LAT / AUTh

The Inspection of In-Use Cars in Order to Attain Minimum Emissions of Pollutants and Optimum Energy Efficiency

Detailed Report 5 - Short Test Evaluation

by LAT / AUTh

Thessaloniki, April 1998

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1. Introduction

This report concerns the evaluation of the possibly applicable short tests in the framework of an enhanced Inspection and Maintenance program. The objective of this report is to describe in detail the methodology used and to show the results of such an evaluation which are the basic input in the cost-effectiveness analysis implemented by TNO and described in the relevant detailed report. The basis of the evaluation and comparison of short tests includes the environmental benefit as regards the percentage of the emitted pollutants avoided and the vehicles which are involved in order for the above objective to be achieved.

The report consists of ten sections. Section one comprises the introduction to the report, while section two includes the measurements carried out by each of the collaborating institutes as well as a brief mention on the nature of the data on which the whole evaluation is based. In section three the short tests which are to be evaluated are presented, while in section four the methodology, which has been used is described in detail. Sections five, six and seven apply the above methodology to three vehicle technologies respectively and give the final results. These technologies are the 3W catalyst equipped, the conventional together with the oxidation catalyst equipped and the diesel vehicles. In Section eight the results of a very thorough sensitivity analysis of the methodology are presented. Section nine applies the above methodology to the current Directive 92/55/EEC and draws conclusions regarding its effectiveness. In section ten the final conclusions are drawn and propositions are made.

This report is complemented by an Annex which includes all detailed results in the form of tables and figures.

2. Measurements

The type of measurements that took place in each of the collaborating institutes are shown in Table 1.

Table 1: Type of measurements

			INRETS	LAT	TNO	TRL	TUEV
Transient	mass emissions	lab	yes	yes	yes	yes	yes
Short	raw avg	lab	no	no	no	yes	yes
Tests	raw avg	gar	yes	yes	no	no	no
	dil avg	lab	no	yes	yes	no	no
Idle (low, high)	raw	gar	yes **	yes	yes	yes	yes *
Steady State	raw	gar	yes	yes	yes	yes	yes
Loaded	raw	lab	no	yes	yes	yes	yes

(shaded dark) yes; (shaded light) no

lab= laboratory analysers; gar= garage analysers

**= incl. free acceleration & autonat; *= incl. free acceleration

mass emissions= bag related emissions
raw avg= average concentration of on-line raw exhaust concentrations
dil avg= average concentration of on-line diluted exhaust concentrations
Steady state loaded= 50 km/h at 7kW

Table 1 shows that instantaneous measurement of raw exhaust concentrations with laboratory analyzers (raw avg-lab) has been carried out only by two institutes, which results in a quite small number of measurements. However, this type of measurement is supposed to be a promising one. Therefore, in order to increase the sample of such measurements the corresponding diluted average concentrations have also been used as input data for their calculation. This applies only to measurements from LAT and TNO where the instantaneous diluted measurements are available. In order to calculate the dilution factor as a function of time LAT was based on the CO_2 tracer which was measured instantaneously both raw and diluted. TNO on the other hand applied per unit of time the formula given by the legislation:

$$DF = \frac{13.4}{(CO_2) + [(HC) + (CO)] \cdot 10^{-4}}$$

(CO2): diluted exhaust concentration of CO2 in %

(HC): diluted exhaust concentration of HC in ppmC1

(CO): diluted exhaust concentration of CO in ppm

The above conversions apply mainly to 3W catalyst equipped vehicles since such vehicles were almost exclusively measured by LAT and TNO.

All measurements taken into account in the evaluation concern vehicles tested before maintenance with normal inertia, when such measurements were available.

3. Short Tests

According to the available measurements presented in Table 1, the short tests which have been evaluated and compared are shown in Table 2 together with their abbreviations. These short tests are different for gasoline and diesel vehicles.

Table 2: Short tests

Short Test	Abbreviation	Gasoline	Diesel
Mass emissions in TUVA#2	meTUV	1	1
Raw average concentration with lab analysers in TUVA#2	ralaTUV	1	0
Raw average concentration with garage analysers in TUVA#2	ragaTUV	2	4
Mass emissions in modem short	meMS	1	1
Raw average concentration with lab analysers in modem short	ralaMS	1	0
Raw average concentration with garage analysers in modem short	ragaMS	2	4
Idle	Idle	2	0
High Idle	H-Idle	2	0
Steady state loaded with garage analysers	ga50-7	2	4*
Steady state loaded with lab analysers	la50-7	1	0
Free acceleration smoke	FAS	0	3
Autonat	AUTONAT	0	3

0 = no measurements
1 = CO, CO2, HC, NOx
2 = CO, CO2, HC
3 = opacity
4 = CO, CO2, HC, opacity
* very few opacity measurements

4. Methodology

4.1 Outline

4.1.1 Basic chart

Figure 1 presents the basic concept upon which the analysis is based and it is a correlation chart between each short test and the type approval cycle of the vehicles as regards a particular pollutant. Actually there are as many such charts as the number of pollutants measured by each short test. This means that there are three charts (CO, HC and NOx) for the short tests using laboratory analyzers and two (CO and HC) for those using garage ones. The first horizontal line represents the emission standard of the vehicles (conformity of production), while the above parallel line a percentage above it. This line has been drawn in order to distinguish the high (groups 3 and 4) and the very high polluters (groups 5 and 6). As the emission standard of the vehicles refers to CO and HC+NOx, the need of splitting the latter standard is raised since each short test is measuring HC and NOx separately. This splitting has been made according to the low polluters of the sample in order not to come up with misleading results due to an engine malfunction. The vertical line which is referred to as cut-point is a limit for approving or not a vehicle according to each short test.

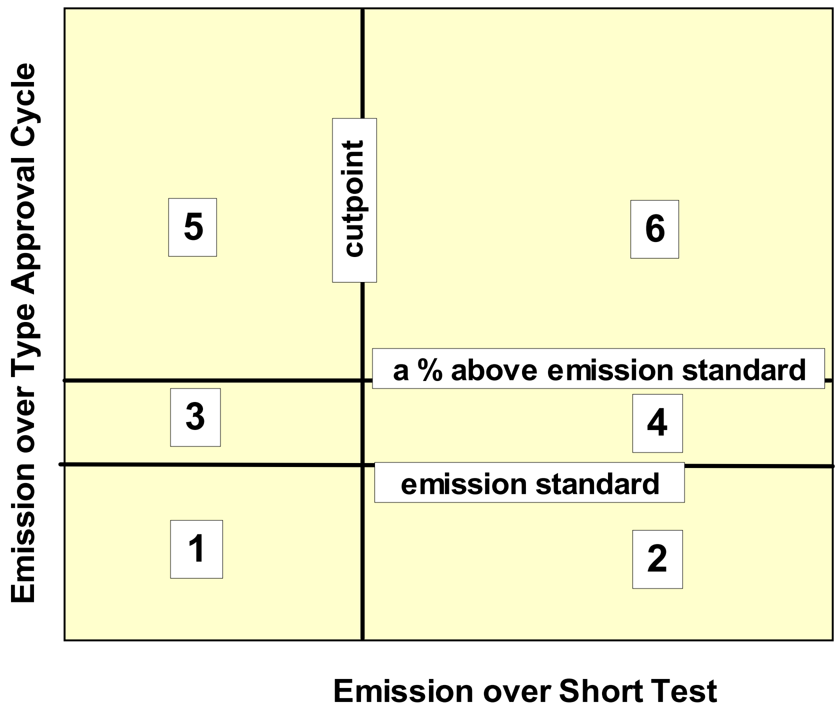


Figure 1: Basic chart

4.1.2 Groups

The vehicles in group 1 are referred to as low polluters and the very high polluters in group 6 are referred to as vehicles to be sent to maintenance. The vehicles in group 2 are the errors of commission which are wrongly detected by the short test, while those in group 5 are the errors of omission which are wrongly not detected by the short test. The errors of commission and omission should be as few as possible with regard to legal protection of citizens and environmental benefit respectively. The way the vehicles in groups 3 and 4 are treated is described later in the report.

Since there are two or three charts (one for each pollutant) an “overlapping” among vehicles’ pollutants is bound to occur. This means that a particular vehicle could be placed either in different or in the same group according to its emissions. Therefore a vehicle is referred to as to be sent to maintenance when at least one pollutant lies in group 6. A vehicle is an error of commission when at least one pollutant lies in group 2, but no one in group 6 (in that case the vehicle would be referred to as to be sent to maintenance). A vehicle is referred to as a low polluter when all pollutants lay in group 1.

4.1.3 Basic concept

The basic concept of this methodology is to identify the vehicles in group 6, send them to maintenance and make them emit afterwards as the low polluters in group 1. Such approach assumes that all vehicles sent to maintenance receive the best repair, i.e. after maintenance the vehicles emit the same as if they were brand new. Actually, this does not always occur and this is the reason why the achieved emission reduction is referred to as “potential”. The vehicles in group 2, which are also detected by the short test are not taken into account since they are actually low polluters and they are expected to emit the same after maintenance as well. These vehicles may have an effect on the cost of the program since the maintenance team is searching for faults which do not actually exist. The environmental benefit after maintenance by the vehicles in group 4 is supposed to be quite small and it is not taken into account as well, since the malfunction of these vehicles seems to be minor and perhaps non repairable. This applies when the percentage above standard for considering a vehicle as a very high polluter is not too high (e.g. 50%) and it is the worst case assumption. These vehicles are referred to as vehicles with low environmental benefit.

4.2 Definitions

4.2.1 Subscripts[1]

$i = CO,\ CO_2,\ HC,\ NOx,\ \text{and FC}$ (pollutants and fuel consumption)

$j = 1,\ 2,\ 3,\ 4,\ 5 \text{ and } 6$ (groups)

4.2.2 Basic indexes

Nj = number of vehicles in group j

Pj = percentage of vehicles tested with the particular short test that lay in group j

Eij = cumulative emissions of pollutant i by the vehicles in group j

PEij = percentage of total emissions of pollutant i by the vehicles in group j

In case one of the subscripts i or j or both in the above indexes are missing, then the index becomes more general (includes all pollutants or all groups or all pollutants and groups respectively).

4.2.3. Derivative indexes

Emission Factor of pollutant i by the vehicles in group j: $EFij = \frac{Eij}{Nj}$

Emission Reduction Potential of pollutant i: $ERPi = (EFi6 - EFi1)N6$

Emission Reduction Rate Potential of pollutant i: $ERRPi = 100 \cdot \frac{ERPi}{Ei}$

All above indexes have been calculated both cumulatively and separately per pollutant and groups of pollutants measured. Therefore, the pollutant(s) which is (are) responsible for sending a vehicle to maintenance as well as the ERRP which is due to this (these) pollutant(s) can be determined. For instance when a vehicle is sent to maintenance due to CO means that this vehicle lies in group 6 only in the CO chart, while when it is sent to maintenance due to HC and NOx means that it lies in group 6 both in the HC and NOx charts but not in group 6 of the CO chart.

[1] In diesel vehicles PM and opacity are used (Section 7)

4.2.4 Parameters

The parameters that should be taken into consideration and characterize a short test are the following:

- Errors of commission (P2)
- Vehicles to be sent to maintenance (P6)
- Environmental benefit according to the type approval cycle (ERRPs)
- Environmental benefit according to Modem “actual” cycle (ERRPs - Modem)

P2 should be minimized (legal protection of citizens), P6 should be minimized as well (minimum number of vehicles maintained), while the ERRPs should be maximized (environmental benefit). These parameters characterize adequately the short test without taking into account the errors of omission, because the main objective is an acceptable reduction of the emissions at a minimum cost.

4.3 Internal cut-point optimization

Before evaluating and comparing the short tests an internal cut-point optimization is implemented within each short test taking into account the above parameters. Mainly the errors of commission are taken into consideration and should not exceed 5% of the vehicles tested with the particular short test without a dramatic decrease in the emission reduction potential. This is based on the technical consideration and requirement that most of the vehicles which comply with the emission standards over the legislated test should also pass the short test. The exceptions to the above rule should be looked at separately and eventually dealt with separate specific cut-points. A thorough sensitivity analysis has been carried out and it has been found that the final results are barely sensitive to modification of the selected cut-points (Section 8).

4.4 Come-along benefits

Since there are no emission standards for CO_2 and FC no charts for these «pollutants» can be drawn. This also applies to NOx emissions with garage analyzers. Therefore, the above indexes and the ERRPs are considered as come-along benefits through the detected vehicles.

The type approval cycle is in most cases the NEDC cold cycle (UDC cold in some older vehicles). This means that the ERRPs are estimated according to the above cycles’ emissions. Since no chart can be drawn having the actual cycle’s emissions (Modem cycle) in its y axis (Figure 1), the corresponding ERRPs according to this cycle are considered as come-along benefits. In this case the abbreviations of the basic and derivative indexes are followed by the letter M: EijM, PEijM, EFijM, ERPiM and ERRPiM.

4.5 Final evaluation

Apart from the parameters mentioned above the cost of each short test should also be taken into account for the final short test evaluation. Here follows an alternative attempt of evaluating the short tests ignoring the cost. In order to produce one parameter capable of characterizing each short test, reductions should be made and weighting factors should be estimated. In order to decrease the parameters which are to be reduced, the ERRPs of CO_2 and FC are not taken into account since they are supposed to be very close to zero and thus insignificant. Furthermore the ERRPs according to the type approval cycle and the Modem cycle have been incorporated into one value (arithmetic mean). The short tests cannot be sorted from 1 to 10 for each parameter because the relevant percentages must be taken into account. On the other hand, the percentages themselves cannot be used directly as criteria since each parameter has a different value range. In order to weight equally all parameters the best short test for each parameter (maximum for ERRPs and minimum for P2 and P6) takes the value of 100 and the others follow relatively. These values are weighted according to what is supposed to be more important and a final weighted value for each short test is derived. From the environmental point of view the ERRP values should be highly weighted, while from the view of the legal protection of the citizens and the cost of the program the P2 and P6 values should be highly weighted.

This final short test evaluation is only presented and no results based on this are drawn since it is very sensitive to the selected weighting factors and therefore it is very subjective. Furthermore these results are not used in the cost effectiveness analysis.

5. 3W Catalyst Equipped Vehicles

5.1 Vehicle sample

The sample of the 3W catalyst equipped vehicles includes almost 190 vehicles and it is supposed to be sufficient in order to apply the methodology described in the previous section and to draw reliable conclusions. The sample has been extended by using the 3W catalyst equipped LPG powered vehicles as well. However as Table 1 shows all the above vehicles have not been tested with all possible types of measurement. The exact number of vehicles tested in each short test is given later in this report. Moreover, two kinds of vehicle samples have been investigated: the total sample (including a number of vehicles known to be very high polluters) and the random sample (including only vehicles representative of the fleet).

As a first approach, the vehicles have been sorted according to their emissions in NEDC cold. Figure 2a presents the high polluters (above emission standard), while Figure 2b the very high polluters (50% above emission standard). In these figures the pollutant(s) which is (are) responsible for considering a vehicle as a high or a very high polluter can be determined. The 3 digits in the legend text refer to CO, HC and NOx respectively while 0 and 1 indicate whether the particular pollutant is below or above the emission standard (or 50% above emission standard). For instance 101 is the percentage of high (or very high) polluters both in CO and NOx.

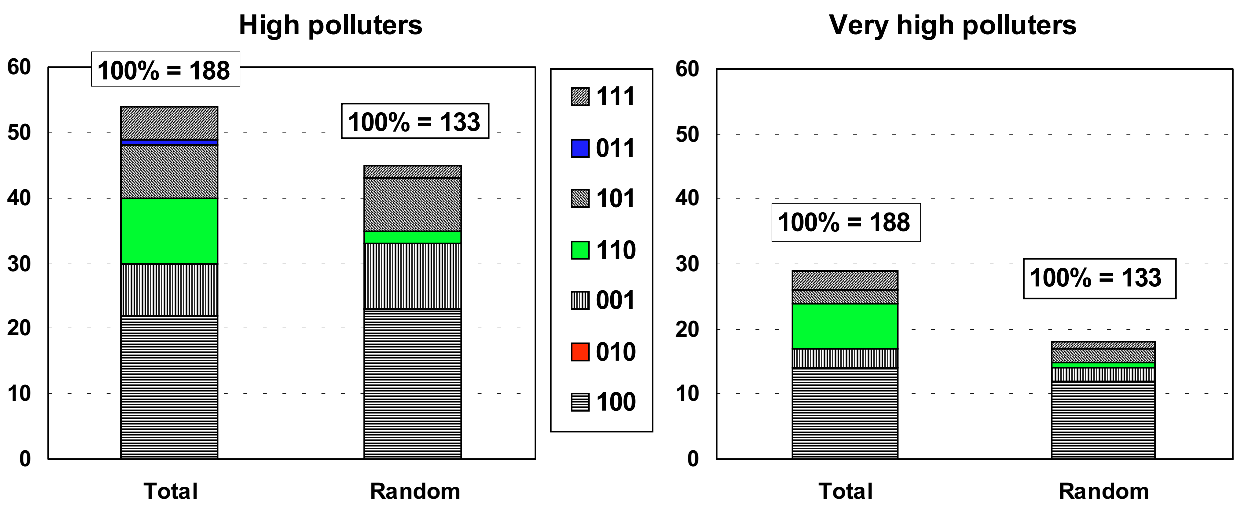


Figure 2: Distribution of 3W-cat vehicles according to NEDC cold emissions

From the above figure it can be derived that especially most of the randomly chosen vehicles are low polluters. Firstly CO and secondly NOx are mainly responsible for the high (and very high) polluters. There are no vehicles emitting only high levels of HC or both HC and NOx. There are also very few vehicles emitting high levels of all three pollutants. The above remarks seem to

lead to the conclusion that when a vehicle is a high polluter it can be detected by measuring CO and perhaps NOx, while further measurement of HC provides no additional values.

5.2 Initial conditions

The methodology described in the previous chapter can be applied to 3W catalyst equipped vehicles. The initial conditions that are used in order to reach to the final results are the following:

- Emission standards for CO, HC and NOx according to Directive 91/441/EEC. This means that the type approval cycle is NEDC cold (y axis in Figure 1).
- After splitting HC+NOx standard according to the low polluters of the sample, it has been derived that HC makes up 53% of the above sum.
- Since the very high polluters are the objective, groups 5 and 6 are defined by a line 50% above the emission standard (a=50, Figure 1).

5.3 Results

Results have been produced for both vehicle samples; total and random. Table 3 shows the selected cut-points for the above cases as well as the percentage of tested vehicles by each short test. Figures 3-5 (a and b) show the parameters of each short test both for total and random vehicle sample.

Table 3: 3W-cat vehicles: cut-points and number of vehicles tested

	Total sample				**Random sample**			
Short test	**Sample (%)**	**Cut-points CO**	**HC**	**NOx**	**Sample (%)**	**Cut-points CO**	**HC**	**NOx**
meTUV	97	2.5	0.3	0.5	97	2	0.3	0.5
ralaTUV	56	0.35	1200	500	56	0.3	1100	400
ragaTUV	37	0.25	500	-	47	0.2	500	-
meMS	97	3	0.4	0.6	98	3	0.4	0.6
ralaMS	57	0.3	1100	500	59	0.3	1000	500
ragaMS	37	0.2	600	-	47	0.2	600	-
Idle	96	0.3	900	-	98	0.2	900	-
H-Idle	96	0.2	700	-	98	0.2	600	-
ga50-7	96	0.25	600	-	98	0.2	400	-
la50-7	88	0.25	600	800	86	0.2	600	800

		CO: in % except for mass emissions in g/km
All	**100%= 188**	HC: in ppmC1 except for mass emissions in g/km
Random	**100%= 133**	NOx: in ppm except for mass emissions in g/km

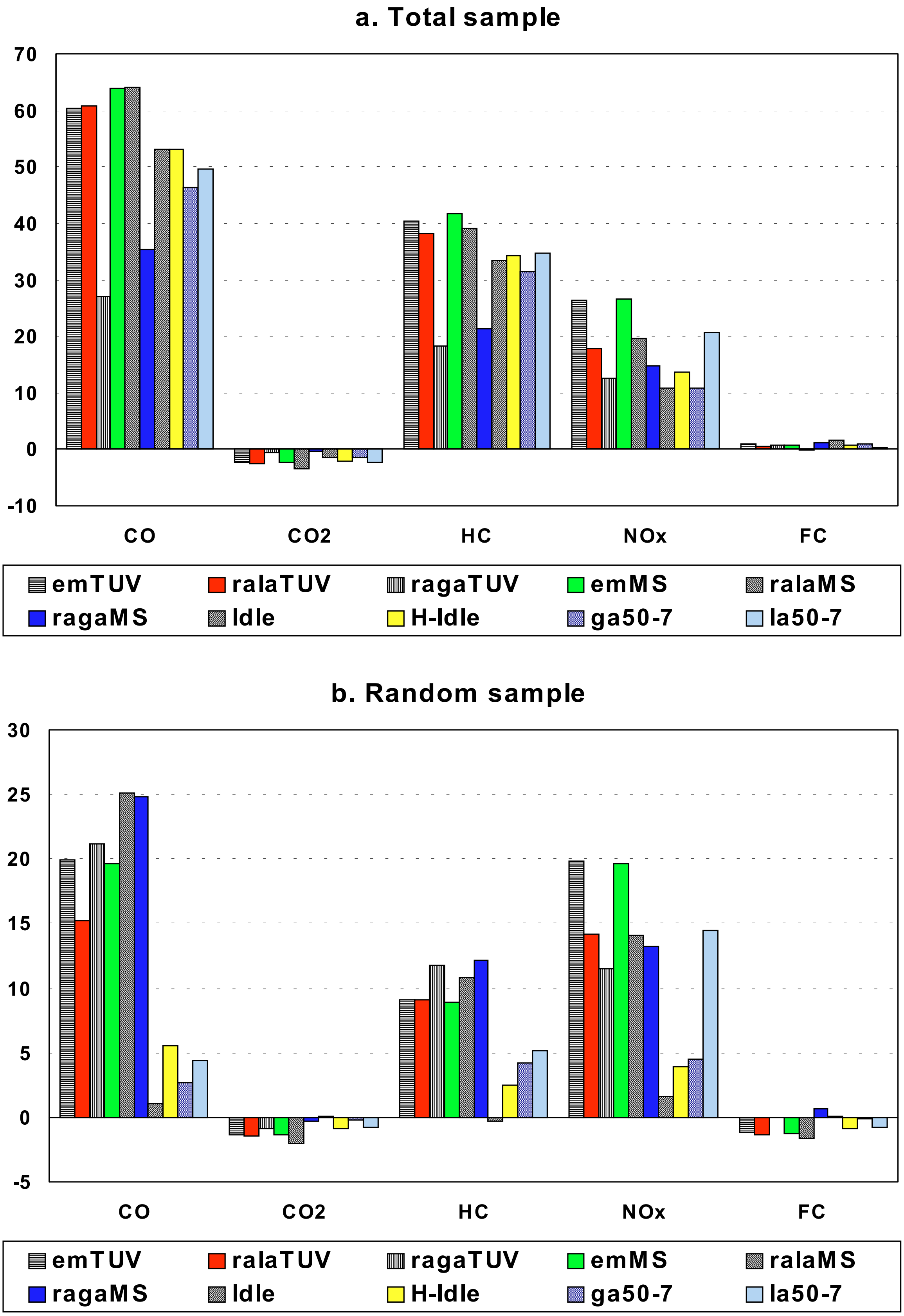


Figure 3: 3W-cat vehicles: ERRPs according to NEDC

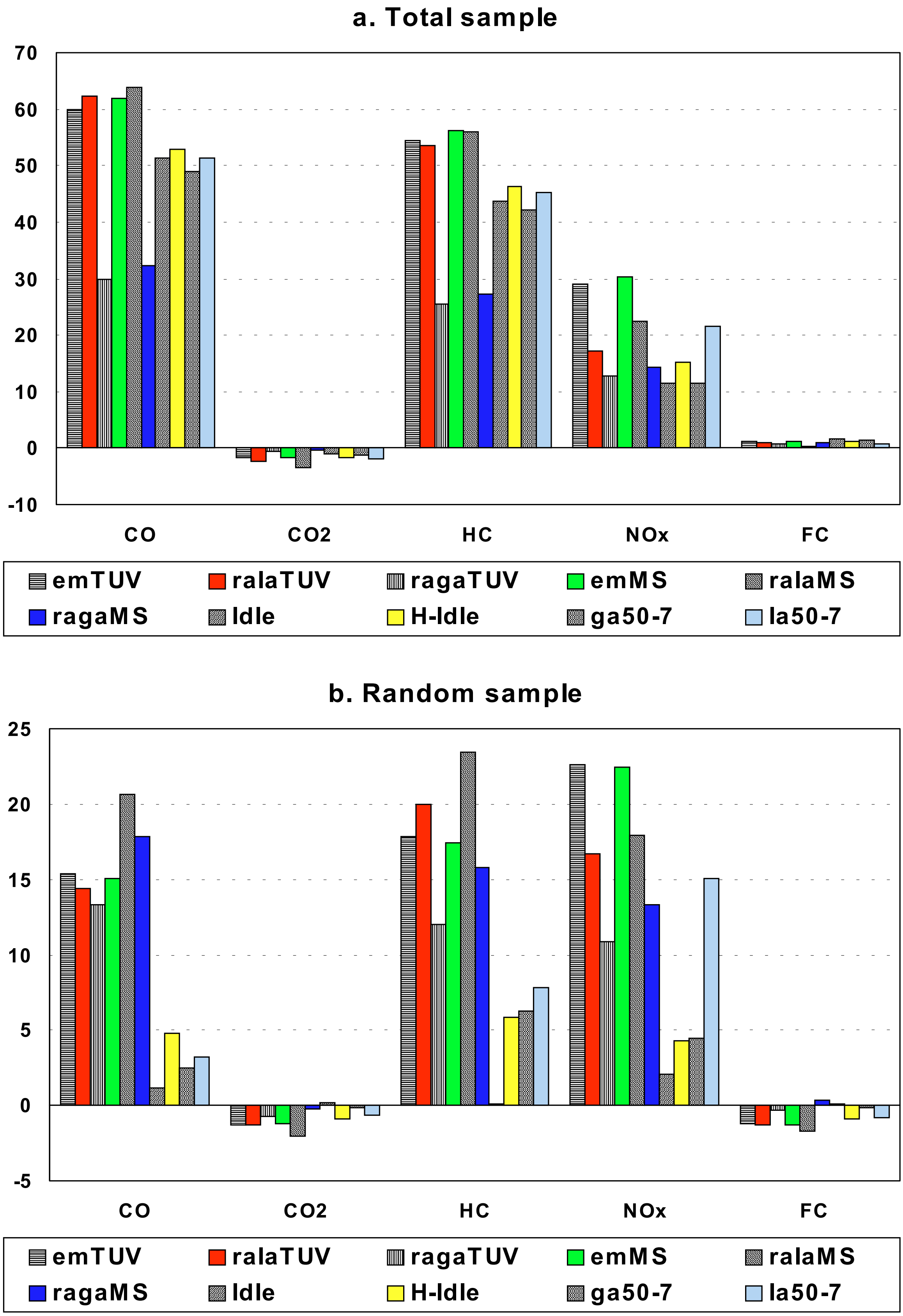
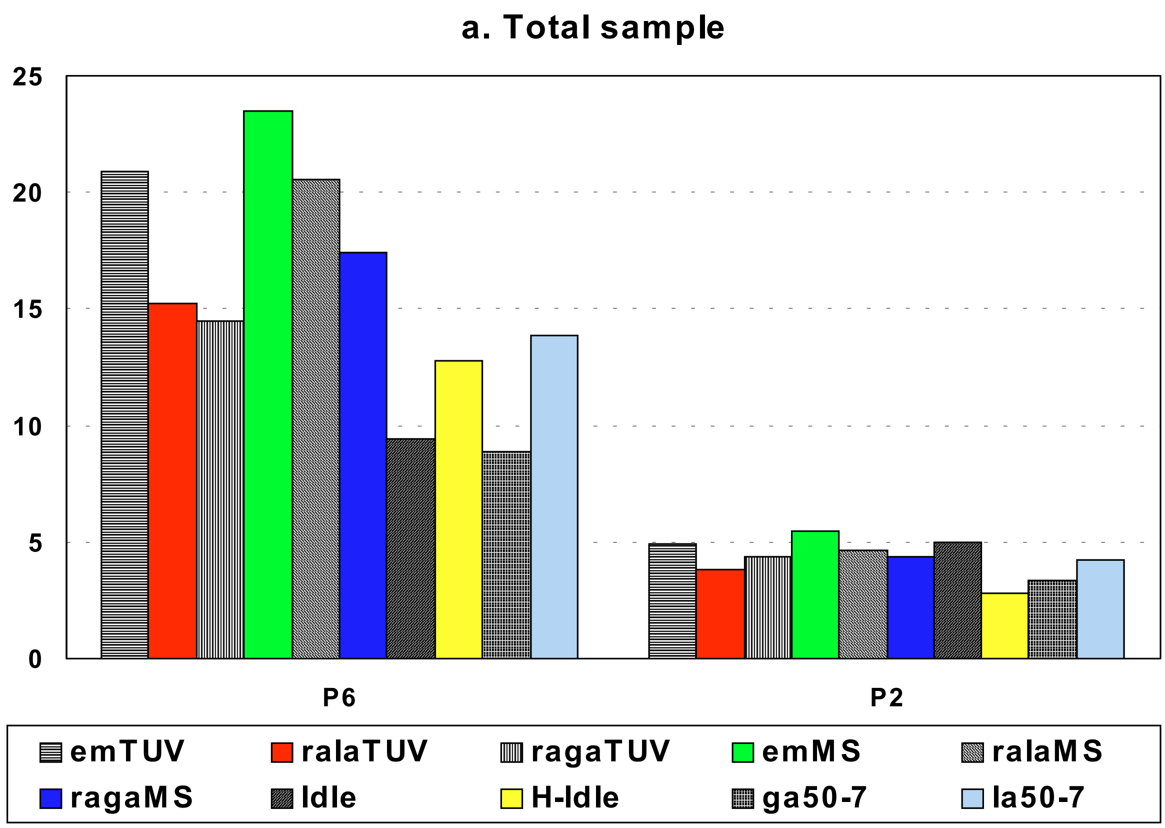


