

Source category (iv): Non-combustion processes

Energy source	Uncontrolled Emissions		Process Modifications			Flue Gas Treatment: (a) Non-catalytic			Flue Gas Treatment: (b) Catalytic (after primary measures)		
	mg/m^3 [1]	kg/t [9]	mg/m^3 [1]	kg/t [9]	ECU/t [2]	mg/m^3 [3]	kg/t	ECU/KW$_{el}$ [2]	mg/m^3 [1]	kg/t [9]	ECU/kW$_{el}$ [2]
Nitric acid:											
– Low pressure (1–2.2 bar)	5 000	16,5									
– Medium pressure (2.3-8 bar)	approx. 1 000	3.3									
– High pressure (8–15 bar)	< 380	< 1.25								0.01–0.8	
– HOKO (-50 bar)	< 380	< 1.25									
Pickling:											
– Brass		25 [10]									
– Stainless steel		0.3									
– Carbon steel		0.1									

Source category (v): Extraction, processing and distribution of fossil fuels

Energy source	Uncontrolled Emissions		Process and Combustion Modifications			Flue Gas Treatment: (a) Non-catalytic			Flue Gas Treatment: (b) Catalytic (after primary measures)		
	mg/m^3 [1]	g/GJ [1]	mg/m^3 [1]	g/GJ [1]	ECU/kW$_{el}$ [2]	mg/m^3 [3]	g/GJ [1]	ECU/KW$_{el}$ [2]	mg/m^3 [1]	g/GJ [1]	ECU/kW$_{el}$ [2]
Refineries [5]	~ 1.000		100–700								

Source category (VI): Waste treatment and disposal

Energy source	Uncontrolled Emissions		Process and Combustion Modifications			Flue Gas Treatment:					
						(a) Non-catalytic			(b) Catalytic (after primary measures)		
	mg/m^3 [1]	g/GJ[1]	mg/m^3 [1]	g/GJ[1]	ECU/kW_{el}[2]	mg/m^3[3]	g/GJ[1]	ECU/KW_{el}[2]	mg/m^3 [1]	g/GJ[1]	ECU/kW_{el}[2]
Incineration [11]	250–500		200–400				<100				

[1] Emissions in mg/m[3] NO_2 (STP dry) resp. g/GJ thermal input. Conversion factors (mg/m^3 tog/GJ) for NO_x emissions from coal (hard coal): 0,35, coal (lignite): 0,42, oil/gas: 0,277, peat: 0,5 wood + bark: 0,588 (1 g/GJ = 3,6 mg/kWh).

[2] Total investments 1 ECU = 2 DM.

[3] Reduction generally achieved in combination with primary measures. Reduction effeciency between 80 and 95%.

[4] At 5% O_2.

[5] At 6% O_2.

[6] At 3% O_2.

[7] Incl. costs for boiler.

[8] At 7% O_2.

[9] Emissions from industrial processes are generally expressed as kg/t of product.

[10] g/m[2] surface area.

[11] At 11% O_2.

[12] Tail gas SCR configuration as opposed to high dust.

[13] At 15% O_2.

[14] Bitumen emulsion.

[15] Untreated wood only.

[16] Heat recovery and gas recirculation.

[17] For dry substance < 75%.

[18] With supplementary firing; approximate additional thermal NO_x: 0–20 g/GJ.

Table 2 Emission control technologies for petrol- and diesel-fuelled passenger cars and light commercial vehicles

Technology option	NO_x emission level (%)	Estimated additional production cost[1)] (US$)
Petrol-fuelled		
A. Uncontrolled situation	100	–
B. Engine modifications (engine design, carburation and ignition systems, air injection)	70	[2)]
C. Open-loop catalyst	50	150–200
D. Closed-loop three-way catalyst	25	250–450[3)]
E. Advanced closed-loop three-way catalyst	10	350–600[3)]
F. Californian low-emission vehicles (advanced option E)	6	> 700[3)]
Diesel-fuelled		
G. Conventional indirect injection diesel engine	40	
H. Indirect injection engine with secondary injection, high injection pressures electronically controlled	30	1 000–1 200[4)]
I. Direct injection engine with turbo-charging	50	1 000–1 200[4)]

Note: Options C, D, E, F require the use of unleaded petrol; options H and I require the use of low-sulphur diesel fuel.

[1)] Per vehicle, relative to technology option B. $NO_{x)}$ requirements may have an effect on fuel prices and refinery production costs, but this is not included in the estimated additional production cost.

[2)] Costs for engine modifications from options A tot B are estamited at US$ 40–100.

[3)] Under technology options D, E and F, CO and VOC emissions are also substantially reduced, in addition to NO_x reductions. Technology options B and C result also in CO and VOC control.

[4)] Fuel consumption is reduced as compared to option G, while particulate emissions of technology option G are considerably higher.

Table 3 Heavy-duty vehicle technologies, emission performance and costs

Technology option	NO_x emission level (%)	Expected additional production cost[1)] (US$)
A. Turbocharged diesel engine (EURO I)	100	0

Technology option	NO_x emission level (%)	Expected additional production cost[1] (US$)
B. Turbocharged diesel engine with intercooling (EURO II)	85	1 500–3 000
C. Turbocharged diesel engine with intercooling, high pressure fuel injection, electronically controlled fuel pump, combustion chamber and port optimalization, exhaust gas recirculation (EGR)	50–60	3 000–6 000
D. Shift to spark ignition engine with three-way-catalytic converter working on LPG, CNG or oxygenated fuels	10–30	up to 10 000

Note: Option C requires the use of low-sulphur diesel fuel.
[1] Per vehicle, and depending on engine size relative to baseline technology A. $NO_{x)}$ requirements may have an effect on fuel prices and refinery production costs, but this is not included in the estimated additional production cost.

Ingevolge artikel 11, vierde lid, van het Protocol zijn de wijzigingen op 23 juli 1995 in werking getreden.

In overeenstemming met artikel 19, tweede lid, van de Rijkswet goedkeuring en bekendmaking verdragen heeft de Minister van Buitenlandse Zaken bepaald dat bovenstaande gewijzigde tekst in Nederland zal zijn bekendgemaakt op de dag na die der uitgifte van dit Tractatenblad.

Uitgegeven de *zeventiende* augustus 1995.

De Minister van Buitenlandse Zaken,

H. A. F. M. O. VAN MIERLO

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