Figure 4: 3W-cat vehicles: ERRPs according to Modem



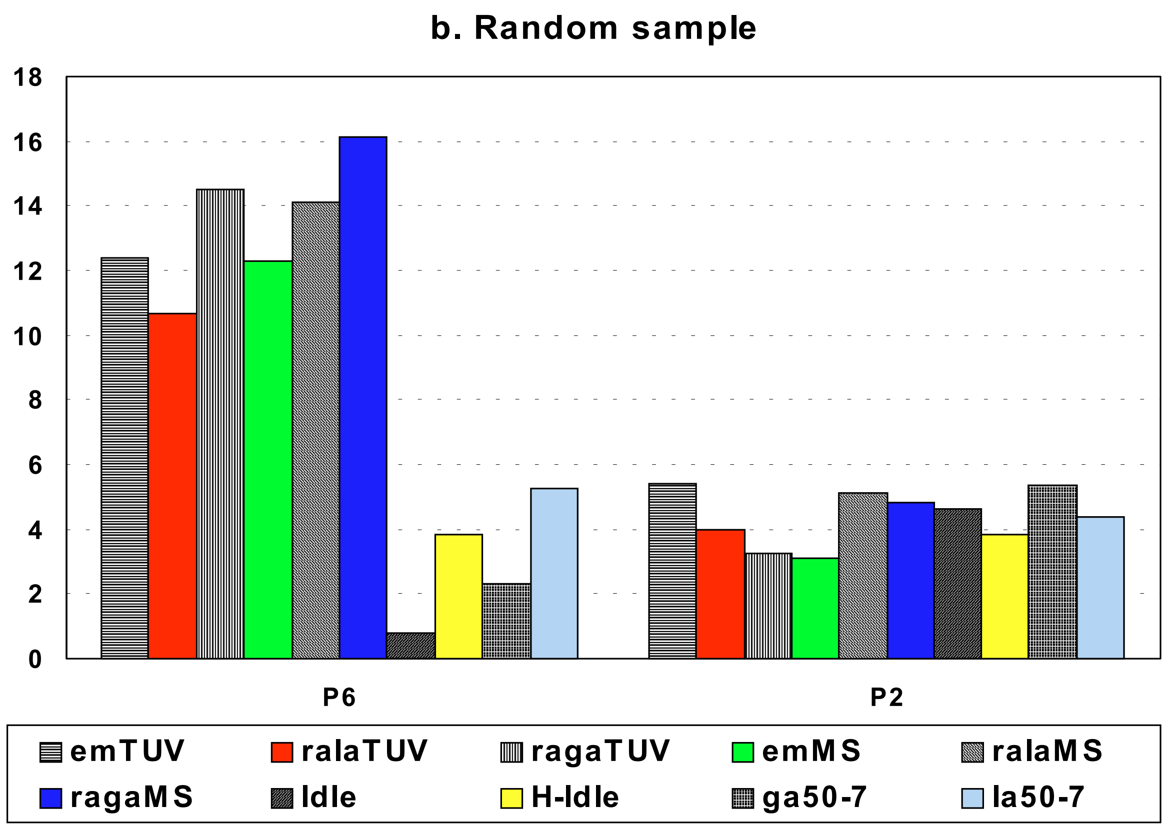


Figure 5: 3W-cat vehicles: P6 and P2

In the Annex there are detailed tables and charts including all parameters both cumulatively and separately per pollutant and groups of pollutants for total and random vehicle sample.

Figures 6 and 7 (a and b) show the reduced parameters and the final short test evaluation for both vehicle samples. This approach does not take into account cost and weights all reduced parameters equally (i.e. 20%).

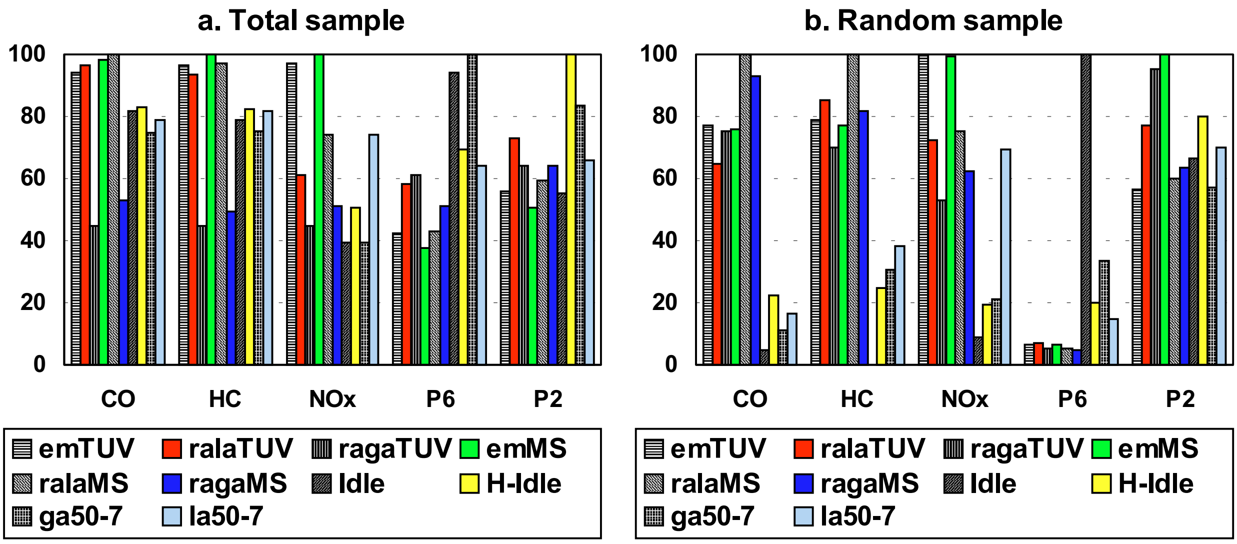


Figure 6: 3W-cat vehicles: reduced parameters

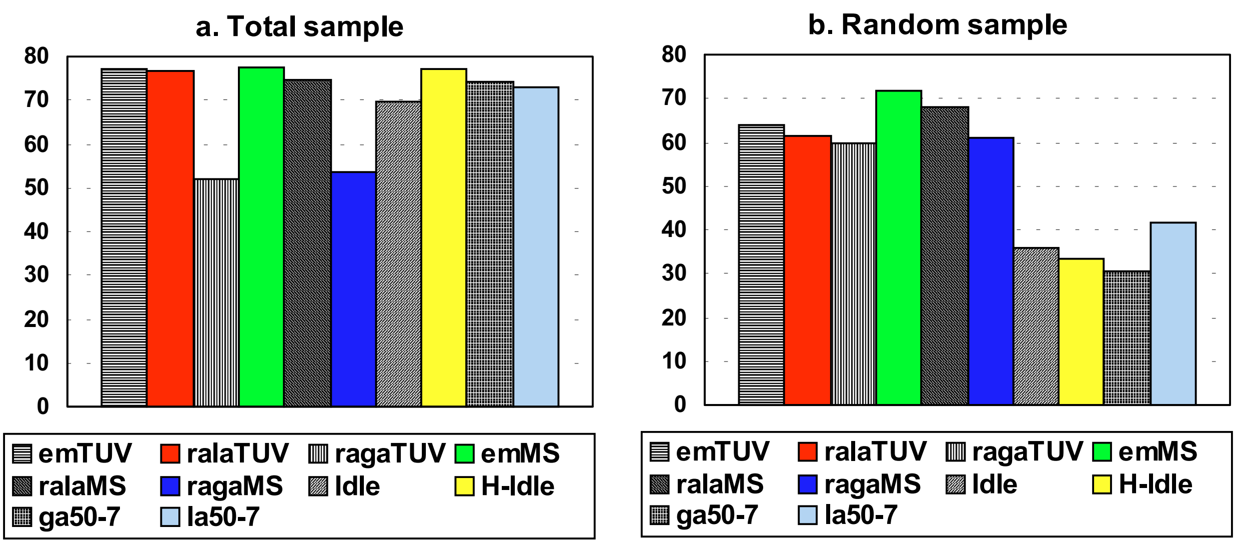


Figure 7: 3W-cat vehicles: final short test evaluation

6. Conventional and Oxidation Catalyst Equipped Vehicles

6.1 Vehicle sample

The number of the conventional and oxidation catalyst equipped vehicles tested is much smaller compared to that of the 3W catalyst equipped. The sample as far as the conventional vehicles are concerned, however, seems to be sufficient enough to draw conclusions, while the number of the oxidation catalyst equipped vehicles is probably too small. Table 4 shows the exact number of the tested vehicles.

Table 4: Number of conventional and oxidation catalyst equipped vehicles tested

Vehicle Technology	Total sample	Random sample
Conventional	33	11
Oxidation catalyst equipped	7	2
Total	40	13

However, as Table 1 shows, all the above vehicles have not been tested with all possible types of measurement. The exact number of vehicles tested by each short test in given later in this report.

Most vehicles comply with the Directive 83/351/EEC (ECE 15/04), which allows different emission standards according to a vehicle's reference weight. As a result the vehicle sample in question is non homogenous as far as the emission standards are concerned. The type approval cycle is UDC cold (y axis in Figure 1) for all vehicles.

Table 5 shows the maximum, minimum and average emission standards of the particular sample.

Table 5: Emission standards for conventional and oxi-cat vehicles

Emission standard	Vehicle technology	CO	HC	NOx
Average	Conventional	18.55	2.82	3.20
	Oxidation catalyst equipped	11.90	1.75	1.98
Maximum	Conventional	22.46	3.19	3.60
	Oxidation catalyst equipped	19.74	2.97	3.35
Minimum	Conventional	13.33	1.75	2.49
	Oxidation catalyst equipped	5.63	0.72	0.82
Total average		17.39	2.63	2.98

The emission standards in Table 5 are expressed in g/km (conversion has been carried out from g/test of UDC). The separate emission standards for HC and NOx have been evaluated according to the low polluters of the sample and it has been found that the percentage of HC in HC+NOx is approximately 47%. This value has been used in order to complete Table 5.

The above vehicles have been sorted according to their emissions in UDC cold which is the type approval cycle. This is presented in Figure 8 (a and b) where the high and very high polluters are distinguished from the low ones with the average emission standard. The abbreviations are the same as in Figure 2.

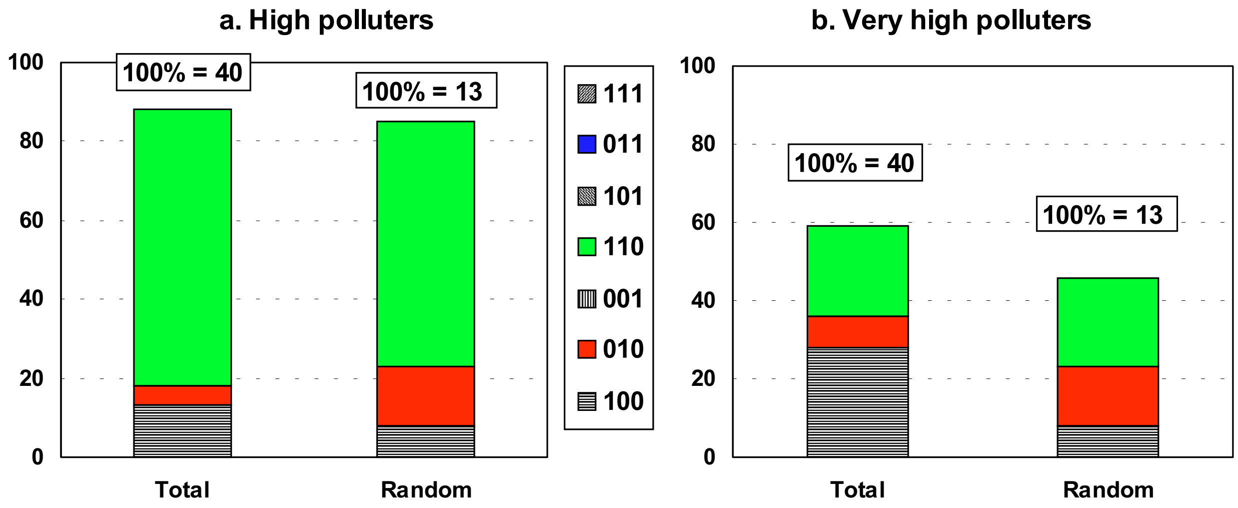


Figure 8: Distribution of conventional and oxi-cat equipped vehicles according to UDC cold emissions

6.2 Initial conditions

The initial conditions that are used in order to apply the methodology described in section 4 and reach to the final results for the conventional and oxidation catalyst equipped vehicles are the following:

- Since the number of oxidation catalyst equipped vehicles is small (Table 4), it is suggested that the two vehicle technologies are treated as one using the total average emission standard of Table 5. According to this table this standard seems to be efficient since the maximum and minimum standards are quite close to it and the dispersion of standards around it is not so high.
- Since the very high polluters are the objective, groups 5 and 6 are defined by a line 50% above the emission standard (a=50, Figure 1).
- An internal cut-point optimization has been carried out targeting to minimize the errors of commission. Since the sample is small one vehicle account for a relatively high percentage, therefore the limit of 5% regarding the errors of commission can be sometimes exceeded.

6.3 Results

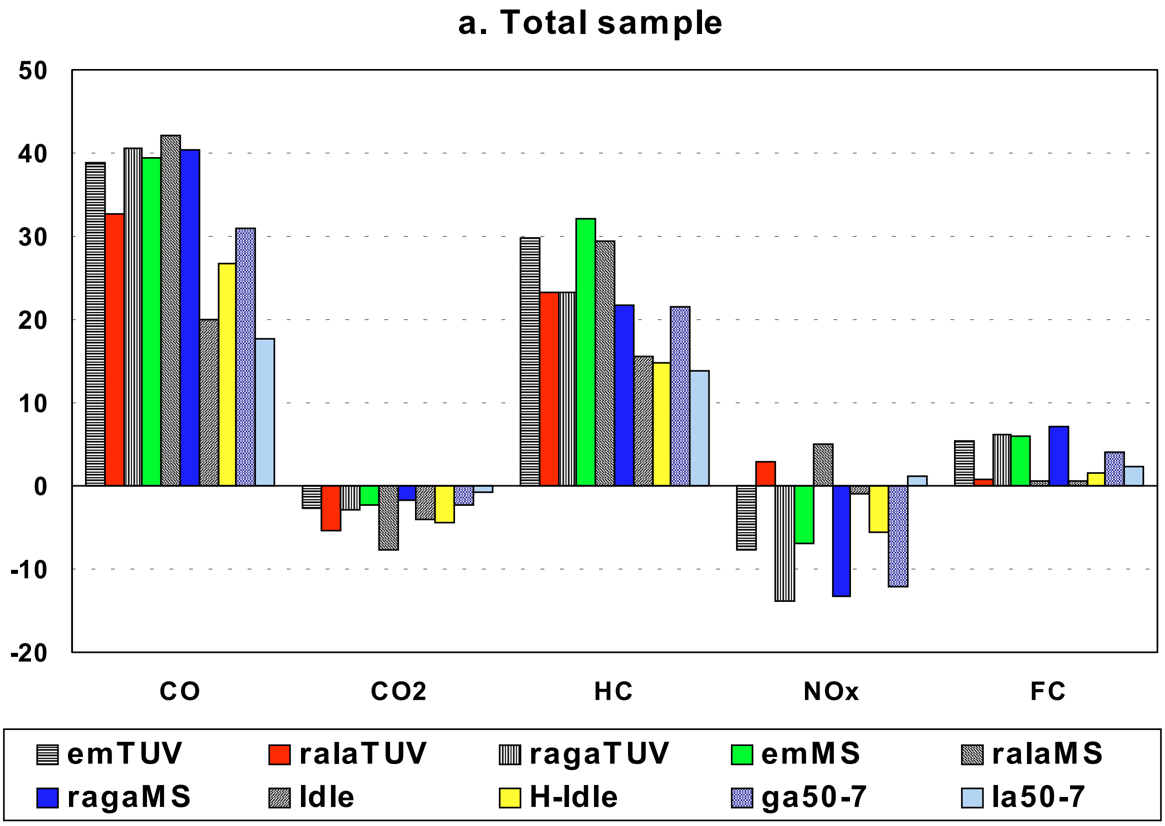
Results have been produced for both vehicle samples: total and random. All parameters related to environmental benefit have been evaluated according to NEDC cold and Modem cycles like in the case of 3W catalyst equipped vehicles, even though the vehicles are separated in groups according to UDC cold cycle. This means that the NEDC emissions are come-along benefits like the Modem emissions.

Table 6 shows the selected cut-points for both vehicle samples as well as the percentage of tested vehicles in each short test. In the case of randomly chosen vehicles the sample becomes too small and perhaps not sufficient to draw specific conclusions. Moreover, four short tests (ralaTUV, ralaMS, la50-7and ga50-7) cannot be evaluated since the vehicle sample consisted of one or three vehicles and no vehicles in group 6 are found with “rational” cut-points according to the short test ga50-7. Figures 9-11 (a and b) show the parameters of each short test for both the above cases.

Since an eventual malfunction in the engine of a conventional vehicle leads usually to rich mixtures, NOx emissions sometimes increase after maintenance. The emission reduction potential should then be negative.

Table 6: Conventional and oxi-cat vehicles: cut-points and number of vehicles tested

	Total sample				**Random sample**			
Short test	**Sample (%)**	**Cut-points**			**Sample (%)**	**Cut-points**		
		CO	**HC**	**NOx**		**CO**	**HC**	**NOx**
meTUV	100	9	3	4.5	100	8	3	4
ralaTUV	40	1	4000	3000	-	-	-	-
ragaTUV	55	1.5	4000	-	85	1.5	4000	-
meMS	100	12	3.5	5	100	12	3	4
ralaMS	40	1.1	4000	3000	-	-	-	-
ragaMS	58	2	4000	-	92	2	4000	-
Idle	100	1.5	3000	-	100	1.5	3000	-
H-Idle	100	1.5	3000	-	100	1.5	2500	-
ga50-7	100	1	3000	-	-	-	-	-
la50-7	53	1.5	3000	4500	-	-	-	-
			CO: in % except for mass emissions in g/km					
All	**100%= 40**		HC: in ppmC1 except for mass emissions in g/km					
Random	**100%= 13**		NOx: in ppm except for mass emissions in g/km					



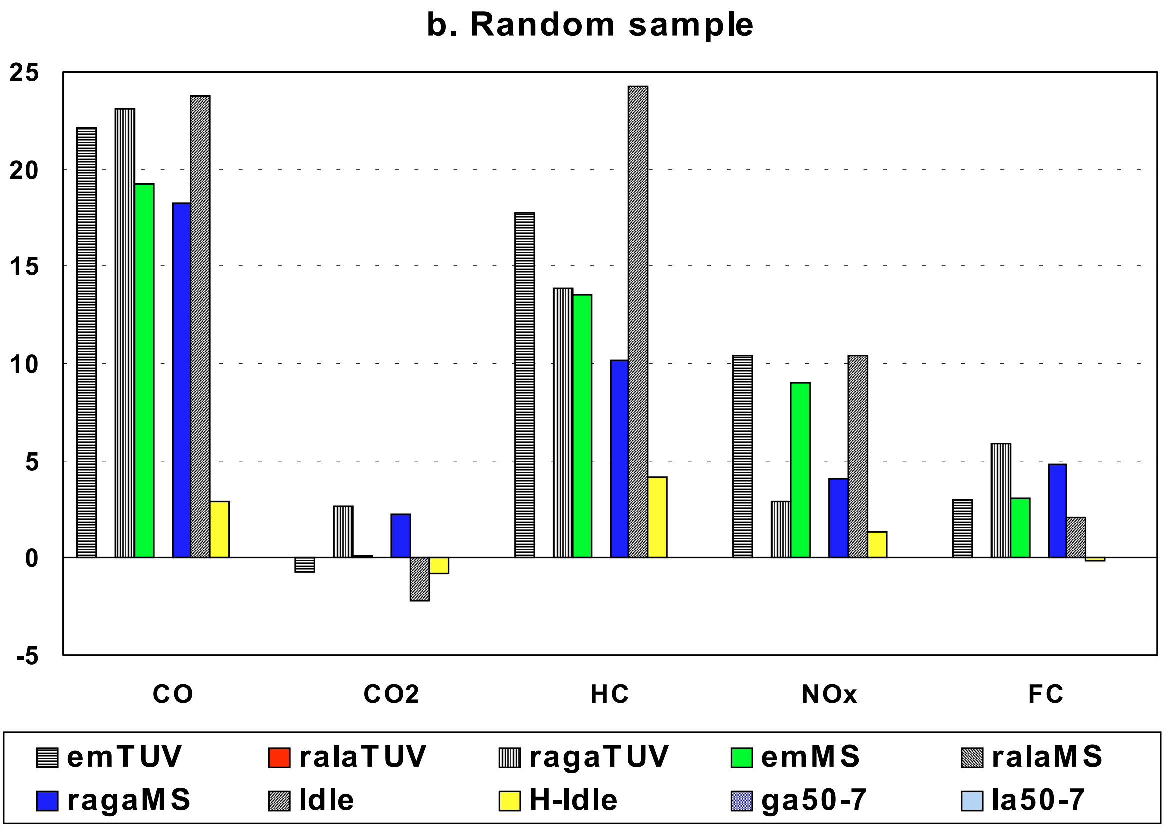


Figure 9: Conventional and oxi-cat vehicles: ERRPs according to NEDC

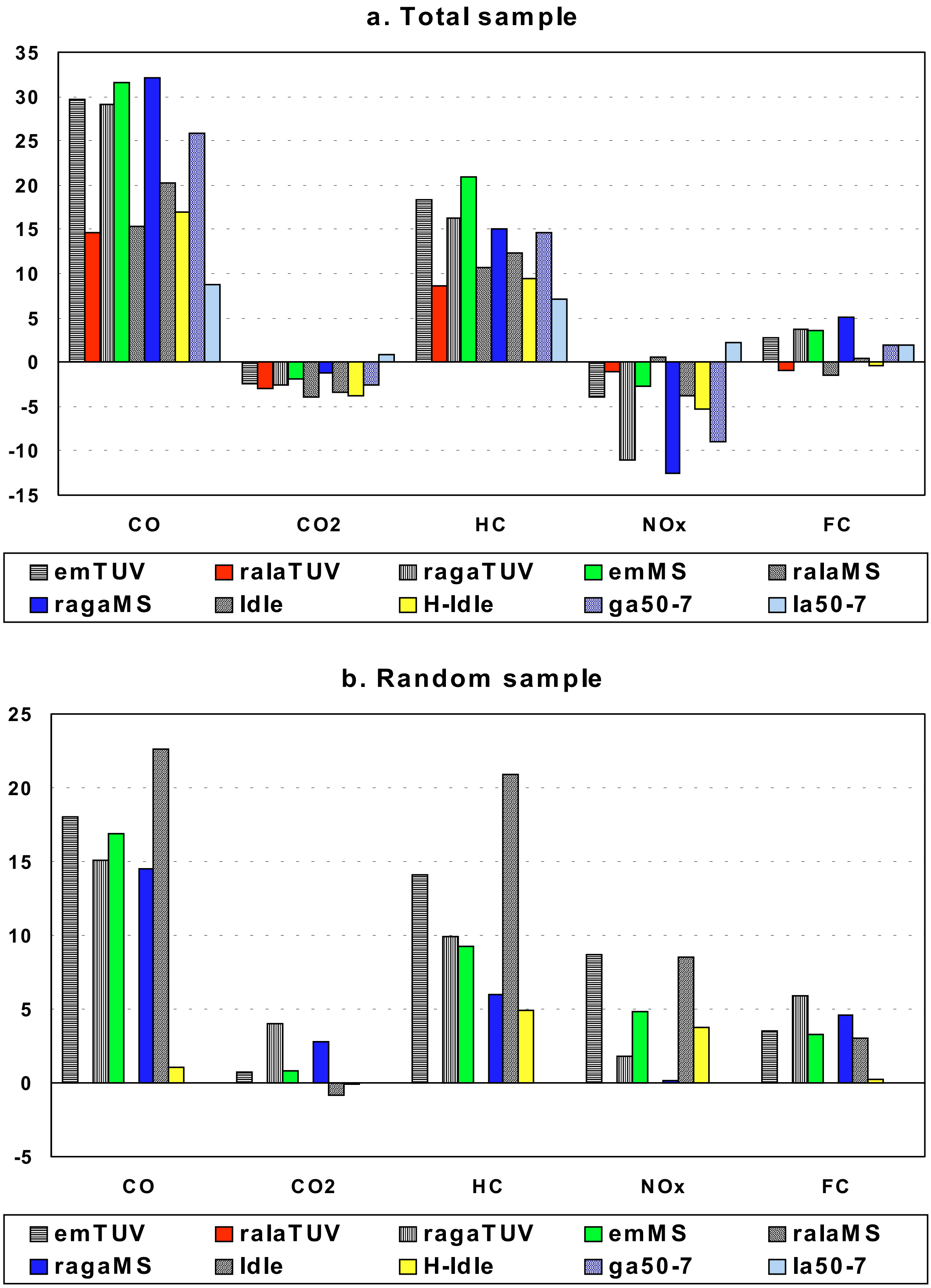


Figure 10: Conventional and oxi-cat vehicles: ERRPs according to Modem

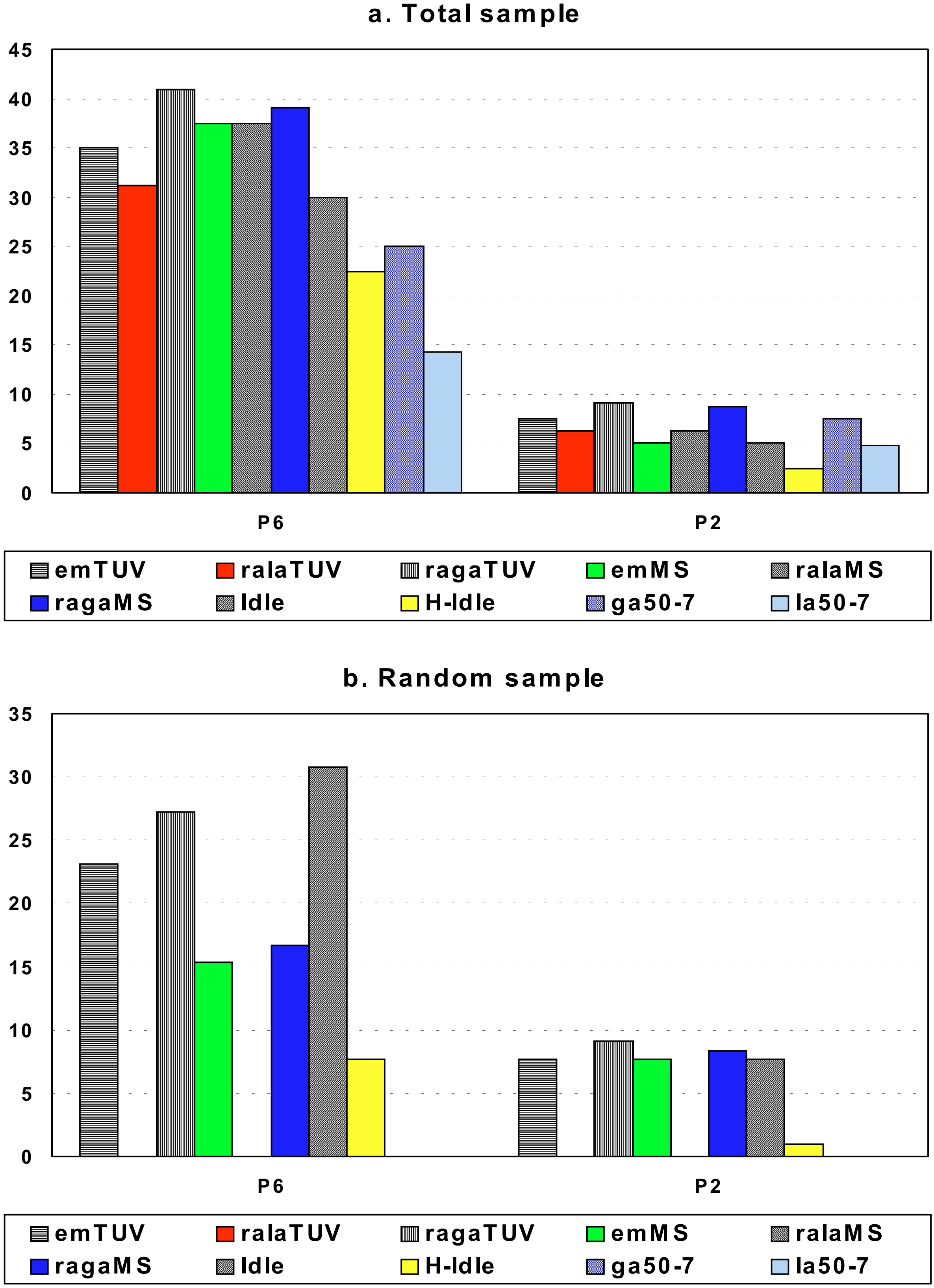


Figure 11: Conventional and oxi-cat vehicles: P6 and P2

In the Annex there are detailed tables and charts including all parameters both cumulatively and separately per pollutant and groups of pollutants for total and random vehicle sample.

Figures 12-13 (a and b) show the reduced parameters and the final short test evaluation for both samples. This approach does not take into account cost and weights all reduced parameters equally (i.e. 25%), since NOx is not taken into account considering that the reduction or increase is small and accidental.

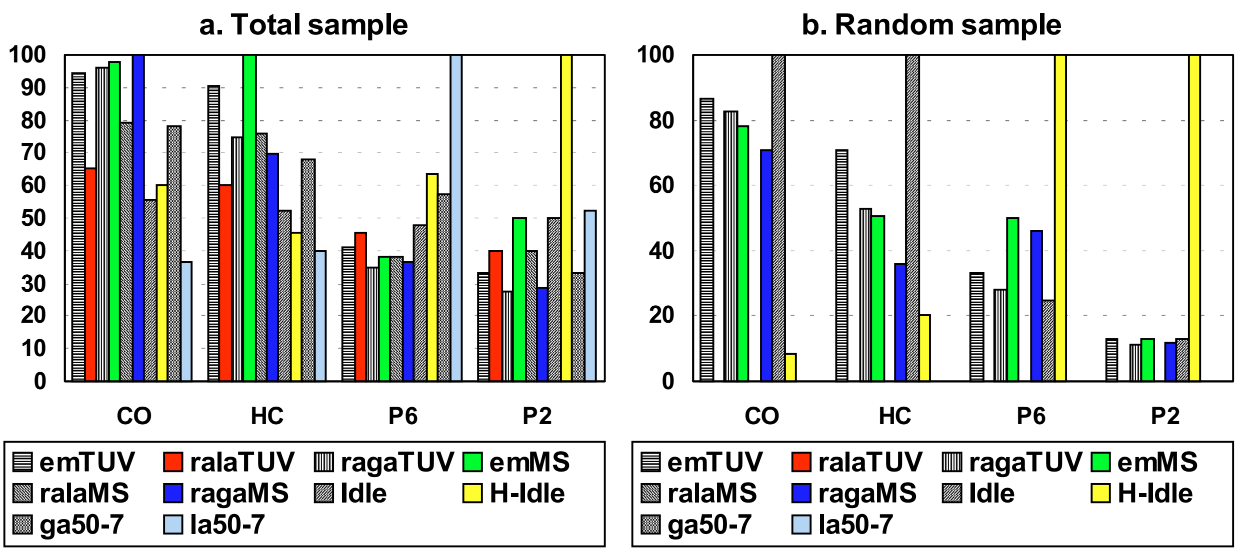


Figure 12: Conventional and oxi-cat vehicles: reduced parameters

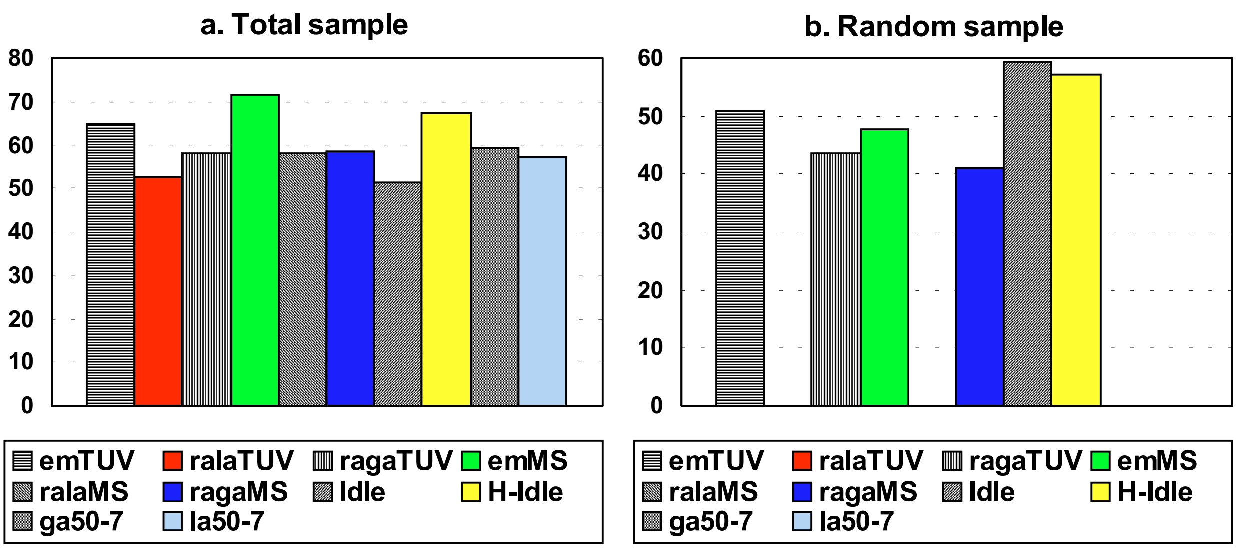


Figure 13: Conventional and oxi-cat vehicles: final short test evaluation

6.4 Alternative approach

As Table 5 shows, the vehicles cannot be compared on a common basis due to the different emission standards according to which they have been certified. The use of the average emission standard seems to be a good and simple approach. An alternative approach in order to overcome the non homogenous nature of the standards, could be the normalization of each vehicle's emissions by the corresponding emission standard. Therefore the y axis of Figure 1 becomes dimensionless and the emission standard for all vehicles becomes 1. However, the weighting of the y axis is not enough since each short test should take into consideration the emission standard of a vehicle as well. This means that the weighting of the x axis is required as well. Therefore, a common cut-point having no dimensions or expressed in (%)/(g/km) or (ppm)/(g/km), according to the short test, for all vehicles could be determined. The actual vehicle's cut-point could then be calculated taking into account the vehicle's emission standard.

7. Diesel Vehicles

7.1 Vehicle sample

The number of the tested diesel vehicles is very small and the application of the methodology described in section 4 seems to be risky. Apart from the size of the sample, its nature adds another difficulty: most vehicles are low polluters and as a result there are low margins for thorough maintenance and high environmental benefits.

Like the conventional and oxidation catalyst equipped vehicle sample, the diesel vehicle sample is non homogenous as far as the type approval tests and the emission standards are concerned. Many vehicles were approved according to UDC and a few according to NEDC and FTP cycles. Furthermore, since former type approvals were dependent either on vehicles' mass or engine capacity, there is a large number of emission standards for the already small number of the tested vehicles. Table 7 shows the emission standards of all tested diesel vehicles.

Table 7: Emission standards for diesel vehicles

Type approval test	CO	HC+NOx	HC	NOx	PM	Number of vehicles
NEDC	3.16	1.13	-		0.18	12
UDC	17.28	5.87	-		(0.35)	2
UDC	22.46	6.79	-		(0.35)	1
UDC	22.46	6.79	-		0.35	1
UDC	17.28	5.87	-		0.35	1
UDC	19.74	6.32	-		(0.35)	1
UDC	8.88	2.47	-		(0.35)	5
UDC	(22.46)	(6.79)	-		(0.35)	1
UDC	18.76	3.7	-		(0.35)	1
FTP	2.1	-	0.25	0.62	0.08	1
FTP	2.1	-	0.25	0.62	0.124	2

The emission standards in Table 7 are expressed in g/km (conversion has been carried out from g/test of UDC). The standards in brackets were assumed so as to be as mild as possible since no emission standards for these vehicles have been found.

A diesel vehicle can be characterized as a high polluter mainly because of the particulate emissions. The other pollutants —CO, HC and probably NOx— are too low and generally they remain unaffected by eventual malfunctions or engine degradation. The validity of the above assumption is demonstrated in Figure 14 (a, b and c) which correlates the type approval cycle (weighted according to paragraph 6.4) and meTUV (as an example) for CO, HC, NOx respectively. The splitting of HC+NOx standard has been carried out according to the low polluters of the sample. It has been found that the percentage of HC in HC+NOx is approximately 15%, i.e. as expected well below the corresponding percentage of gasoline vehicles.

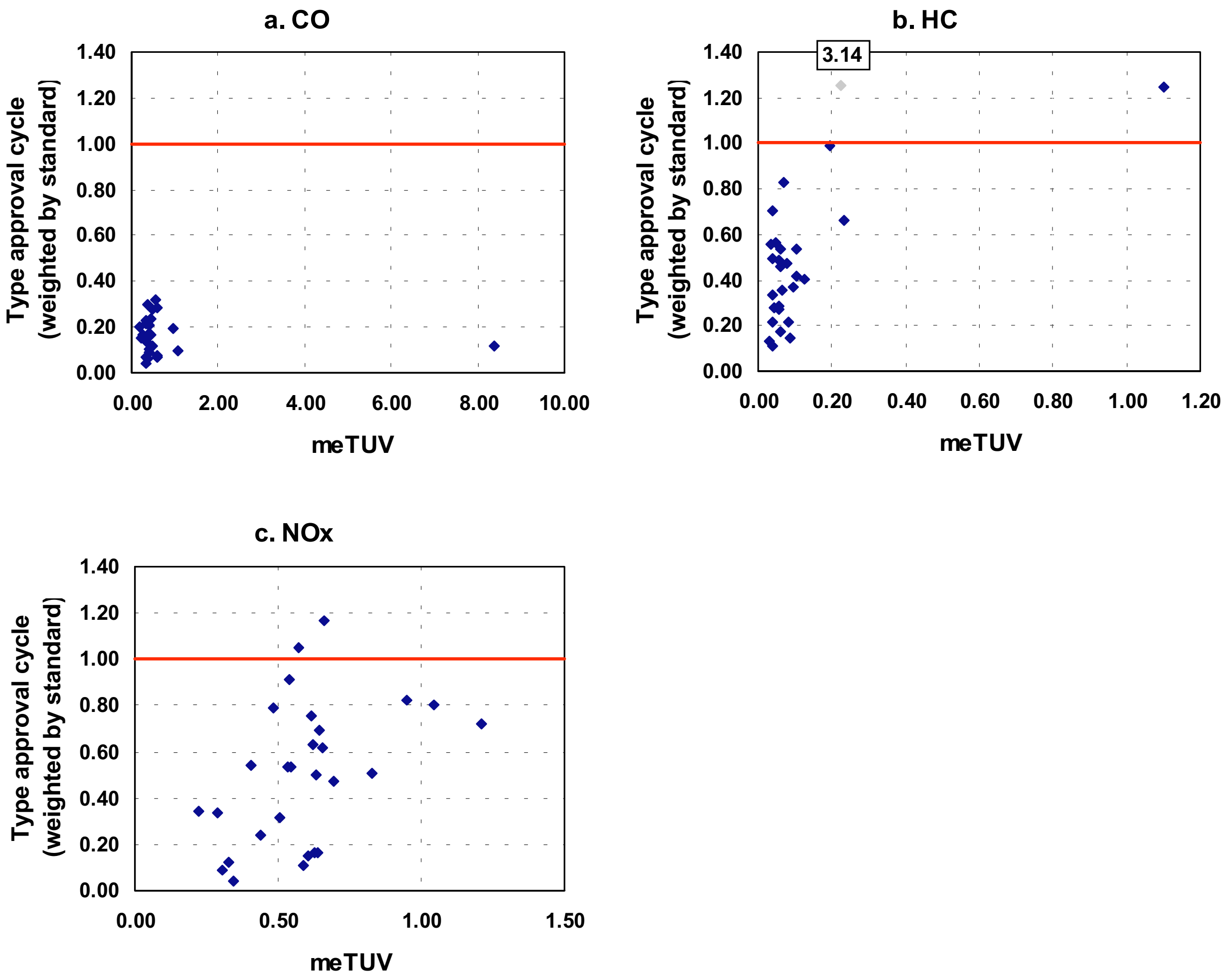


Figure 14: Diesel vehicles: type approval cycle and meTUV correlation

It is obvious that most vehicles have y coordinate in all figures well below 1. There are two vehicles emitting 1.16 g/km HC (weighted: 3.14) and 1.27 g/km HC (weighted: 1.15) respectively in UDC. The first is a Ford Escort with identification number 588008 and the second a VW bus with identification number 91027. Ignoring these two exemptions these figures demonstrate the already known conclusion that diesel vehicles can easily meet CO and HC standards since these standards have been defined for both gasoline and diesel vehicles.

Therefore, the analysis focuses basically on the measurement of exhaust gas opacity or smoke number. As a result PM becomes the only and guide pollutant in the evaluation. The short tests measuring opacity and the exact number of tests carried out are shown in Table 8.

Table 8: Short tests measuring opacity and number of measurements

Laboratory	ragaTUV	ragaMS	FAS	AUTONAT
TUEV	12	12	13	0
INRETS	13	14	14	15

The abbreviation ga stands for the opacimeter

As Table 7 shows, PM emission standard varies a lot among vehicles. The assumed standard of 0.35 g/km exceeds, for example, the mean particulate emission of the diesel vehicle sample (mean model year 1988, latest model year 1990) of the Swiss/German emission factor program by a factor of 2.8. This means that this standard has never influenced diesel vehicle technology, and it becomes obvious that problems will occur when using each vehicle’s PM standard for the identification of high polluters. Therefore it is suggested that the common PM emission standard should be 0.18 g/km.

7.2 Correlations

As far as the short tests measuring opacity are concerned, conclusions can be drawn on the basis of their correlation to NEDC cold cycle. Since only the correlation factor is investigated, all vehicles should be correlated irrespectively of their type approval. Figure 15 (a, b, c and d) shows this correlation.

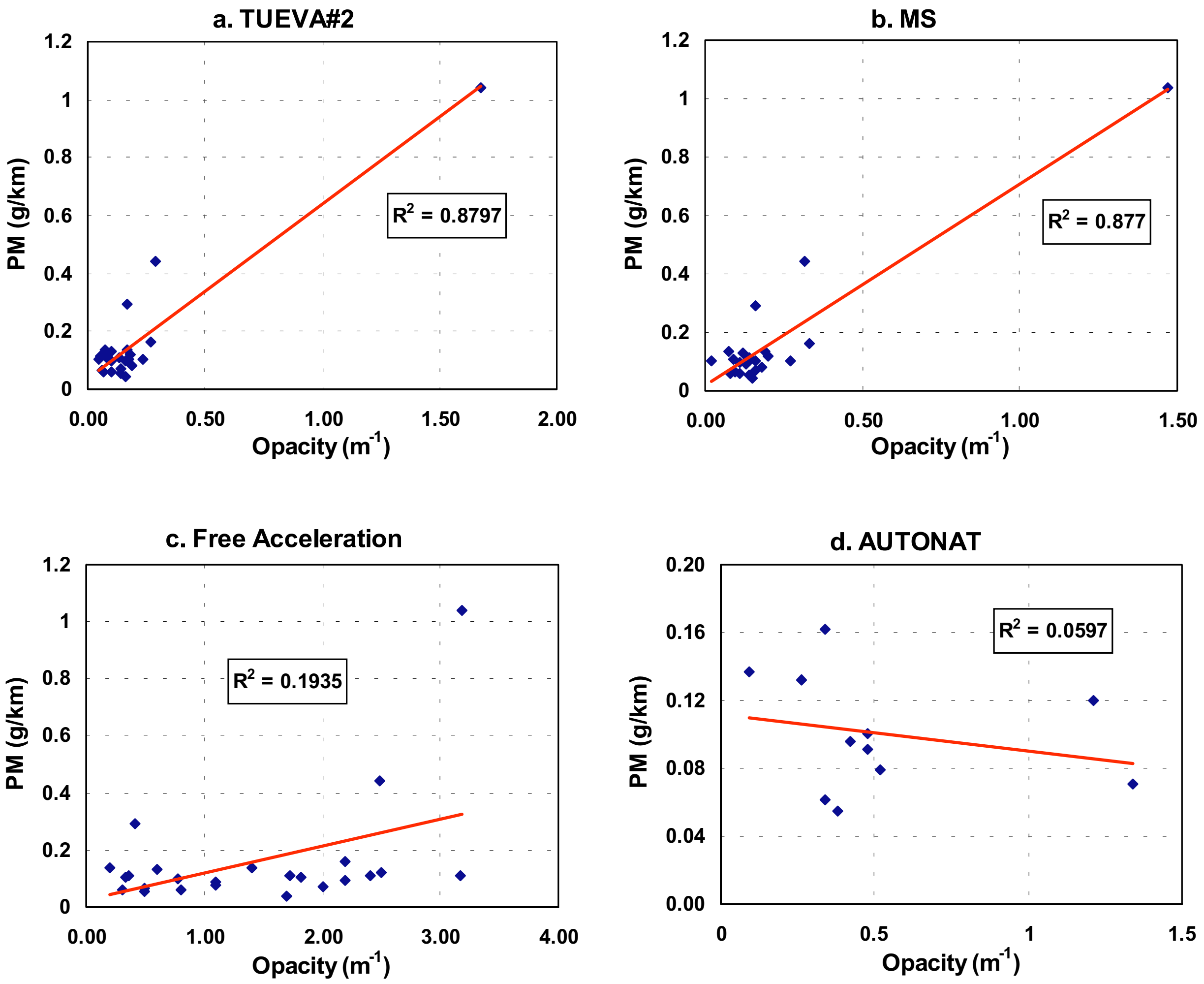


Figure 15: Diesel vehicles: NEDC PM and short tests opacity correlation

From these figures it can be derived that both short transient tests (Figures 15a and 15b) show an increasing tendency for the high polluters with a good correlation factor. The free acceleration test (Figure 15c) also shows such a tendency but not so clearly as the transient tests. According to this chart the very high polluters seem to be indicated but the dispersion is very high (low correlation factor). However, the above good correlations deteriorate if the VW bus is excluded (R^2=0.29, 0.27 and 0.04 for TUEVA#2, MS and FAS respectively). The Autonat test (Figure 15d) can hardly show such an increasing tendency. This leads to the conclusion that even though the sample is very small (only vehicles from INRETS are included) there is no correlation between this test and the NEDC cycle.

TNO has found very similar results in the frame of an in-use compliance project /1/[2]. As Figure 16 shows there is no correlation between the particulate emissions in the NEDC with cold start and the results of the free acceleration test. Since this conclusion is based on a larger sample the tendency shown in Figure 15c may be accidental.

[2] 1/ R.C. Rijkeboer and R.P. Binkhorst Project in use compliance, air pollution by cars in use. Annual Report 1996 TNO Road vehicles research institute, on behalf of Netherlands Ministry of the Environment

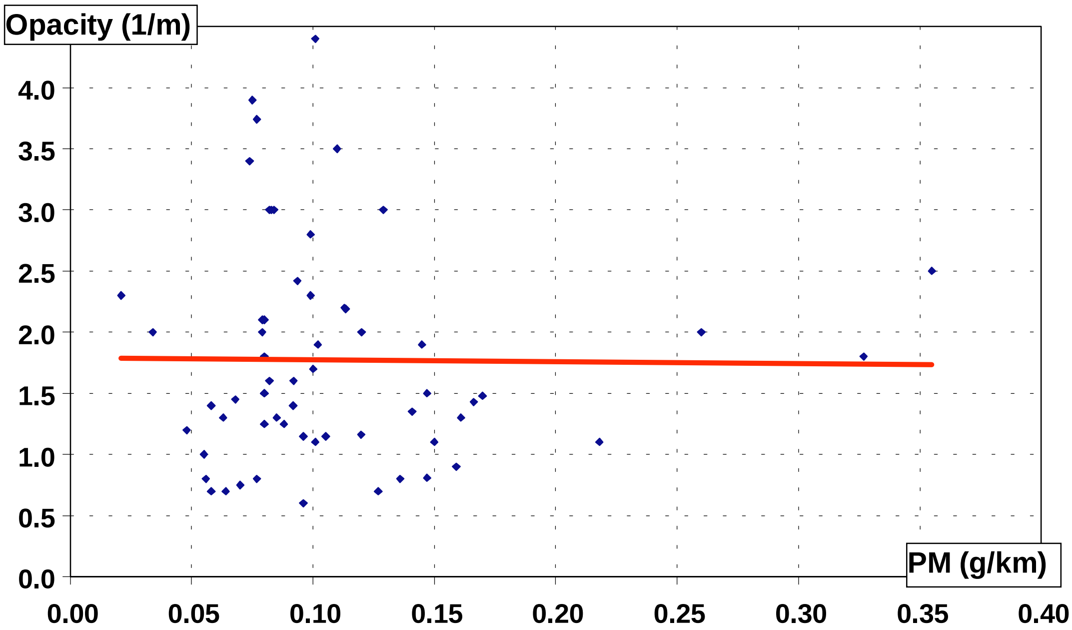


Figure 16: Diesel vehicles: FAS and PM correlation

7.3 Results

Even though the sample is quite small a demonstrative attempt to evaluate the short tests according to Section 4 has been carried out. The Autonat test has been excluded from the evaluation because it does not show any correlation to the NEDC cold cycle at all.

As stated in paragraph 7.1 the selected PM emission standard is 0.18 g/km, which seems to be sufficiently close to real emission results. Groups 5 and 6 are defined by a line 50% above the emission standard, i.e. 0.27 g/km. The cut-points are selected in such a way so that the very high polluters can be detected by all short tests. All vehicles are included in the evaluation because the random vehicle sample is too small to draw conclusions. Table 9 includes all the relevant calculations (VW bus has been excluded from the evaluation because the ERRPs become too high and therefore not representative of the diesel vehicle fleet).

Table 9: Diesel vehicles: evaluation of short tests

Short Test	Group	N	P	NEDC			Modem		
				E	EF	ERRP	E	EF	ERRP
ragaTUVA#2	1	18	86	1.661	0.092		2.333	0.130	
	2	1	5	0.162			0.260		
	4	0	0	0.000			0.000		
	6	1	5	0.443	0.443	14	0.725	0.725	17
	Cutpoint= 0.25 m^{-1} N= 21 78 % E= 2.56						E= 3.53		
ragaMS	1	19	86	1.753	0.092		2.508	0.132	
	2	1	5	0.162			0.260		
	4	0	0	0.000			0.000		
	6	1	5	0.443	0.443	13	0.725	0.725	16
	Cutpoint= 0.3 m^{-1} N= 22 81 % E= 2.65						E= 3.70		
FAS	1	17	77	1.584	0.093		2.250	0.132	
	2	3	14	0.341			0.604		
	4	0	0	0.000			0.000		
	6	1	5	0.443	0.443	13	0.725	0.725	16
	Cutpoint= 2.4 m^{-1} N= 22 81 % E= 2.66						E= 3.79		

7.4 Comments on the free acceleration smoke test

As Table 9 shows the free acceleration test seems capable of identifying the very high polluters, but the errors of commission are as expected significantly high, due to the dispersion of the measurements (very low correlation factor).

Since FAS is a transient test it may be better correlated to a more transient cycle than NEDC, which may represent the actual driving conditions better. Therefore FAS has been correlated to Modem “actual” cycle in Figure 17. This figure demonstrates that the correlation of FAS to Modem cycle is no better than to NEDC even though the latter is not so transient.

Since EUDC is a high load partial cycle and Modem urban free flow partial cycle (mUFF) is the most transient from all partial tests, they may exhibit a better correlation to FAS test. This correlation is demonstrated in Figure 18. In this figure the vehicles have been sorted in ascending order according to mUFF emissions. Surprisingly neither EUDC nor FAS seem to follow this increasing tendency. However, there is a general but not so clear increasing tendency accompanied by high dispersion. This remark leads to the conclusion that since FAS is a transient short test it is better correlated to actual driving conditions than to NEDC, but the high dispersion makes the test unreliable to judge the vehicle fleet.

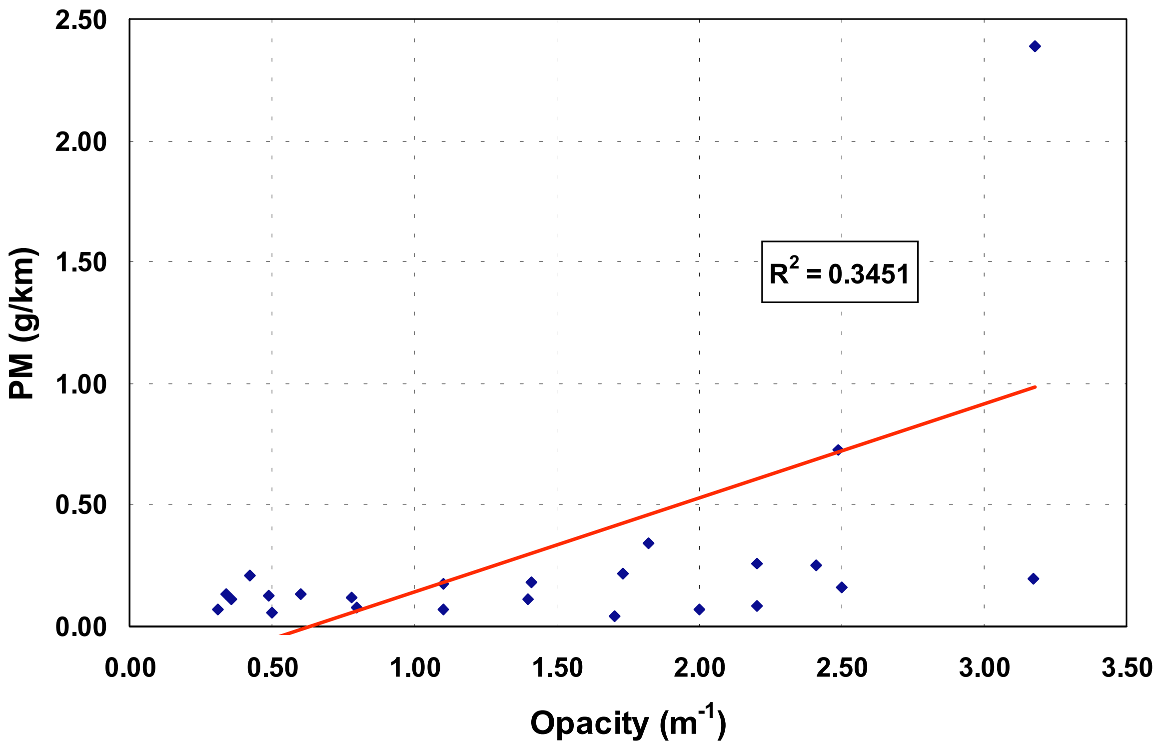


Figure 17: Diesel vehicles: FAS and Modem cycle correlation

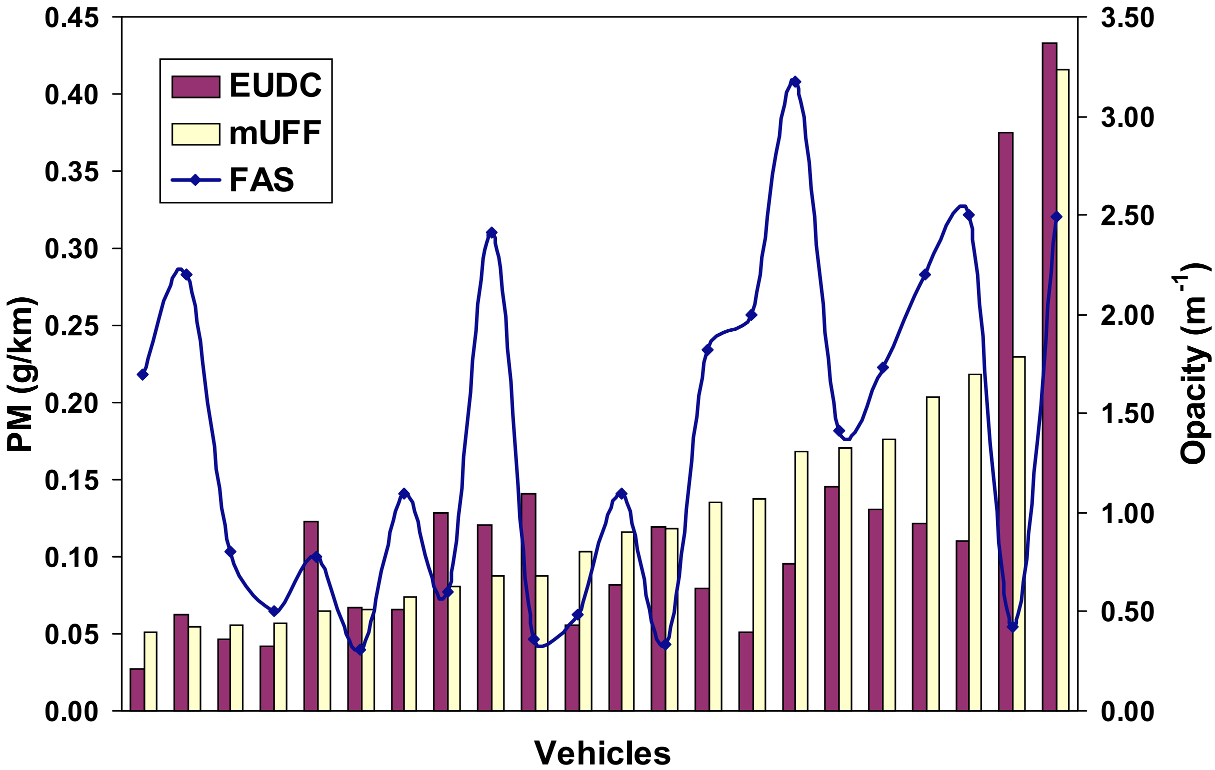


Figure 18: Diesel vehicles: FAS, EUDC and mUFF correlation

8. Sensitivity Analysis

8.1 3W catalyst equipped vehicles

The sensitivity analysis of the methodology that has been carried out concerns the internal cut-point optimization within each short test (paragraph 4.3) only for the random vehicle sample. To this effect results have been produced using all possible combinations of cut-points around the selected "optimum" cut-point. Table 10 shows the limits (maximum and minimum) between which the parameters ERRPi and ERRPiM vary for all possible combinations of cut-points between the values presented in the same table.

Table 10: Sensitivity analysis for the 3W-cat vehicles

		Cutpoints			ERRP - NEDC			ERRP - MODEM		
		CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
meTUV	max	2.66	0.40	0.67	21	9	20	16	18	23
	min	1.62	0.24	0.41	9	6	18	9	13	21
ralaTUV	max	0.40	1464	532	15	9	14	15	21	17
	min	0.24	891	324	10	8	9	10	14	9
ragaTUV	max	0.27	666		26	13	14	18	15	14
	min	0.16	405		12	7	10	12	11	9
meMS	max	3.99	0.53	0.80	21	9	20	17	19	24
	min	2.43	0.32	0.49	9	6	18	7	11	20
ralaMS	max	0.40	1331	666	25	11	14	21	24	18
	min	0.24	810	405	21	10	9	16	19	10
ragaMS	max	0.27	799		27	14	18	22	18	17
	min	0.16	486		25	12	13	18	16	13
Idle	max	0.27	1198		2	1	3	2	2	3
	min	0.16	729		0	0	0	0	0	0
H-Idle	max	0.27	799		6	3	4	6	7	5
	min	0.16	486		3	1	0	2	1	0
ga50-7	max	0.27	532		3	4	5	3	6	4
	min	0.16	324		1	1	1	1	2	1
la50-7	max	0.27	799	1065	4	5	15	3	8	15
	min	0.16	486	648	3	5	13	2	6	13

Comparing the results of Table 10 and those in Section 5 it is obvious that the already selected cut-points indeed give the "optimum" results. The small differences are attributed to the fact that the all maximum ERRPs may not be achieved with the same cut-points and if they do then the errors of commission by far exceed 5% of the tested vehicles. For instance by decreasing the CO cut-point from 0.2% to 0.15% in the short tests ragaTUV and ragaMS the ERRPs presented in Table 10 can be achieved, but the errors of commission make up 8% and 23% respectively of the tested vehicles.

8.2 Conventional and oxidation catalyst equipped vehicles

The same approach has been done for the conventional and oxidation catalyst equipped vehicles. The sensitivity analysis is presented in Table 11 for the total vehicle sample since the random is extremely small for such sensitivity analysis.

Table 11: Sensitivity analysis for the conventional and oxi-cat vehicles

		Cutpoints			ERRP - NEDC			ERRP - MODEM		
		CO	HC	NOx	CO	HC	NOx	CO	HC	NOx
meTUV	max	11.98	3.33	5.99	41	36	-5	33	25	-2
	min	7.29	2.03	3.65	31	20	-8	25	13	-5
ralaTUV	max	1.33	7321	5324	42	29	5	15	11	1
	min	0.81	3500	2500	28	15	-2	10	4	-3
ragaTUV	max	1.60	5324		46	30	-14	29	17	-11
	min	0.97	3240		41	23	-18	29	16	-13
meMS	max	13.98	5.99	6.66	47	44	-4	39	34	14
	min	8.51	3.50	4.05	37	25	-9	27	16	-4
ralaMS	max	1.60	7986	5324	45	34	15	23	19	17
	min	0.97	3500	2500	16	13	-2	7	4	-3
ragaMS	max	2.66	5324		44	24	-13	32	17	-12
	min	1.62	3240		38	21	-16	28	14	-13
Idle	max	2.66	5324		28	17	-1	19	10	0
	min	1.00	2500		14	11	-3	12	9	-3
H-Idle	max	2.66	5324		31	22	-4	19	12	-5
	min	1.00	2500		20	9	-6	14	5	-7
ga50-7	max	2.40	4659		31	22	-4	26	15	-3
	min	1.00	2835		17	8	-12	15	6	-9
la50-7	max	2.66	3993	7321	28	24	5	20	13	4
	min	1.00	2430	4455	4	2	0	6	3	0

The same remarks apply in this case too. For instance, lowering the cut-points of ralaMS short test the above ERRPs can be achieved, but the errors of commission become 19% of the tested vehicles.

8.3 Diesel vehicles

According to Section 7 an alternative approach has been done in the case of diesel vehicles; the cut-points have been selected in such way in order all short tests to detect the very high polluters and the percentage of the errors of commission has been investigated. Therefore, no sensitivity analysis has been implemented.

9. Directive 92/55/EEC

9.1 Methodology

In this section the methodology described in section 4 is applied to the current Directive 92/55/EEC as regards the 3W catalyst equipped vehicles. The partial tests included and the corresponding cut-points are shown in Table 12.

Table 12: Partial tests and cut-points of Directive 92/55/EEC

Partial tests	Cut-points	
	CO (%)	lambda
Idle	0.5	-
High idle	0.3	1 ± 0.03

As Table 12 shows, there are two cut-points for lambda therefore, the basic chart is somewhat different since there are two groups in the chart defined as groups 2, 4 and 6. This chart is presented in Figure 19.

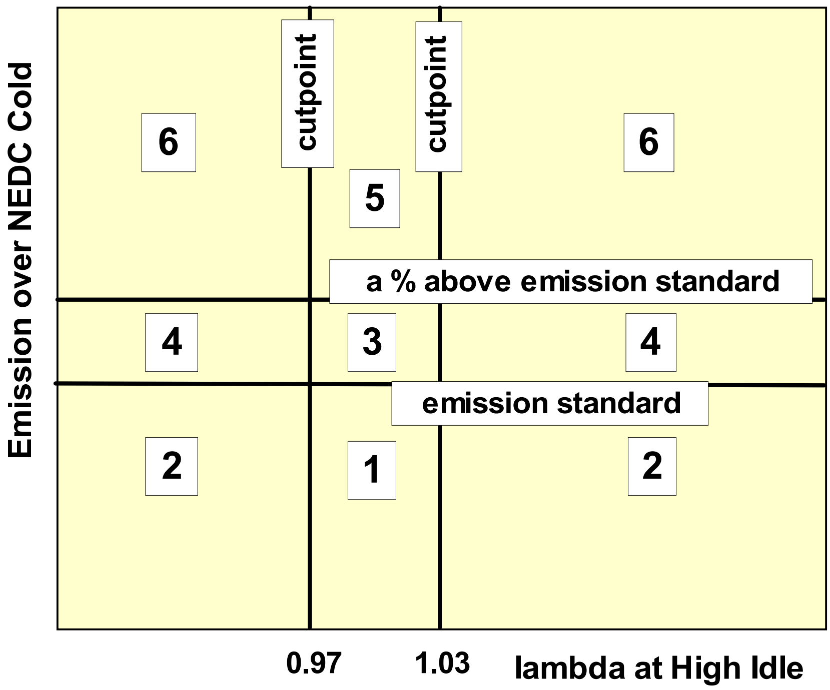


Figure 19: Lambda chart

Since there are 3 charts like the one of Figure 19, having CO, HC and NOx in the y axis respectively, the short test comprises of 5 charts in all. Therefore, a vehicle is considered as to be sent to maintenance when it belongs to group 6 in either of the following charts:

1. CO at idle - NEDC CO
2. CO at high idle - NEDC CO
3. Lambda at high idle - NEDC CO
4. Lambda at high idle - NEDC HC
5. Lambda at high idle - NEDC NOx

A vehicle is an error of commission when it belongs to group 2 in any of the above charts. Furthermore, it should not belong to any chart in group 6 (in that case it would be considered as a vehicle to be sent to maintenance).

Since the added value of each partial short test (CO at idle, CO at high idle and lambda at high idle) is the objective, the whole methodology has been adjusted in order to evaluate these added values (ERRPs, P6 and P2) of each partial short test on top of the previous one(s).

9.2 Vehicle sample

The vehicle sample and the initial conditions are the same as in the short test evaluation regarding the 3W catalyst equipped vehicles (Section 5).

Lambda has been calculated according to emission concentrations using simplified formulae. These formulae can be found in the Annex and vary from one laboratory to another.

9.3 Results

Results have been produced for both total and random vehicle sample. Figures 20-22 (a and b) show the parameters of the short test for both above cases.

It is also interesting to investigate the short test by splitting the basic charts into 4 groups (0% above standard) targeting to the high polluters. The results after following this approach are presented in Figures 23-25 (a and b). According to the definition of the errors of commission, following this approach, the errors or commission are bound to decrease and therefore, the short test will prove to be more effective.

All tables used in order to draw the following charts can be found in the Annex.

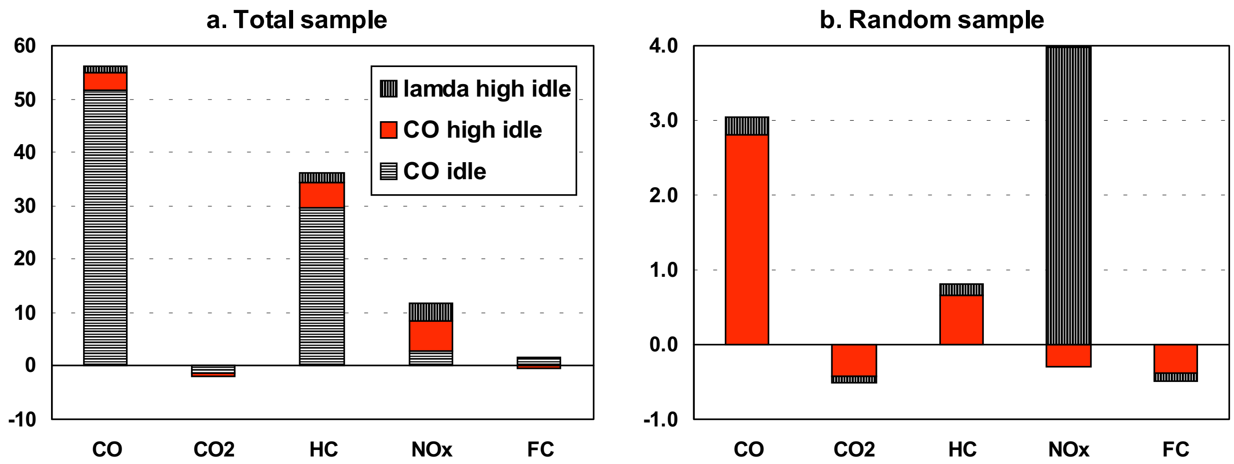


Figure 20: Directive 92/55/EEC: ERRPs according to NEDC (50% above std)

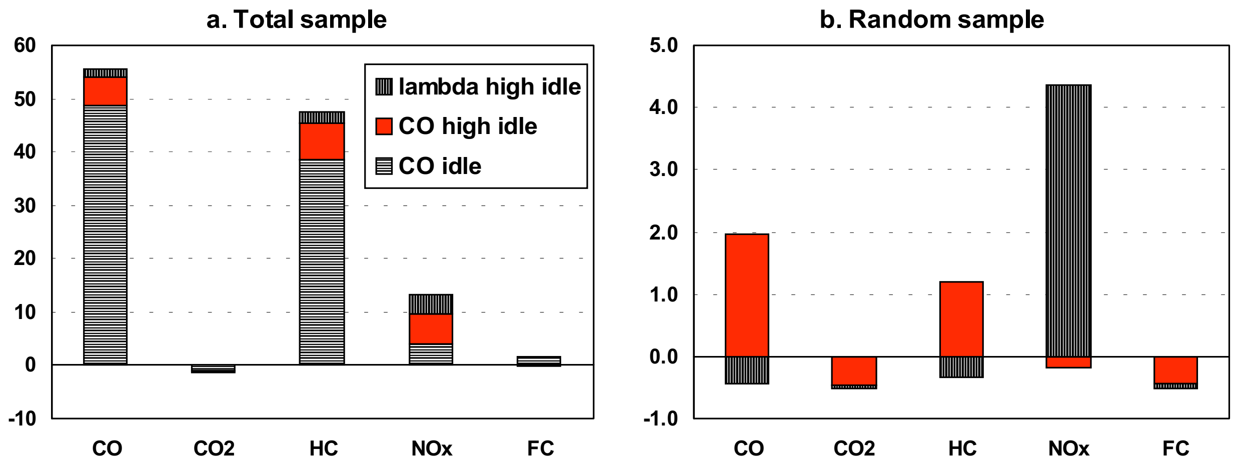


Figure 21: Directive 92/55/EEC: ERRPs according to Modem (50% above std)

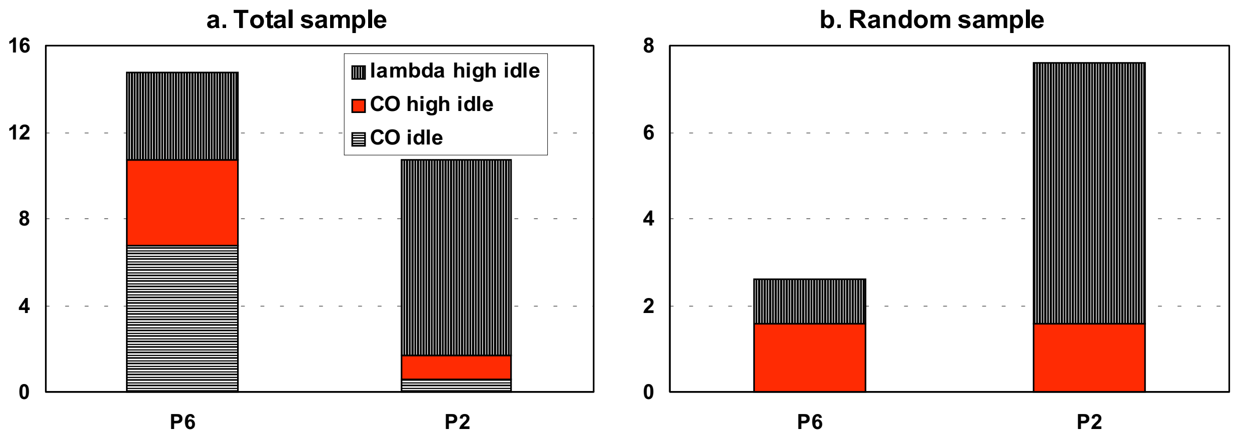


Figure 22: Directive 92/55/EEC: P6 and P2 (50% above std)

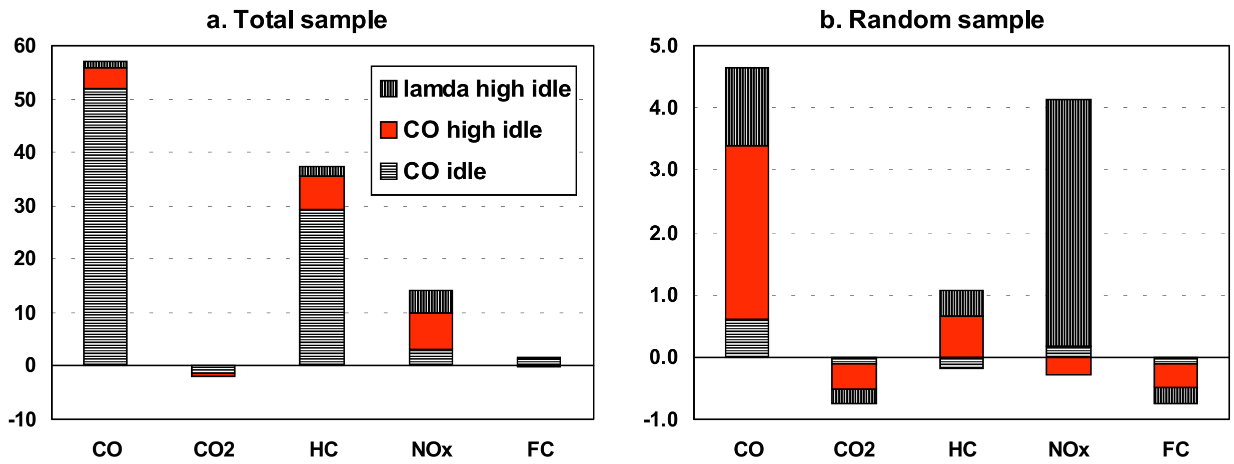


Figure 23: Directive 92/55/EEC: ERRPs according to NEDC (0% above std)

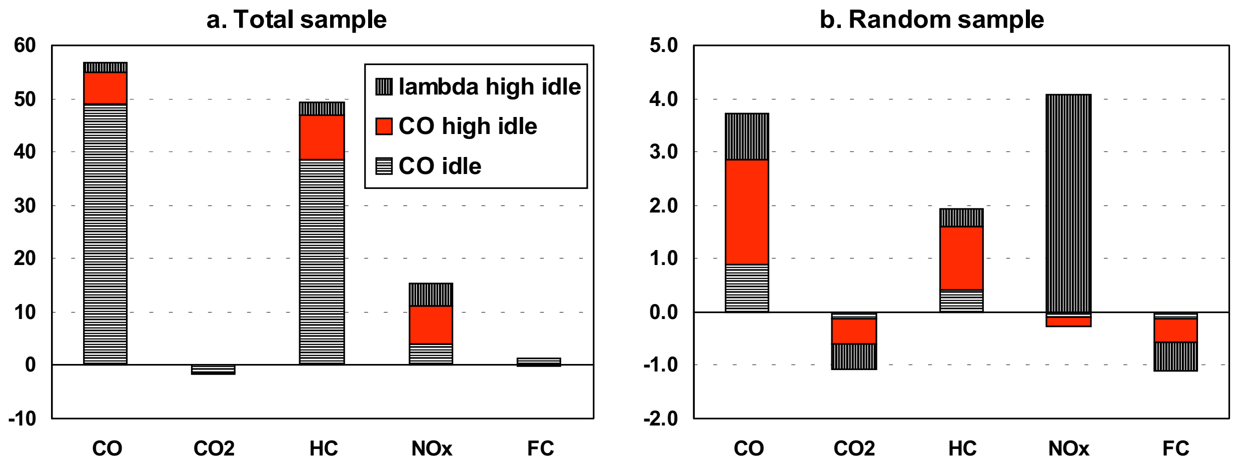


Figure 24: Directive 92/55/EEC: ERRPs according to Modem (0% above std)

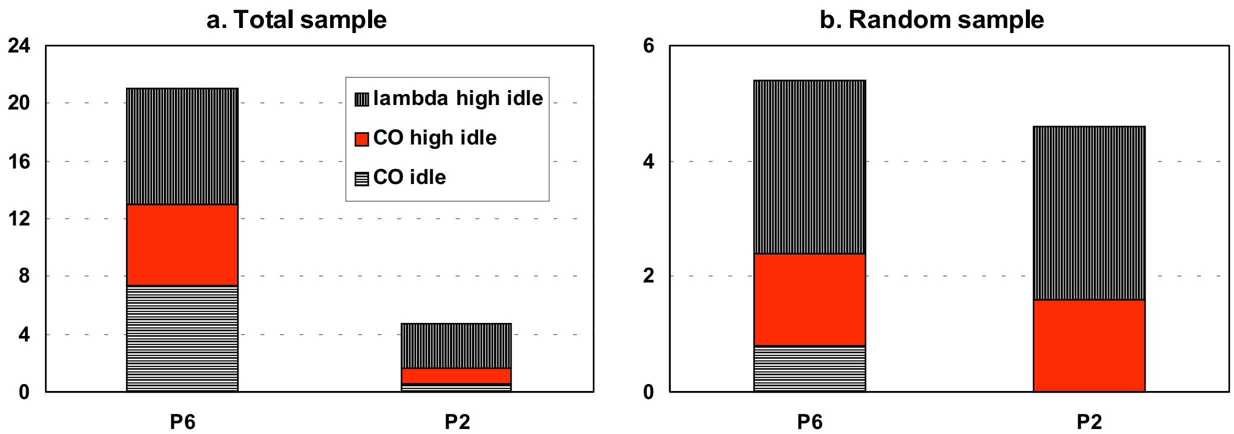


Figure 25: Directive 92/55/EEC: P6 and P2 (0% above std)

9.4 Discussion

According to the above figures the following remarks come up:

- The short test in question seems to be efficient enough when the vehicle sample comprises of many high polluters (total sample). However, this environmental benefit is accompanied by a relatively large number of errors of commission especially when only the very high polluters is the objective (50% above standard).
- When only the random vehicle sample is taken into account the environmental benefit becomes extremely small. This remark along with the fact that there are many errors of commission lead to the conclusion that this short test is completely uneffective when applied to 3W catalyst equipped vehicles, which is representative to the vehicle fleet.
- The first partial test measuring CO at idle seems to have no effect on the short test when only the randomly chosen vehicles are selected. It detects very few vehicles and as a result the environmental benefit is extremely small.
- Lambda measurement is, as expected, capable of detecting vehicles emitting high levels in NOx. However, it is the main responsible for the errors of commission. This is particularly obvious when targeting only to very high polluters (50% above standard) due to the definition of errors of commission (paragraph 8.1). When targeting to high polluters (0% above standard) it can be stated that even though lambda measurement adds approximately 3% errors of commission, it also contributes to environmental benefit (1% CO, 0.5% HC and 4.5% NOx) by detecting almost 3% of high polluters.

The validity of the above results and the fact that the randomly chosen vehicles are indeed representative of the vehicle fleet has been proved by comparing these results to those coming from RWTUEV[3]. According to it 3.47% of the vehicles have been detected as high emitters, while in the sample of this report the corresponding percentage is 8.73%. The difference is attributed to the fact that the former is an official inspection program and as a result the owners have their vehicles maintained before being tested, while the latter is only a laboratory research.

[3] AU-Pruefergebnisse von RWTUEV und TUEV Rheinland, 2. Jahreshaelfte 1996

10. Conclusions

10.1 3W catalyst equipped vehicles

- When the total sample is involved in the evaluation (high share of gross polluters in the fleet), idle tests have high ERRPs especially in CO and HC but as expected not in NOx. Steady state loaded tests generally perform the same as idle tests having however high ERRP in NOx as well. Transient tests are however more effective than all the other tests but the difference is not very large (Figures 3a, 4a)
- When only the random vehicle sample is taken into account (representative vehicles of the fleet) all steady state tests appear to be ineffective with the exception of la50-7 in NOx emissions. In this case transient tests are by far the most effective tests (Figures 3b, 4b).
- There seems to be a little difference between the two short transient tests. Therefore, in view of these negligible differences, it is suggested to refer only to a short transient test without specifically referring to either, by averaging the effectiveness of TUVA#2 and modem short (Figures 3 and 4).
- There is also not a large difference when estimating the environmental benefit according to NEDC or Modem cycles. Since Modem is an "actual" cycle simulating the real driving conditions, it is preferable to base the evaluation on this cycle (Figures 3 and 4)
- No vehicles have been found emitting high levels of HC only (i.e. being low emitters in CO and NOx) or both HC and NOx (i.e. being low emitters in CO). This means that those vehicles which are HC gross polluters emit high CO too and thus they may be captured via this pollutant (Figure 2).
- Most gross polluters and consequently the major part of emission reduction potentials are identified with the CO measurement. The added value of HC measurement is practically zero, while it adds to errors of commission. The added value of NOx measurement is concentrated almost exclusively in NOx emissions themselves: via NOx measurement 40% of the total NOx emission reduction potential is achieved. It adds about 5% in CO and HC emissions reduction potential. However, NOx measurement may add from 15 to 80% to total errors of commission (Figures from Annex).
- The effect of all types of short tests on fuel consumption and CO_2 emissions was found insignificant. It ranges from a small reduction to a small increase of the order of ± 2%, depending on the character of the sample (Figures 3 and 4).
- It is difficult to explain the result that garage analyzers perform better than laboratory ones in the case of raw average concentrations with transient tests when only randomly chosen vehicles are involved and emissions are based on NEDC. This may be related to the difference in the sample size and composition behind the two options since only some vehicles from LAT have been measured both with laboratory and garage analyzers (Table 3, Figure 3).
- On the basis of the test results of the random vehicle sample, the short test legislated by the 92/55/EEC was found to be completely ineffective. It can identify only 15% of the high

polluters, while the environmental benefit (ERRPs) from it does not exceed 4% reduction in any of the pollutants involved. Especially as regards the lambda test, it was found to add in the direction of NOx emitters identification, having the drawback of increasing the errors of commission. It is of importance to note that that there is virtually no improvement at all if to the current CO measurement at idle and high idle, HC measurement is added to these points (Figures 20b, 21b, 23b and 24b).

- However, the efficiency of this test clearly increases with increasing share of gross polluters in the fleet. This is demonstrated in the case of the total sample, where the 92/55/EEC test was found able to identify about 50% of the high polluters (Figures 20a, 21a, 23a and 24a).
- Of all the short tests used, the transient short cycles were found to have the greatest potential in terms of environmental benefit. They can identify practically all gross polluters (i.e. vehicles emitting more than 50% above the emission standards) and offer an emission reduction potential of the order of 15 to 20% for all pollutants CO, HC and NOx on the basis of the randomly selected car sample (Figures 3a and 4a).

10.2 Conventional and oxidation catalyst equipped vehicles

- In the case of these cars the idle test of 92/55/EEC was found to be very effective. However, the following improvements seem to be necessary: (a) reduce the CO cut-point from the current 3.5% to 1.5% and (b) introduce an additional HC cut-point of 3000 ppm C_1 i.e. 500 ppm hexane equivalent (Table 6, Figures 9b, 10b)
- Moreover, it was also found that adding a high idle test to the current low idle does not add in high emitter identification (Figures 9b, 10b).
- NOx emissions were found to decrease in the case of randomly chosen cars, while an increase was identified in the case of all vehicles, as in the latter case lambda was found to be in the rich area (Figures 9 and 10).
- An improvement of fuel consumption of the order 5% has been measured in all cases (Figures 9 and 10).
- The same remark regarding the garage analyzers in 3W-cat vehicles applies to this vehicle technology as well (Figure 9).

10.3 Diesel vehicles

- As expected the diesel cars were found to be high polluters only in the case of particulate emissions. CO, HC and NOx emissions were always found to be well below the emission standards (Figure 14).
- The continuous opacity measurement over the short transient cycles seems to be quite promising, as it provides a good correlation to NEDC (Figure 15a and 15b).
- The free acceleration test may be better correlated to transient cycles, but this is not very clear. The fact is that even though it may have a potential as regards the ERRP, it is related to a high number of errors of commission and as a result it is not reliable for detecting high polluters (Figure 18).

Nomenclature

mass emissions	bag related mass emissions
raw avg	average concentration of on-line raw exhaust concentrations
dil avg	average concentration of on-line diluted exhaust concentrations
lab	laboratory analysers
gar	garage analysers
meTUV	mass emissions in TUEVA#2
ralaTUV	raw average concentration with lab analysers in TUEVA#2
ragaTUV	raw average concentration with garage analysers in TUEVA#2
meMS	mass emissions in modem short
ralaMS	raw average concentration with lab analysers in modem short
ragaMS	raw average concentration with garage analysers in modem short
Idle	Idle
H-Idle	High idle
ga50-7	Steady state loaded (50 km/h, 7kW) with garage analysers
la50-7	Steady state loaded (50 km/h, 7kW) with lab analysers
FAS	Free acceleration smoke test
AUTONAT	Autonat test
i	pollutants and fuel consumption
j	groups of vehicles
Nj	number of vehicles in group j
Pj	percentage of vehicles tested with the particular short test that lay in group j
Eij	cumulative emissions of pollutant i by the vehicles in group j according to NEDC
EijM	cumulative emissions of pollutant i by the vehicles in group j according to Modem
PEij	percentage of total emissions by the vehicles in group 6 according to NEDC
PEijM	percentage of total emissions by the vehicles in group 6 according to Modem
EFij	average emission (emission factor) of pollutant i by the vehicles in group j according to NEDC
EFijM	average emission (emission factor)of pollutant i by the vehicles in group j according to Modem
ERPi	emission reduction potential of pollutant i according to NEDC
ERPiM	emission reduction potential of pollutant i according to Modem
ERRPi	emission reduction rate potential of pollutant i according to NEDC
ERRPiM	emission reduction rate potential of pollutant i according to Modem

List of Tables

List of Figures

Annex

The tables and figures in the Annex include detailed results for each short test and vehicle sample. Furthermore there are tables and figures from the current directive 92/55/EEC and the formulae used by each laboratory for the calculation of lambda.

The next table is a demonstrative one and presents the way the next tables have been completed.

Demonstrative table

Vehicles measured			**Low Polluters**		**Vehicles to be sent to maintenance**				
N **N/Ntot**			**N1** **N1/N**		**N6** **N6/N**				
		E	**E**	**EF**	**E**	**PE**	**EF**	**ERP**	**ERRP**
NEDC	**CO**	ECO	ECO1	ECO1/N1	ECO6	ECO6/ECO	ECO6/N6	(EFCO6-EFCO1)N6	ERPCO/ECO
	CO2	ECO2	ECO21	ECO21/N1	ECO26	ECO26/ECO2	ECO26/N6	(EFCO26-EFCO21)N6	ERPCO2/ECO2
	HC	EHC	EHC1	EHC1/N1	EHC6	EHC6EHC	EHC6/N6	(EFHC6-EFHC1)N6	ERPHC/EHC
	NOx	ENOx	ENOx1	ENOx1/N1	ENOx6	ENOx6/ENOx	ENOx6/N6	(EFNOx6-EFNOx1)N6	ERPNOx/ENOx
	FC	FC	FC1	FC1/N1	FC6	FC6/FC	FC6/N6	(FCF6-FCF1)N6	RPFC/FC
MODEM	**CO**	ECOM	ECO1M	ECO1M/N1	ECO6M	ECO6M/ECOM	ECO6M/N6	(EFCO6M-EFCO1M)N6	ERPCOM/ECOM
	CO2	ECO2M	ECO21M	ECO21M/N1	ECO26M	ECO26M/ECO2M	ECO26M/N6	(EFCO26M-EFCO21M)N6	ERPCO2M/ECO2M
	HC	EHCM	EHC1M	EHC1M/N1	EHC6M	EHC6M/EHCM	EHC6M/N6	(EFHC6M-EFHC1M)N6	ERPHCM/EHCM
	NOx	ENOx	ENOx1M	ENOx1M/N1	ENOx6M	ENOx6M/ENOxM	ENOx6M/N6	(EFNOx6M-EFNOx1M)N6	ERPNOxM/ENOxM
	FC	FCM	FC1M	FC1M/N1	FC6M	FC6M/FCM	FC6M/N6	(FCF6M-FCF1M)N6	RPFCM/FCM
Vehicles detected		**N2+N4+N6**	**(N2+N4+N6)/N**		**Errors of commission**				
Vehicles with low benefit		**N4**	**N4/N**			**N2**	**N2/N**		

In the following figures the three digits in the legend texts (two in the case of garage analyzers) refer to each pollutant CO, HC and NOx (CO and HC for garage analyzers) respectively. 1 means that the particular pollutant is responsible and 0 that it is not. For instance 011 means that despite CO both HC and NOx are responsible.

Short Tests

3W Catalyst Equipped Vehicles

Short test: meTUV

Total sample

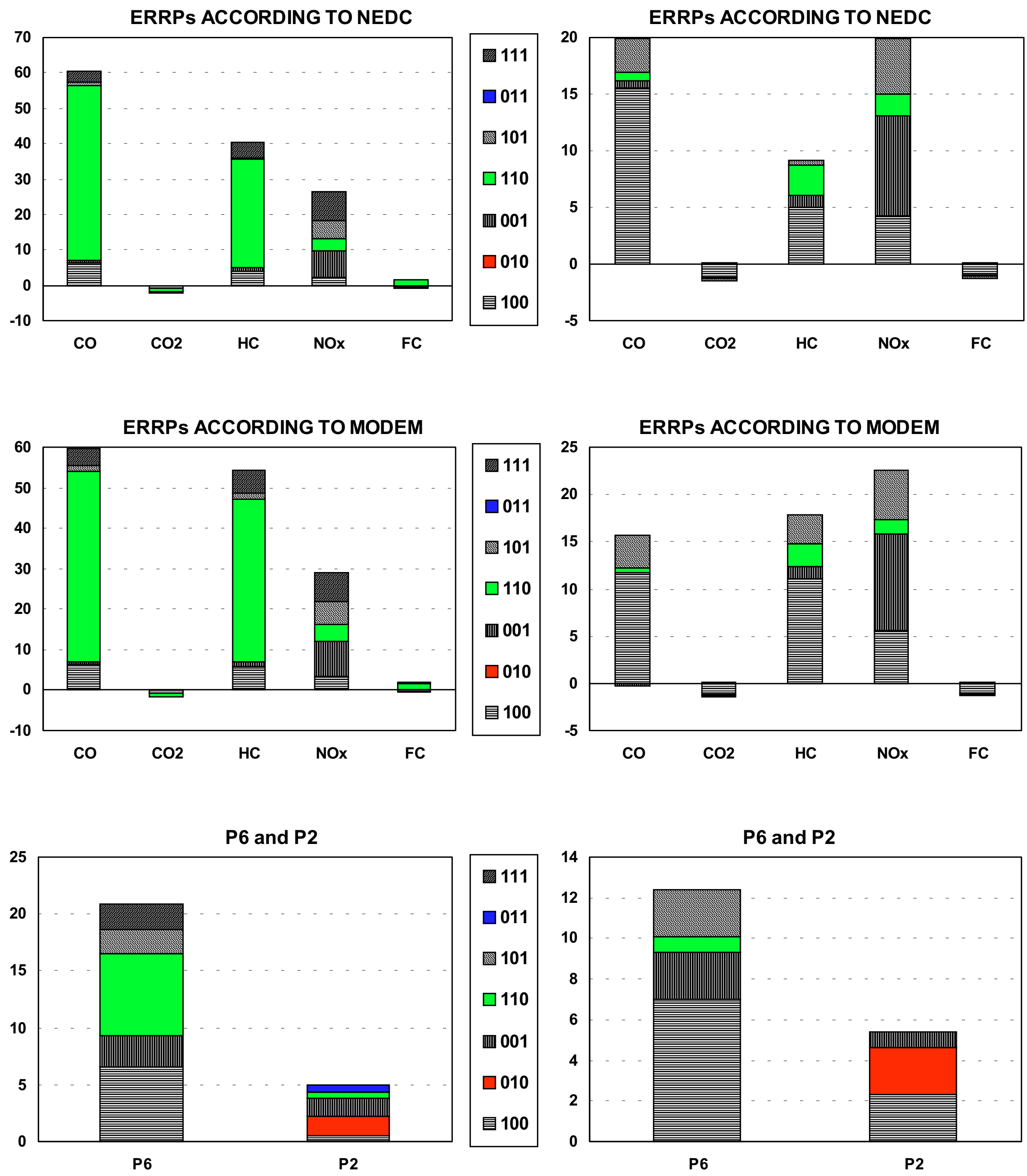
Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 182 97 %			N= 85 47 %		N= 38 21 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	1246	158	1.85	823	66.03	21.65	752	60
	CO2	35602	17170	202.00	6870	19.30	180.78	-806	-2
	HC	88	21	0.25	45	51.02	1.18	35	40
	NOx	74	20	0.24	28	38.39	0.75	19	26
	FC	12226	5644	66.40	2634	21.54	69.31	111	1
MODEM	CO	1236	168	1.97	814	65.89	21.43	739	60
	CO2	36243	17447	205.26	7189	19.83	189.17	-611	-2
	HC	60	10	0.12	37	61.74	0.97	33	54
	NOx	105	26	0.31	42	40.23	1.11	30	29
	FC	12404	5736	67.48	2722	21.94	71.63	158	1
Vehicles detected		63	35 %		Errors of commission				
Vehicles with low benefit		16	9 %		N= 9		5 %		

Random sample

Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 129 97 %			N= 70 54 %		N= 16 12 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	402	124	1.78	108	26.96	6.78	80	20
	CO2	25644	14290	204.14	2907	11.33	181.66	-360	-1
	HC	39	17	0.24	7	19.19	0.47	4	9
	NOx	47	16	0.23	13	27.67	0.82	9	20
	FC	8579	4717	67.39	976	11.38	61.00	-102	-1
MODEM	CO	378	121	1.73	86	22.71	5.37	58	15
	CO2	25822	14452	206.46	2976	11.53	186.00	-327	-1
	HC	21	7	0.10	5	25.40	0.34	4	18
	NOx	66	20	0.28	19	29.43	1.21	15	23
	FC	8615	4768	68.11	985	11.43	61.55	-105	-1
Vehicles detected		35	27 %		Errors of commission				
Vehicles with low benefit		12	9 %		N= 7		5 %		

3W Catalyst Equipped Vehicles

Short test: meTUV



Short test parameters (left: total sample, right: random sample)

3W Catalyst Equipped Vehicles

Short test: ralaTUV

Total sample

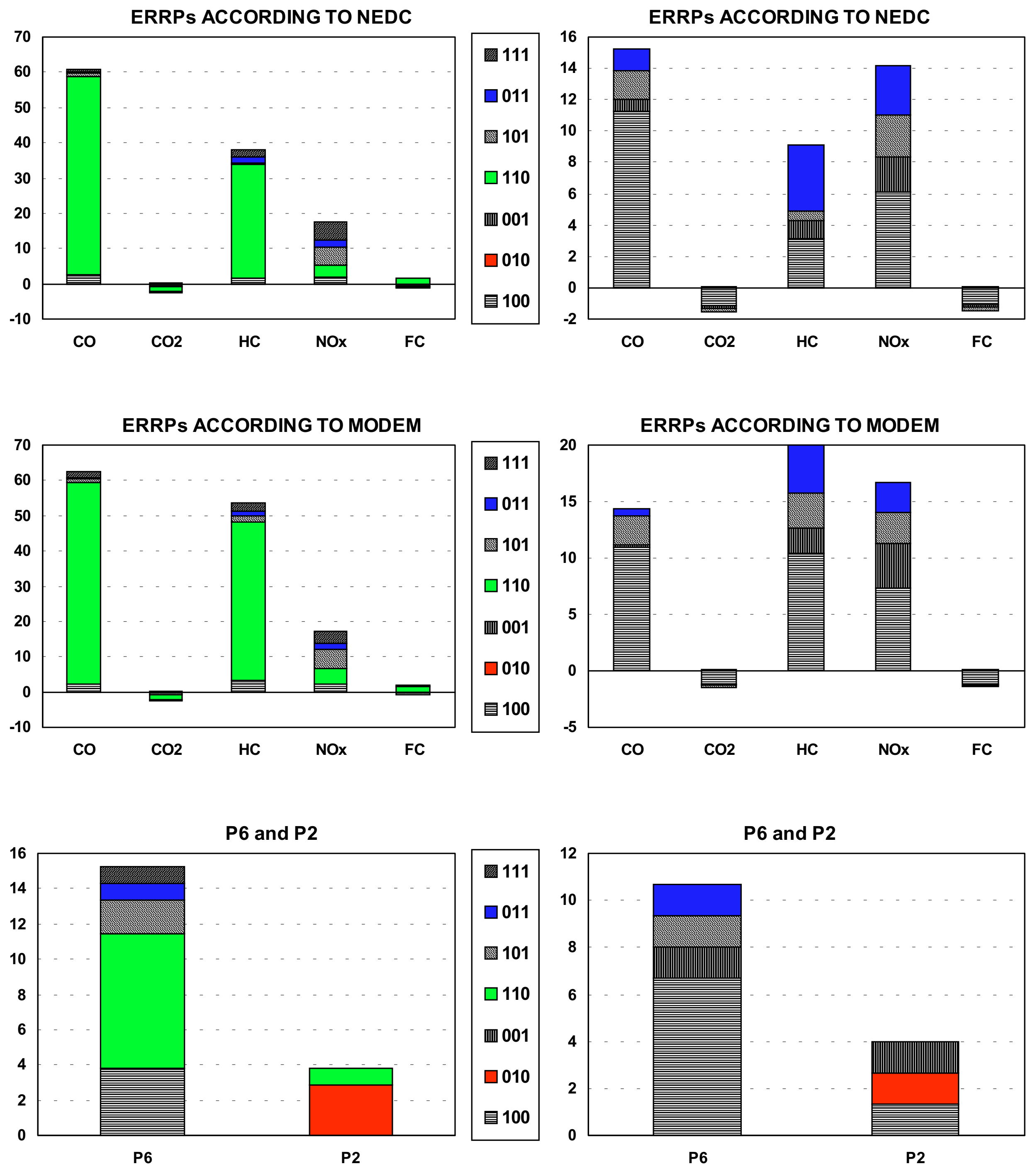
Vehicles measured			Low Polluters		Vehicles be sent to maintenance				
N= 105 56 %			N= 51 49 %		N= 16 15 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	733	94	1.84	474	64.73	29.65	445	61
	CO2	21800	11048	216.63	2933	13.45	183.30	-533	-2
	HC	54	14	0.27	25	45.97	1.56	21	38
	NOx	44	13	0.26	12	26.98	0.75	8	18
	FC	7497	3654	71.64	1184	15.79	74.00	38	1
MODEM	CO	798	100	1.96	529	66.33	33.07	498	62
	CO2	22260	11269	220.96	3019	13.56	188.70	-516	-2
	HC	38	6	0.11	22	58.37	1.39	20	54
	NOx	61	16	0.32	16	25.68	0.97	10	17
	FC	7665	3728	73.10	1235	16.12	77.22	66	1
Vehicles detected		26	25 %		Errors of commission				
Vehicles with low benefit		6	6 %		N= 4		4 %		

Random sample

Vehicles measured			Low Polluters		Vehicles be sent to maintenance				
N= 75 56 %			N= 45 60 %		N= 8 11 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	217	78	1.74	47	21.68	5.89	33	15
	CO2	15960	9808	217.96	1514	9.49	189.25	-230	-1
	HC	24	12	0.26	4	17.88	0.53	2	9
	NOx	28	11	0.25	6	21.43	0.74	4	14
	FC	5343	3254	72.30	504	9.43	62.99	-75	-1
MODEM	CO	215	81	1.80	45	21.11	5.67	31	14
	CO2	16203	9975	221.68	1558	9.62	194.80	-215	-1
	HC	13	5	0.10	3	26.60	0.42	3	20
	NOx	38	13	0.30	9	22.89	1.09	6	17
	FC	5415	3310	73.56	516	9.54	64.54	-72	-1
Vehicles detected		14	19 %		Errors of commission				
Vehicles with low benefit		3	4 %		N= 3		4 %		

3W Catalyst Equipped Vehicles

Short test: ralaTUV



Short test parameters (left: total sample, right: random sample)

3W Catalyst Equipped Vehicles

Short test: ragaTUV

Total sample

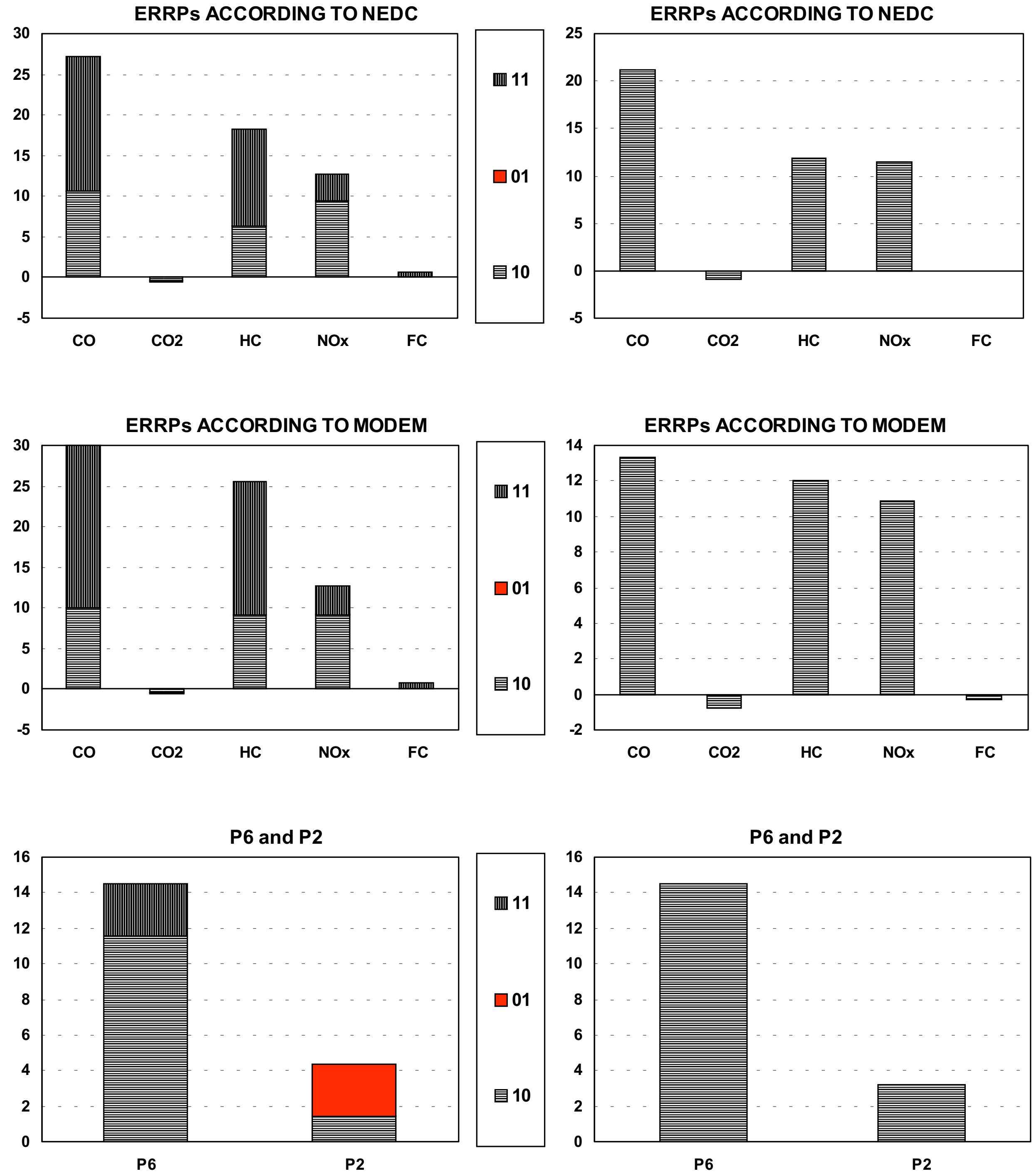
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 69 37 %			N= 28 41 %		N= 10 14 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	334	58	2.09	112	33.39	11.15	91	27
	CO2	12022	4796	171.27	1642	13.66	164.20	-71	-1
	HC	24	6	0.23	7	27.62	0.66	4	18
	NOx	26	6	0.21	5	20.75	0.54	3	13
	FC	3975	1544	55.16	579	14.58	57.94	28	1
MODEM	CO	330	66	2.35	123	37.12	12.26	99	30
	CO2	11969	4807	171.69	1659	13.86	165.90	-58	0
	HC	18	4	0.15	6	33.98	0.62	5	26
	NOx	38	9	0.34	8	21.45	0.83	5	13
	FC	3959	1559	55.67	590	14.89	58.96	33	1
Vehicles detected		16	23 %		Errors of commission				
Vehicles with low benefit		3	4 %		N= 3		4 %		

Random sample

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 62 47 %			N= 25 40 %		N= 9 15 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	257	51	2.05	73	28.41	8.11	55	21
	CO2	10883	4329	173.17	1464	13.45	162.64	-95	-1
	HC	19	5	0.21	4	21.95	0.47	2	12
	NOx	23	5	0.20	4	19.20	0.49	3	12
	FC	3573	1393	55.73	501	14.03	55.72	0	0
MODEM	CO	234	59	2.36	52	22.40	5.83	31	13
	CO2	10785	4323	172.92	1475	13.67	163.86	-82	-1
	HC	13	4	0.15	3	22.19	0.33	2	12
	NOx	33	7	0.30	6	18.93	0.70	4	11
	FC	3534	1402	56.09	494	13.97	54.85	-11	0
Vehicles detected		15	24 %		Errors of commission				
Vehicles with low benefit		4	6 %		N= 2		3 %		

3W Catalyst Equipped Vehicles

Short test: ragaTUV



Short test parameters (left: total sample, right: random sample)

3W Catalyst Equipped Vehicles

Short test: meMS

Total sample

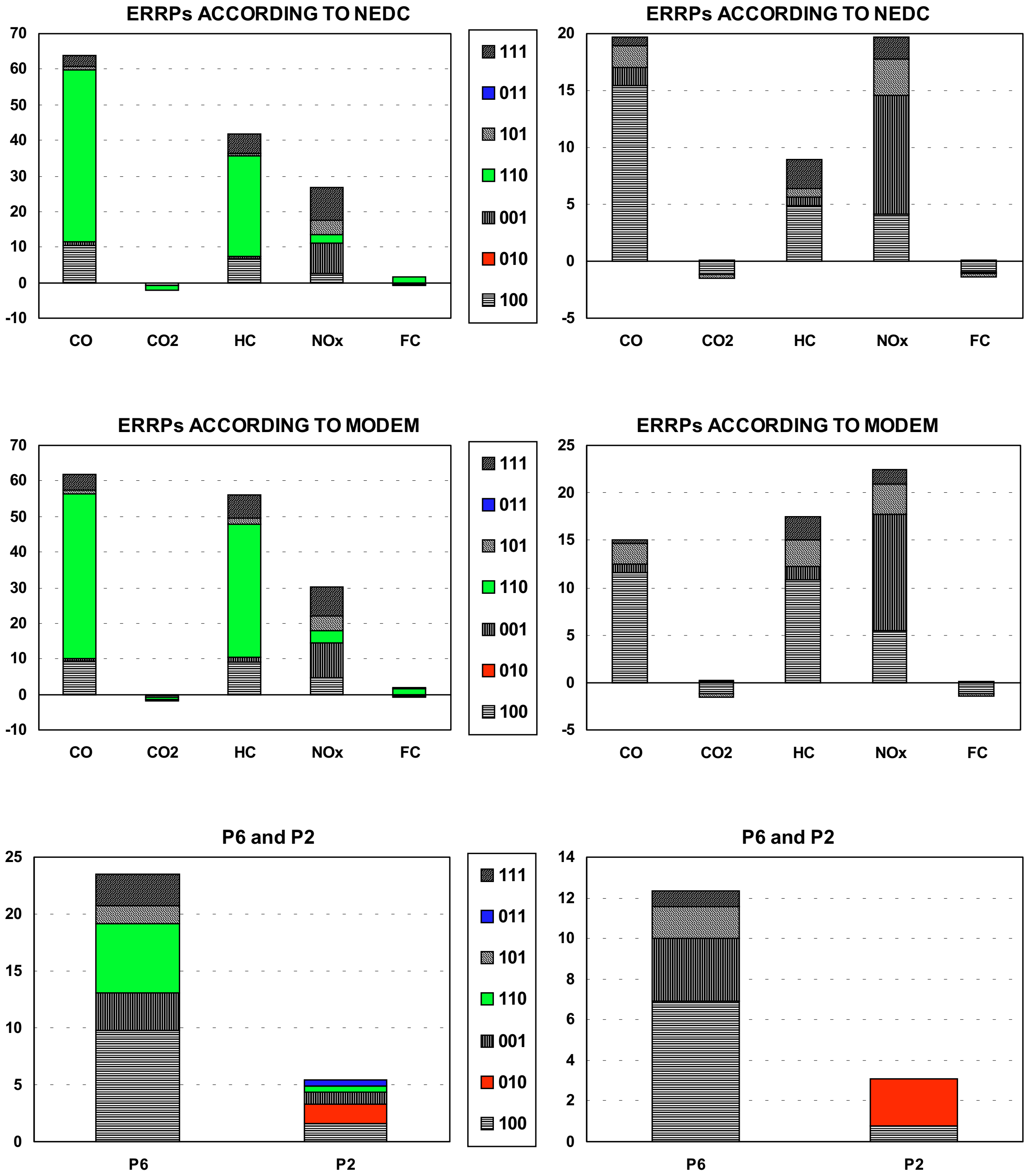
Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 183 97 %			N= 80 44 %		N= 43 23 %				
		E	**E**	**EF**	**E**	**PE**	**EF**	**ERP**	**ERRP**
NEDC	**CO**	1250	146	1.82	877	70.15	20.40	799	64
	CO2	35805	16106	201.32	7820	21.84	181.86	-837	-2
	HC	88	20	0.25	48	53.85	1.11	37	42
	NOx	74	19	0.23	30	40.26	0.70	20	27
	FC	12293	5331	66.64	2963	24.10	68.90	97	1
MODEM	**CO**	1238	151	1.89	848	68.52	19.73	767	62
	CO2	36449	16350	204.37	8163	22.40	189.84	-625	-2
	HC	60	9	0.11	38	64.01	0.89	34	56
	NOx	105	24	0.30	45	42.55	1.04	32	30
	FC	12471	5412	67.65	3047	24.44	70.87	139	1
Vehicles detected		**70**	**38 %**		**Errors of commission**				
Vehicles with low benefit		**17**	**9 %**		**N= 10**		**5 %**		

Random sample

Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 130 98 %			N= 71 55 %		N= 16 12 %				
		E	**E**	**EF**	**E**	**PE**	**EF**	**ERP**	**ERRP**
NEDC	**CO**	406	126	1.78	108	26.68	6.78	80	20
	CO2	25847	14483	203.98	2907	11.25	181.66	-357	-1
	HC	39	18	0.25	7	19.00	0.47	3	9
	NOx	48	17	0.24	13	27.60	0.82	9	20
	FC	8646	4809	67.73	976	11.29	61.00	-108	-1
MODEM	**CO**	380	127	1.79	86	22.58	5.37	57	15
	CO2	26029	14661	206.50	2976	11.43	186.00	-328	-1
	HC	22	7	0.10	5	25.17	0.34	4	17
	NOx	66	20	0.28	19	29.40	1.21	15	22
	FC	8681	4867	68.55	985	11.34	61.55	-112	-1
Vehicles detected		**33**	**25 %**		**Errors of commission**				
Vehicles with low benefit		**13**	**10 %**		**N= 4**		**3 %**		

3W Catalyst Equipped Vehicles

Short test: meMS



Short test parameters (left: total sample, right: random sample)

3W Catalyst Equipped Vehicles

Short test: ralaMS

Total sample

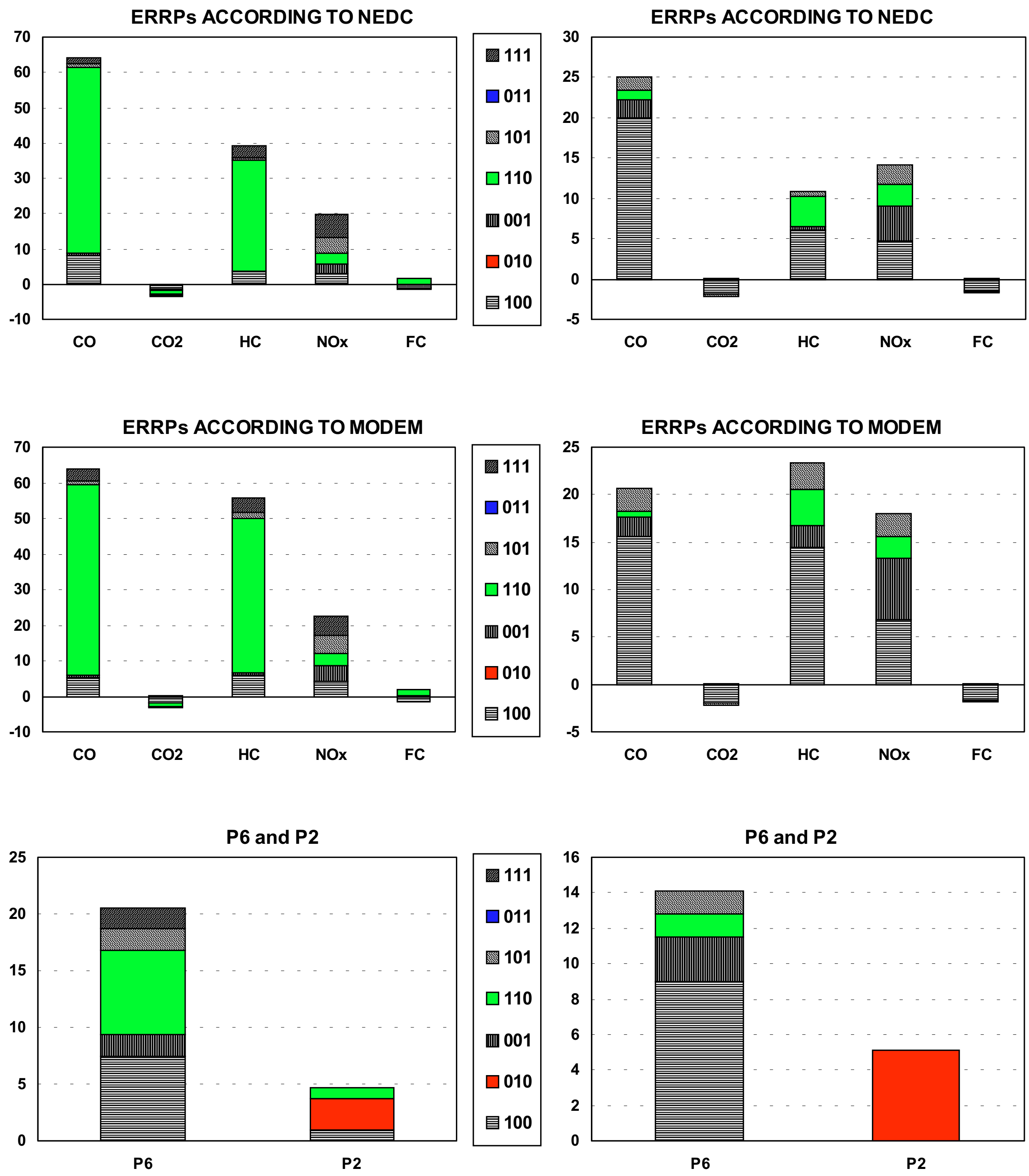
Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 107 57 %			N= 43 40 %		N= 22 21 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	768	77	1.80	532	69.25	24.18	492	64
	CO2	22172	9509	221.13	4105	18.52	186.60	-760	-3
	HC	56	12	0.28	28	50.12	1.27	22	39
	NOx	48	12	0.27	15	32.12	0.70	9	20
	FC	7531	3102	72.15	1585	21.04	72.03	-3	0
MODEM	CO	832	77	1.78	570	68.48	25.90	531	64
	CO2	22663	9744	226.61	4233	18.68	192.39	-753	-3
	HC	39	4	0.10	24	61.75	1.10	22	56
	NOx	66	14	0.32	22	33.35	1.00	15	23
	FC	7701	3168	73.68	1640	21.29	74.53	19	0
Vehicles detected		39	36 %		Errors of commission				
Vehicles with low benefit		12	11 %		N= 5		5 %		

Random sample

Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 78 59 %			N= 40 51 %		N= 11 14 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	252	69	1.74	82	32.64	7.49	63	25
	CO2	16355	8779	219.49	2083	12.74	189.38	-331	-2
	HC	26	11	0.28	6	22.59	0.53	3	11
	NOx	31	11	0.27	7	23.58	0.67	4	14
	FC	5385	2868	71.69	702	13.04	63.85	-86	-2
MODEM	CO	241	67	1.67	68	28.27	6.20	50	21
	CO2	16659	8985	224.62	2133	12.80	193.89	-338	-2
	HC	14	4	0.10	4	31.18	0.39	3	23
	NOx	44	12	0.31	11	25.82	1.03	8	18
	FC	5464	2923	73.09	710	12.99	64.52	-94	-2
Vehicles detected		19	24 %		Errors of commission				
Vehicles with low benefit		4	5 %		N= 4		5 %		

3W Catalyst Equipped Vehicles

Short test: ralaMS



Short test parameters (left: total sample, right: random sample)

3W Catalyst Equipped Vehicles

Short test: ragaMS

Total sample

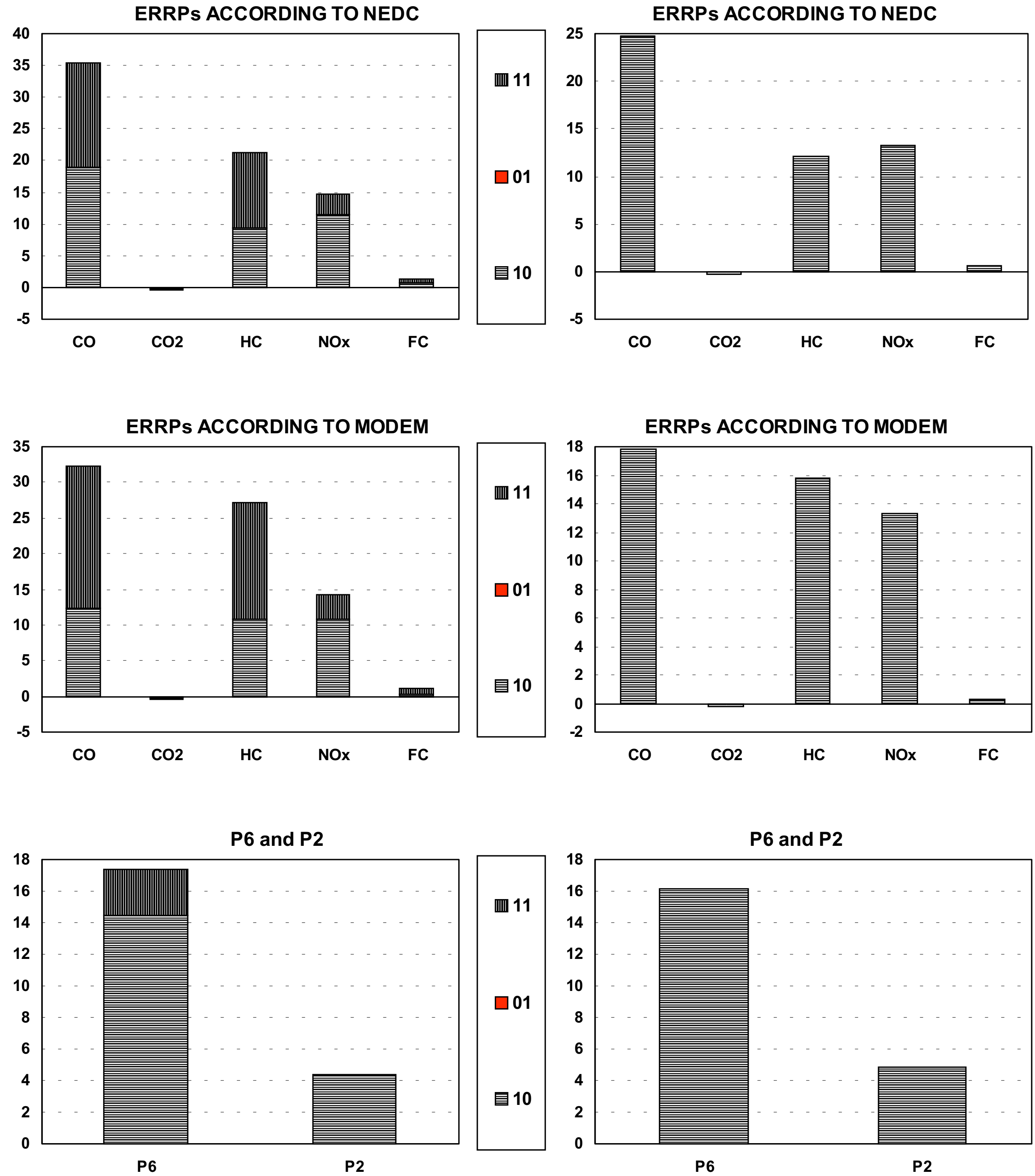
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 69 37 %			N= 27 39 %		N= 12 17 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	334	56	2.09	143	42.93	11.95	118	35
	CO2	12022	4613	170.86	2006	16.69	167.16	-44	0
	HC	24	6	0.23	8	32.62	0.65	5	21
	NOx	26	6	0.21	6	24.42	0.53	4	15
	FC	3975	1486	55.03	711	17.89	59.24	51	1
MODEM	CO	330	65	2.42	136	41.03	11.29	107	32
	CO2	11969	4628	171.42	2016	16.84	167.98	-41	0
	HC	18	4	0.16	7	37.81	0.58	5	27
	NOx	38	9	0.33	10	24.71	0.79	6	14
	FC	3959	1502	55.63	709	17.91	59.10	42	1
Vehicles detected		20	29 %		Errors of commission				
Vehicles with low benefit		5	7 %		N= 3		4 %		

Random sample

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 62 47 %			N= 24 39 %		N= 10 16 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	257	49	2.04	84	32.73	8.41	64	25
	CO2	10883	4122	171.75	1682	15.46	168.25	-35	0
	HC	19	5	0.22	5	23.64	0.45	2	12
	NOx	23	5	0.20	5	22.12	0.51	3	13
	FC	3573	1327	55.28	576	16.13	57.63	24	1
MODEM	CO	234	55	2.30	65	27.64	6.48	42	18
	CO2	10785	4115	171.47	1689	15.66	168.93	-25	0
	HC	13	4	0.15	4	26.79	0.36	2	16
	NOx	33	7	0.30	7	22.51	0.75	4	13
	FC	3534	1335	55.61	568	16.08	56.81	12	0
Vehicles detected		18	29 %		Errors of commission				
Vehicles with low benefit		5	8 %		N= 3		5 %		

3W Catalyst Equipped Vehicles

Short test: ragaMS



Short test parameters (left: total sample, right: random sample)

3W Catalyst Equipped Vehicles

Short test: Idle

Total sample

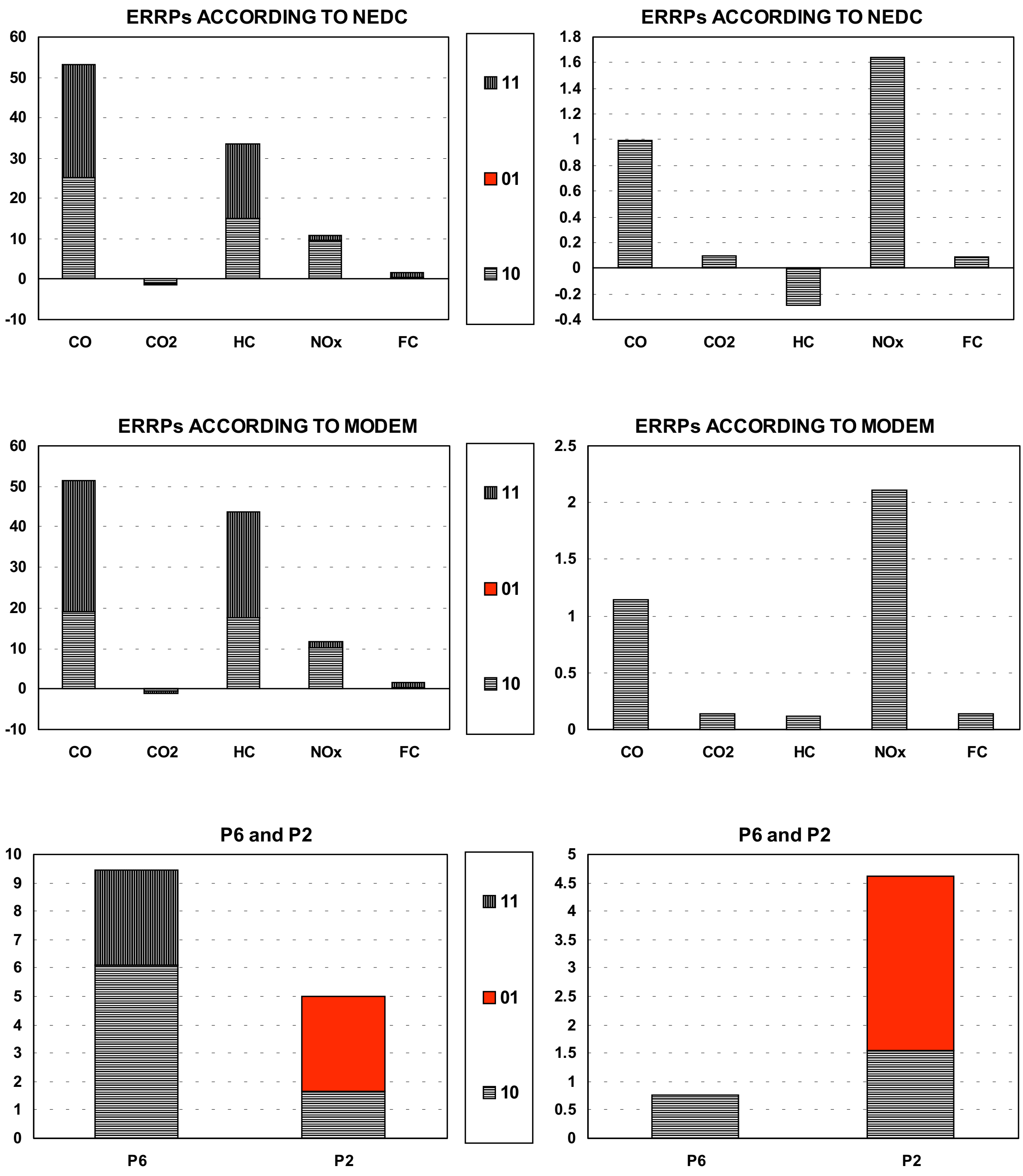
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 180 96 %			N= 82 46 %		N= 17 9 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	1229	150	1.82	684	55.63	40.23	653	53
	CO2	35249	16716	203.86	2983	8.46	175.48	-483	-1
	HC	87	21	0.25	33	38.36	1.96	29	33
	NOx	73	20	0.24	12	16.53	0.71	8	11
	FC	12102	5498	67.05	1326	10.96	78.01	186	2
MODEM	CO	1224	157	1.91	661	53.97	38.87	628	51
	CO2	35890	16966	206.90	3165	8.82	186.15	-353	-1
	HC	59	9	0.11	28	46.81	1.63	26	44
	NOx	103	24	0.30	17	16.46	0.99	12	12
	FC	12284	5580	68.05	1366	11.12	80.35	209	2
Vehicles detected		27	15 %		Errors of commission				
Vehicles with low benefit		1	1 %		N= 9		5 %		

Random sample

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 130 98 %			N= 72 55 %		N= 1 1 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	405	129	1.79	6	1.44	5.83	4	1
	CO2	25797	14734	204.63	228	0.89	228.33	24	0
	HC	39	18	0.25	0	0.36	0.14	0	0
	NOx	48	17	0.24	1	2.15	1.02	1	2
	FC	8629	4861	67.52	75	0.87	75.01	7	0
MODEM	CO	382	132	1.84	6	1.62	6.20	4	1
	CO2	25993	14934	207.42	243	0.94	243.15	36	0
	HC	21	8	0.11	0	0.61	0.13	0	0
	NOx	66	21	0.29	2	2.55	1.67	1	2
	FC	8671	4919	68.32	80	0.92	79.85	12	0
Vehicles detected		8	6 %		Errors of commission				
Vehicles with low benefit		1	1 %		N= 6		5 %		

3W Catalyst Equipped Vehicles

Short test: Idle



Short test parameters (left: total sample, right: random sample)

3W Catalyst Equipped Vehicles

Short test: H-Idle

Total sample

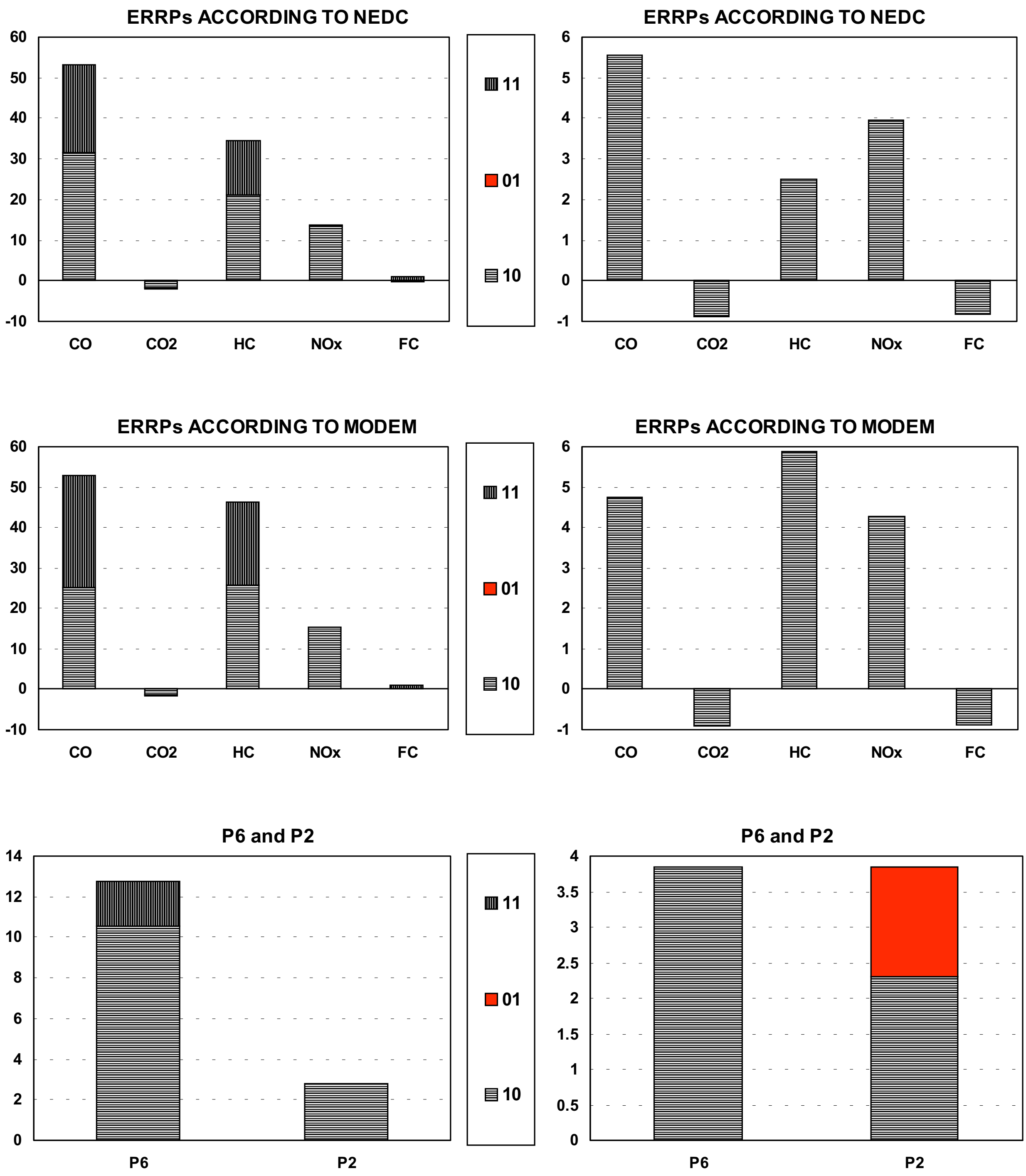
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 180			N= 82		N= 23				
96 %			46 %		13 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	1229	149	1.81	695	56.57	30.24	654	53
	CO2	35249	16637	202.90	3951	11.21	171.78	-716	-2
	HC	87	20	0.25	36	40.97	1.55	30	34
	NOx	73	20	0.25	16	21.38	0.68	10	14
	FC	12102	5501	67.09	1639	13.54	71.26	96	1
MODEM	CO	1224	160	1.95	693	56.58	30.11	648	53
	CO2	35890	16898	206.08	4168	11.61	181.20	-572	-2
	HC	59	10	0.12	30	50.82	1.31	27	46
	NOx	103	25	0.31	23	22.06	0.99	16	15
	FC	12284	5581	68.06	1700	13.84	73.92	135	1
Vehicles detected		33	18 %		Errors of commission				
Vehicles with low benefit		5	3 %		N= 5		3 %		

Random sample

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 130			N= 72		N= 5				
98 %			55 %		4 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	405	128	1.78	31	7.75	6.28	23	6
	CO2	25797	14723	204.48	794	3.08	158.73	-229	-1
	HC	39	18	0.25	2	5.71	0.45	1	2
	NOx	48	17	0.24	3	6.48	0.62	2	4
	FC	8629	4886	67.86	268	3.10	53.55	-72	-1
MODEM	CO	382	131	1.82	27	7.13	5.45	18	5
	CO2	25993	14919	207.21	798	3.07	159.59	-238	-1
	HC	21	8	0.11	2	8.43	0.36	1	6
	NOx	66	21	0.29	4	6.47	0.85	3	4
	FC	8671	4943	68.65	267	3.08	53.34	-77	-1
Vehicles detected		12	9 %		Errors of commission				
Vehicles with low benefit		2	2 %		N= 5		4 %		

3W Catalyst Equipped Vehicles

Short test: H-Idle



Short test parameters (left: total sample, right: random sample)

3W Catalyst Equipped Vehicles

Short test: ga50-7

Total sample

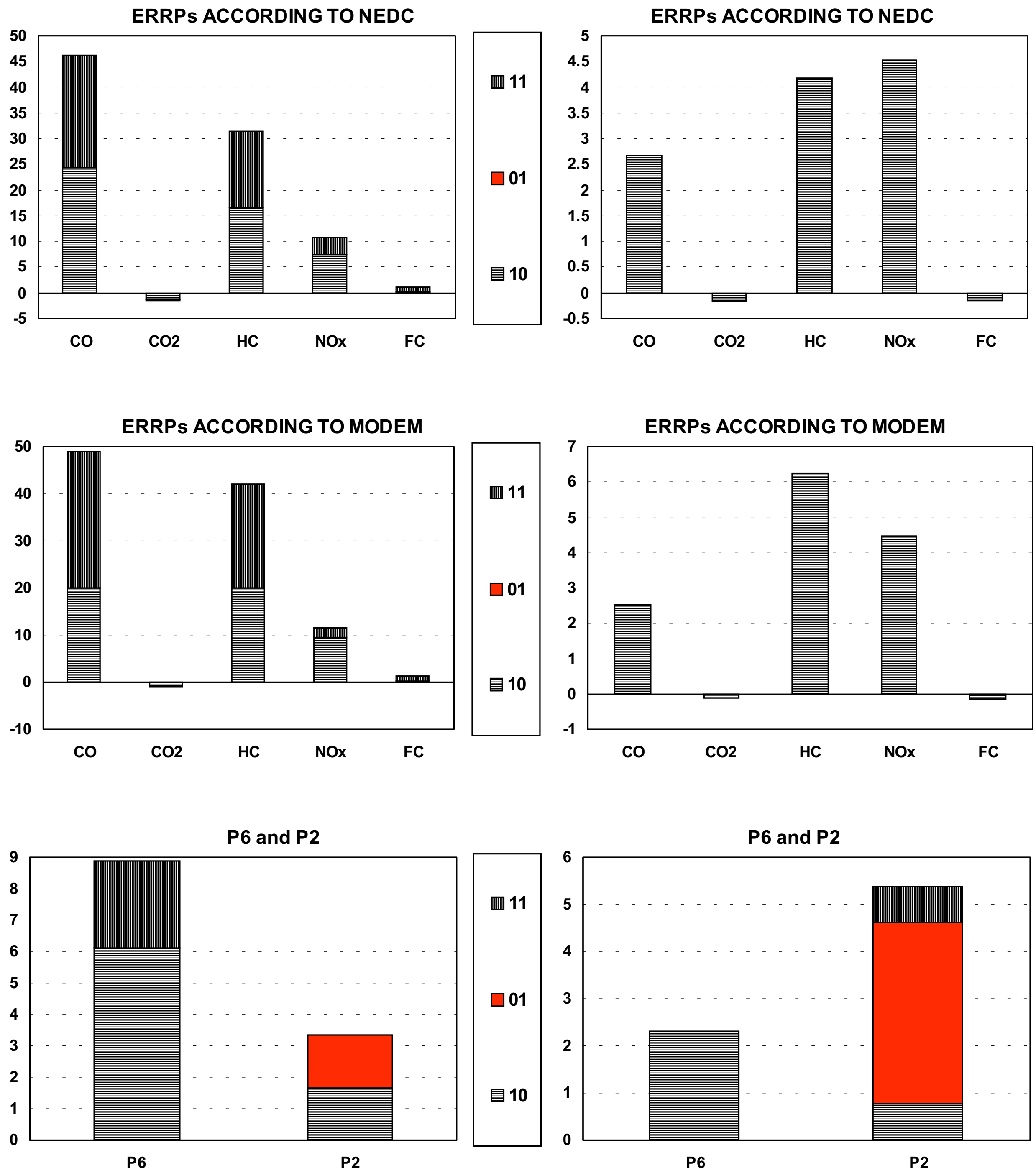
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 180			N= 84		N= 16				
96 %			47 %		9 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	1227	154	1.83	597	48.68	37.33	568	46
	CO2	35210	17109	203.68	2728	7.75	170.50	-531	-2
	HC	87	21	0.25	31	35.97	1.95	27	31
	NOx	74	21	0.24	12	16.15	0.74	8	11
	FC	12089	5652	67.29	1201	9.93	75.05	124	1
MODEM	CO	1221	164	1.95	628	51.45	39.26	597	49
	CO2	35857	17387	206.99	2899	8.08	181.17	-413	-1
	HC	59	10	0.12	27	45.24	1.68	25	42
	NOx	103	26	0.30	17	16.22	1.04	12	11
	FC	12271	5737	68.29	1265	10.31	79.08	173	1
Vehicles detected		24	13 %		Errors of commission				
Vehicles with low benefit		2	1 %		N= 6		3 %		

Random sample

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 130			N= 72		N= 3				
98 %			55 %		2 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	405	127	1.76	16	3.99	5.38	11	3
	CO2	25797	14731	204.59	572	2.22	190.72	-42	0
	HC	39	18	0.25	2	6.06	0.79	2	4
	NOx	48	17	0.24	3	6.04	0.96	2	5
	FC	8629	4887	67.88	190	2.20	63.41	-13	0
MODEM	CO	382	131	1.82	15	3.94	5.02	10	3
	CO2	25993	14948	207.60	591	2.27	196.99	-32	0
	HC	21	7	0.10	2	7.67	0.55	1	6
	NOx	66	21	0.29	4	5.79	1.27	3	4
	FC	8671	4950	68.75	195	2.25	65.03	-11	0
Vehicles detected		11	8 %		Errors of commission				
Vehicles with low benefit		1	1 %		N= 7		5 %		

3W Catalyst Equipped Vehicles

Short test: ga50-7



Short test parameters (left: total sample, right: random sample)

3W Catalyst Equipped Vehicles

Short test: la50-7

Total sample

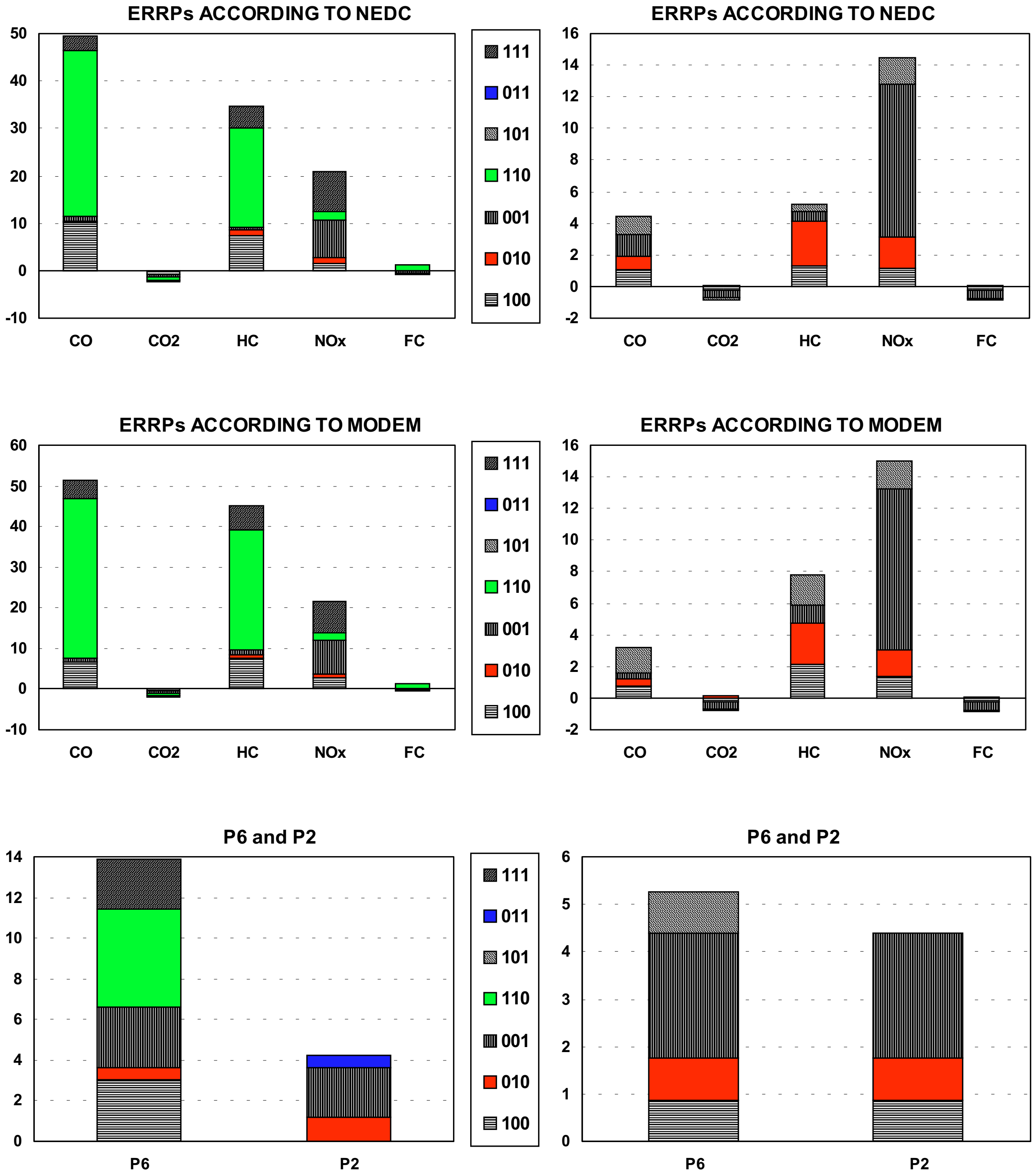
Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 166 88 %			N= 74 45 %		N= 23 14 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	1201	135	1.82	637	53.04	27.69	595	50
	CO2	33073	15513	209.63	4040	12.21	175.64	-782	-2
	HC	84	19	0.26	35	41.67	1.52	29	35
	NOx	71	18	0.25	20	28.76	0.89	15	21
	FC	11405	5139	69.45	1640	14.38	71.30	43	0
MODEM	CO	1207	144	1.95	664	55.07	28.89	620	51
	CO2	33820	15793	213.42	4259	12.59	185.17	-650	-2
	HC	58	9	0.12	29	49.80	1.26	26	45
	NOx	99	22	0.30	28	28.52	1.23	21	22
	FC	11627	5234	70.73	1717	14.77	74.65	90	1
Vehicles detected		38		23 %	Errors of commission				
Vehicles with low benefit		8		5 %	N= 7			4 %	

Random sample

Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 114 86 %			N= 61 54 %		N= 6 5 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	359	107	1.75	26	7.33	4.38	16	4
	CO2	23266	12987	212.90	1100	4.73	183.32	-177	-1
	HC	35	16	0.25	3	9.57	0.56	2	5
	NOx	44	15	0.25	8	17.80	1.32	6	14
	FC	7807	4327	70.94	362	4.64	60.36	-63	-1
MODEM	CO	351	108	1.77	22	6.21	3.63	11	3
	CO2	23557	13195	216.31	1137	4.83	189.53	-161	-1
	HC	20	6	0.11	2	10.97	0.36	2	8
	NOx	61	17	0.28	11	17.80	1.81	9	15
	FC	7889	4388	71.93	371	4.70	61.78	-61	-1
Vehicles detected		15		13 %	Errors of commission				
Vehicles with low benefit		4		4 %	N= 5			4 %	

3W Catalyst Equipped Vehicles

Short test: la50-7



Short test parameters (left: total sample, right: random sample)

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: meTUV

Total sample

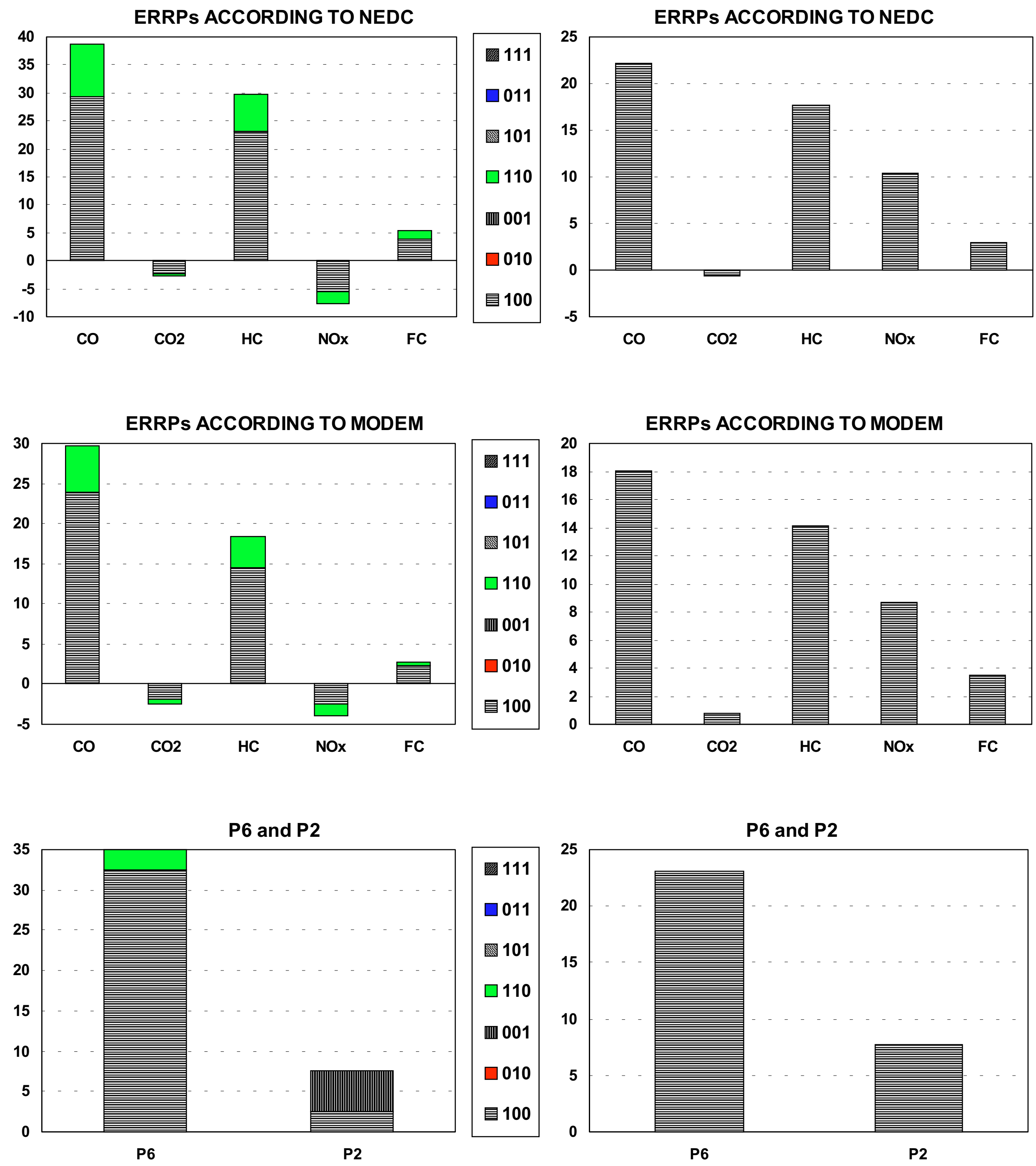
Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 40 100 %			N= 4 10 %		N= 14 35 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	768	34	8.62	419	54.53	29.92	298	39
	CO2	5826	593	148.14	1917	32.90	136.92	-157	-3
	HC	86	4	0.93	39	44.82	2.75	26	30
	NOx	59	6	1.51	17	27.86	1.18	-5	-8
	FC	2299	207	51.85	848	36.90	60.59	122	5
MODEM	CO	641	37	9.18	319	49.70	22.76	190	30
	CO2	5805	582	145.59	1898	32.70	135.58	-140	-2
	HC	70	4	0.98	27	37.87	1.90	13	18
	NOx	79	7	1.75	21	27.29	1.53	-3	-4
	FC	2214	206	51.38	781	35.28	55.78	62	3
Vehicles detected		23	58 %		Errors of commission				
Vehicles with low benefit		6	15 %		N= 3		8 %		

Random sample

Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 13 100 %			N= 2 15 %		N= 3 23 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	196	17	8.44	69	35.09	22.88	43	22
	CO2	1937	307	153.50	447	23.09	149.06	-13	-1
	HC	26	2	1.03	8	29.67	2.55	5	18
	NOx	19	2	1.17	5	29.06	1.82	2	10
	FC	731	107	53.53	182	24.92	60.74	22	3
MODEM	CO	201	18	8.85	63	31.20	20.94	36	18
	CO2	1955	295	147.49	457	23.39	152.42	15	1
	HC	23	2	1.00	6	26.85	2.10	3	14
	NOx	26	3	1.42	6	25.20	2.16	2	9
	FC	738	104	51.77	181	24.57	60.41	26	4
Vehicles detected		7	54 %		Errors of commission				
Vehicles with low benefit		3	23 %		N= 1		8 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: meTUV



Short test parameters (left: total sample, right: random sample)

Conventional and Oxidation Catalyst Equipped Vehicles

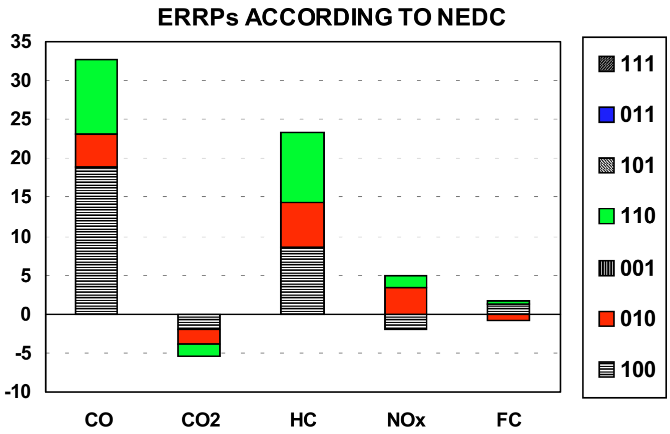
Short test: ralaTUV

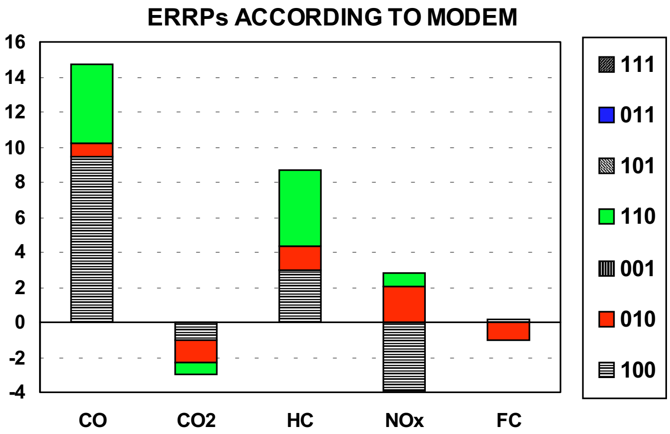
Total sample

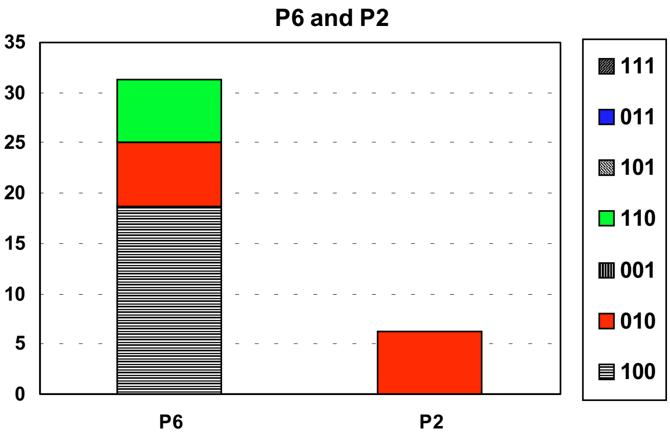
Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 16 40 %			N= 2 13 %		N= 5 31 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	273	16	8.21	130	47.70	26.05	89	33
	CO2	2483	343	171.31	721	29.02	144.15	-136	-5
	HC	29	2	0.80	11	37.10	2.17	7	23
	NOx	27	2	1.15	7	24.10	1.31	1	3
	FC	947	118	58.88	302	31.94	60.47	8	1
MODEM	CO	185	17	8.31	69	37.18	13.74	27	15
	CO2	2467	328	164.02	746	30.22	149.12	-75	-3
	HC	24	2	0.94	7	28.38	1.36	2	9
	NOx	36	4	1.82	9	24.42	1.75	0	-1
	FC	893	113	56.73	276	30.88	55.14	-8	-1
Vehicles detected		11	69 %		Errors of commission				
Vehicles with low benefit		5	31 %		N= 1		6 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: ralaTUV







Short test parameters (total sample)

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: ragaTUV

Total sample

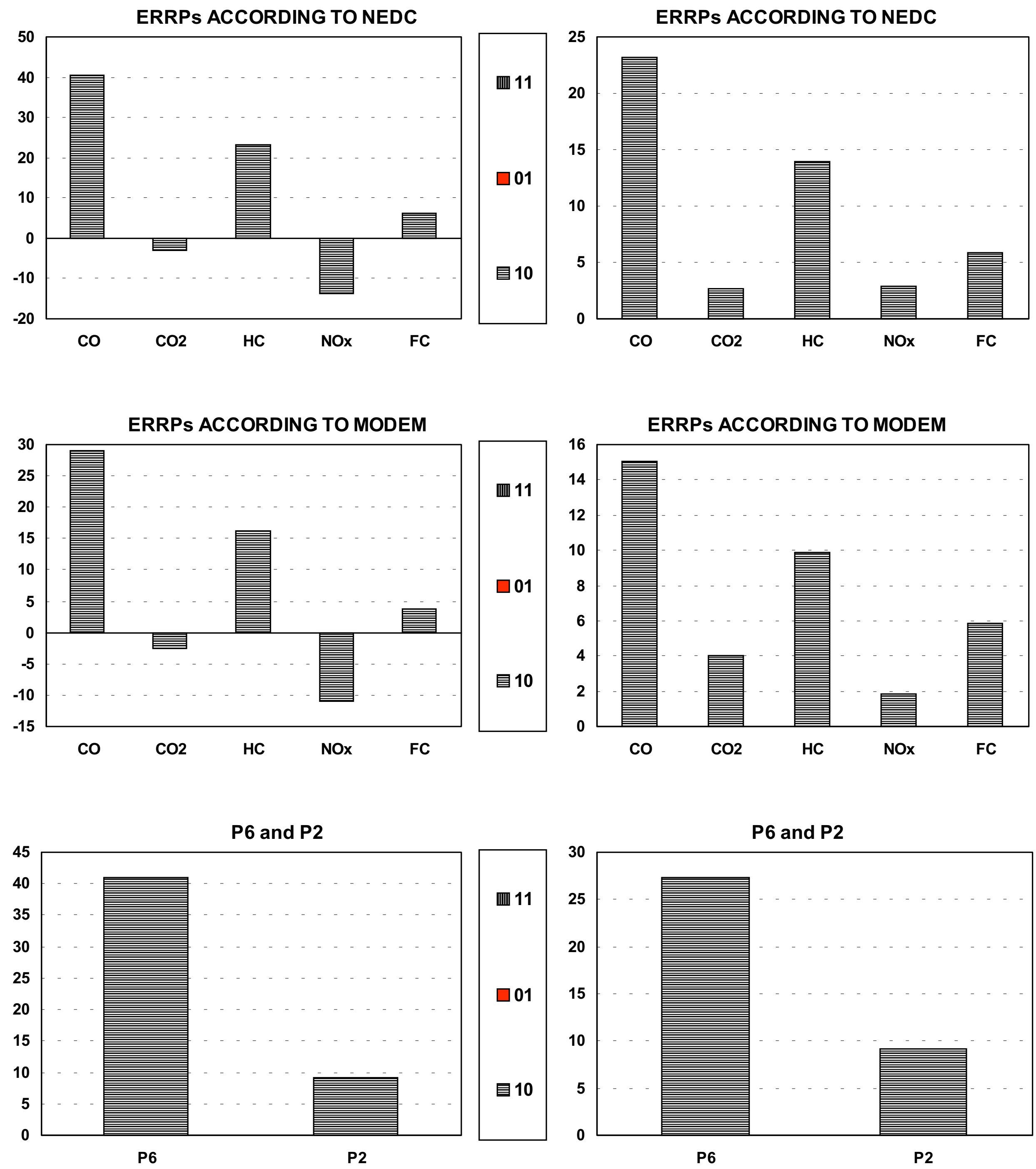
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 22 55 %			N= 1 5 %		N= 9 41 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	460	10	9.98	276	60.11	30.71	187	41
	CO2	3028	134	134.44	1121	37.02	124.53	-89	-3
	HC	52	1	1.49	25	49.30	2.82	12	23
	NOx	29	2	1.65	11	36.58	1.20	-4	-14
	FC	1230	49	48.64	514	41.79	57.12	76	6
MODEM	CO	423	12	11.74	229	54.12	25.42	123	29
	CO2	3012	130	130.36	1097	36.43	121.91	-76	-3
	HC	42	1	1.39	19	46.07	2.15	7	16
	NOx	39	2	2.02	14	35.81	1.54	-4	-11
	FC	1197	48	48.13	477	39.85	53.02	44	4
Vehicles detected		14	64 %		Errors of commission				
Vehicles with low benefit		3	14 %		N= 2		9 %		

Random sample

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 11 85 %			N= 1 9 %		N= 3 27 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	167	10	9.98	69	41.03	22.88	39	23
	CO2	1622	134	134.44	447	27.56	149.06	44	3
	HC	23	1	1.49	8	33.37	2.55	3	14
	NOx	17	2	1.65	5	31.54	1.82	1	3
	FC	615	49	48.64	182	29.60	60.74	36	6
MODEM	CO	183	12	11.74	63	34.27	20.94	28	15
	CO2	1640	130	130.36	457	27.88	152.42	66	4
	HC	21	1	1.39	6	29.40	2.10	2	10
	NOx	24	2	2.02	6	27.56	2.16	0	2
	FC	628	48	48.13	181	28.88	60.41	37	6
Vehicles detected		7	64 %		Errors of commission				
Vehicles with low benefit		3	27 %		N= 1		9 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: ragaTUV



Short test parameters (left: total sample, right: random sample)

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: meMS

Total sample

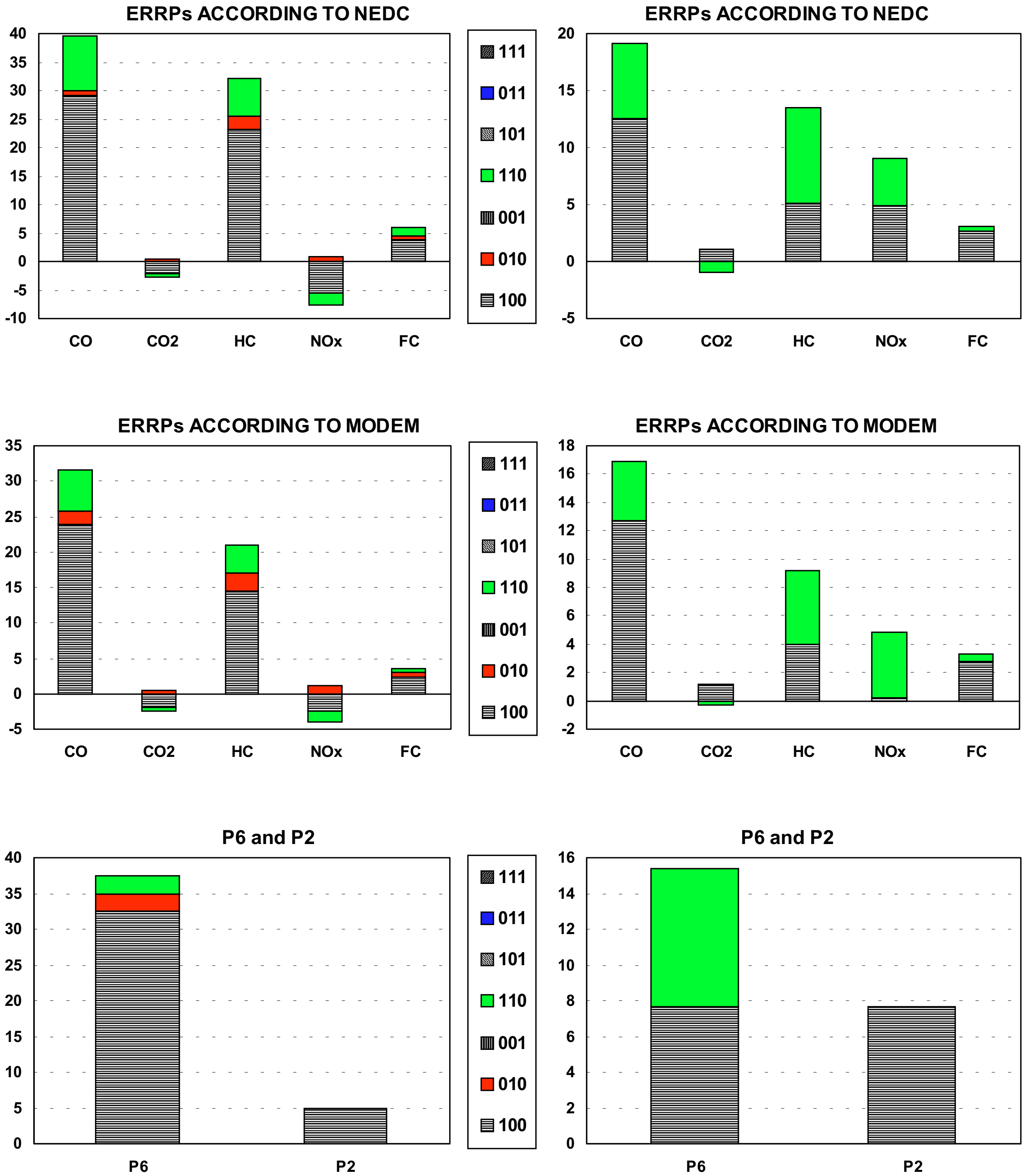
Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 40 100 %			N= 4 10 %		N= 15 38 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	768	34	8.62	433	56.32	28.84	303	39
	CO2	5826	593	148.14	2091	35.88	139.37	-131	-2
	HC	86	4	0.93	42	48.31	2.77	28	32
	NOx	59	6	1.51	19	31.17	1.24	-4	-7
	FC	2299	207	51.85	913	39.71	60.86	135	6
MODEM	CO	641	37	9.18	340	53.04	22.67	202	32
	CO2	5805	582	145.59	2074	35.72	138.26	-110	-2
	HC	70	4	0.98	29	41.85	1.96	15	21
	NOx	79	7	1.75	24	30.76	1.61	-2	-3
	FC	2214	206	51.38	850	38.39	56.65	79	4
Vehicles detected		23	58 %		Errors of commission				
Vehicles with low benefit		6	15 %		N= 2		5 %		

Random sample

Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 13 100 %			N= 2 15 %		N= 2 15 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	196	17	8.44	54	27.83	27.22	38	19
	CO2	1937	307	153.50	309	15.94	154.38	2	0
	HC	26	2	1.03	6	21.51	2.77	3	14
	NOx	19	2	1.17	4	21.49	2.02	2	9
	FC	731	107	53.53	130	17.73	64.81	23	3
MODEM	CO	201	18	8.85	52	25.71	25.88	34	17
	CO2	1955	295	147.49	311	15.89	155.35	16	1
	HC	23	2	1.00	4	17.72	2.08	2	9
	NOx	26	3	1.42	4	15.88	2.04	1	5
	FC	738	104	51.77	128	17.30	63.80	24	3
Vehicles detected		6	46 %		Errors of commission				
Vehicles with low benefit		3	23 %		N= 1		8 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: meMS



Short test parameters (left: total sample, right: random sample)

Conventional and Oxidation Catalyst Equipped Vehicles

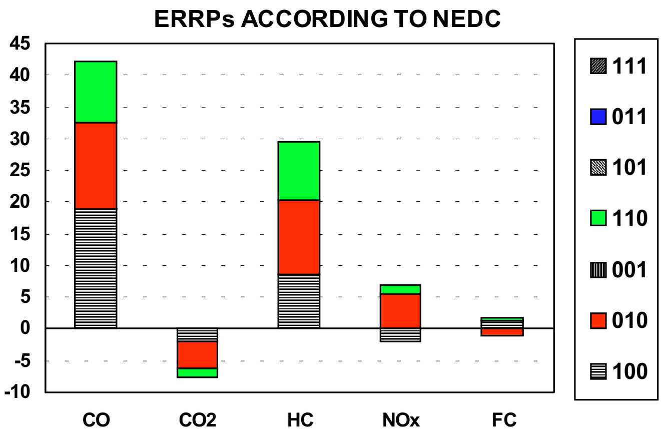
Short test: ralaMS

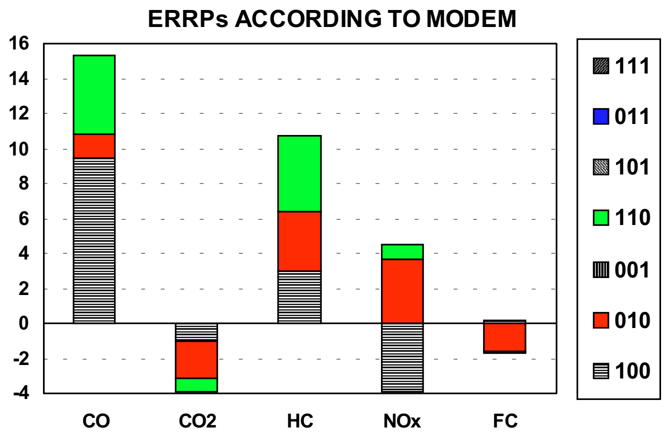
Total sample

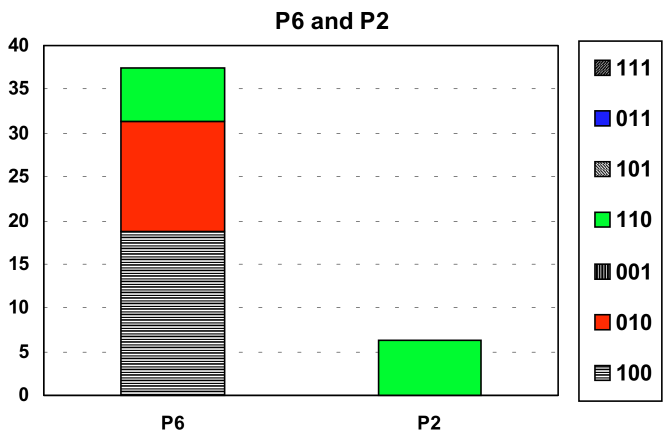
Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 16 40 %			N= 2 13 %		N= 6 38 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	273	16	8.21	164	60.12	27.36	115	42
	CO2	2483	343	171.31	837	33.71	139.52	-191	-8
	HC	29	2	0.80	13	46.02	2.24	9	29
	NOx	27	2	1.15	8	30.40	1.38	1	5
	FC	947	118	58.88	358	37.86	59.74	5	1
MODEM	CO	185	17	8.31	78	42.25	13.02	28	15
	CO2	2467	328	164.02	888	35.99	148.02	-96	-4
	HC	24	2	0.94	8	34.39	1.37	3	11
	NOx	36	4	1.82	11	31.16	1.86	0	1
	FC	893	113	56.73	327	36.59	54.45	-14	-2
Vehicles detected		13	81 %		Errors of commission				
Vehicles with low benefit		6	38 %		N= 1		6 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: ralaMS







Short test parameters (total sample)

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: ragaMS

Total sample

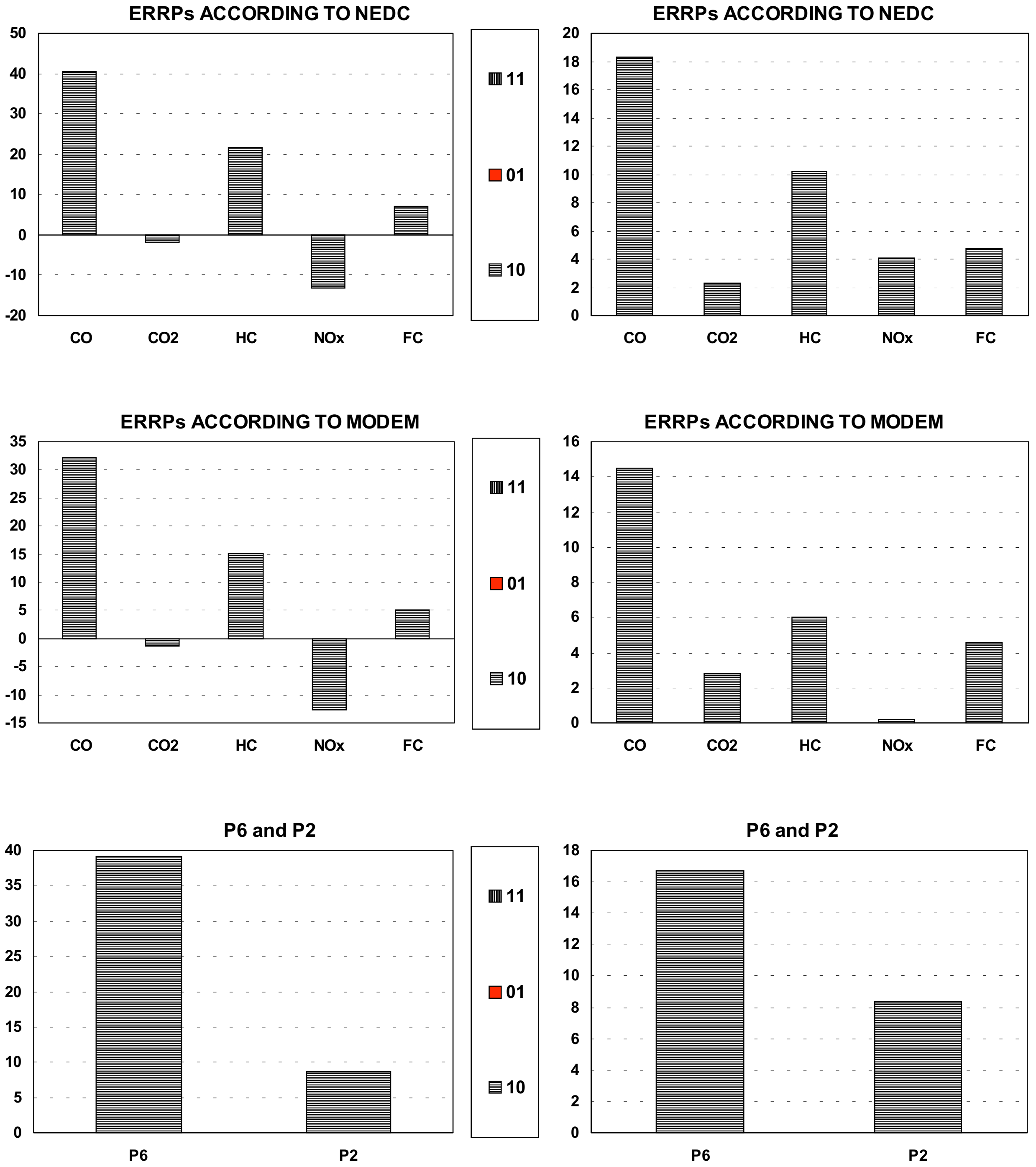
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 23 58 %			N= 1 4 %		N= 9 39 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	481	10	9.98	284	59.01	31.56	194	40
	CO2	3169	134	134.44	1155	36.45	128.35	-55	-2
	HC	54	1	1.49	25	46.66	2.79	12	22
	NOx	30	2	1.65	11	35.88	1.21	-4	-13
	FC	1288	49	48.64	529	41.05	58.72	91	7
MODEM	CO	435	12	11.74	245	56.45	27.27	140	32
	CO2	3162	130	130.36	1133	35.84	125.92	-40	-1
	HC	44	1	1.39	19	43.88	2.12	7	15
	NOx	40	2	2.02	13	32.59	1.46	-5	-13
	FC	1252	48	48.13	497	39.66	55.18	63	5
Vehicles detected		15	65 %		Errors of commission				
Vehicles with low benefit		4	17 %		N= 2		9 %		

Random sample

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 12 92 %			N= 1 8 %		N= 2 17 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	189	10	9.98	54	28.85	27.22	34	18
	CO2	1764	134	134.44	309	17.50	154.38	40	2
	HC	25	1	1.49	6	21.99	2.77	3	10
	NOx	18	2	1.65	4	22.31	2.02	1	4
	FC	673	49	48.64	130	19.27	64.81	32	5
MODEM	CO	195	12	11.74	52	26.49	25.88	28	14
	CO2	1791	130	130.36	311	17.35	155.35	50	3
	HC	23	1	1.39	4	18.19	2.08	1	6
	NOx	25	2	2.02	4	16.41	2.04	0	0
	FC	682	48	48.13	128	18.71	63.80	31	5
Vehicles detected		6	50 %		Errors of commission				
Vehicles with low benefit		3	25 %		N= 1		8 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: ragaMS



Short test parameters (left: total sample, right: random sample)

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: Idle

Total sample

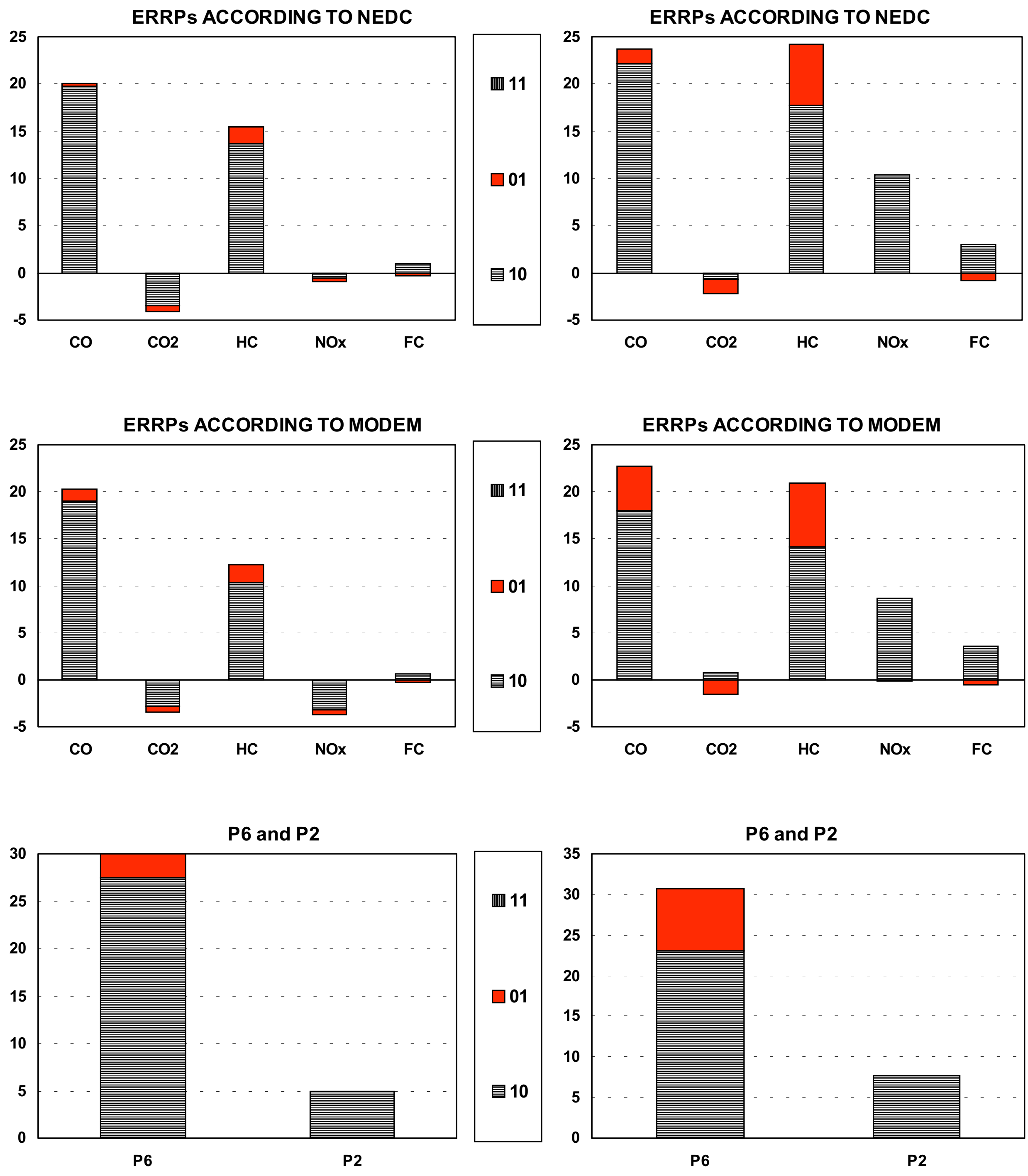
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 40 100 %			N= 4 10 %		N= 12 30 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	768	36	9.04	263	34.18	21.88	154	20
	CO2	5826	619	154.78	1621	27.82	135.06	-237	-4
	HC	86	4	1.10	26	30.79	2.21	13	16
	NOx	59	5	1.35	16	26.39	1.31	-1	-1
	FC	2299	217	54.31	666	28.97	55.49	14	1
MODEM	CO	641	42	10.44	255	39.78	21.25	130	20
	CO2	5805	598	149.53	1594	27.46	132.84	-200	-3
	HC	70	5	1.19	23	32.53	1.90	9	12
	NOx	79	8	1.88	20	24.95	1.64	-3	-4
	FC	2214	214	53.43	650	29.37	54.18	9	0
Vehicles detected		19	48 %		Errors of commission				
Vehicles with low benefit		5	13 %		N= 2		5 %		

Random sample

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 13 100 %			N= 2 15 %		N= 4 31 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	196	17	8.44	80	41.01	20.05	46	24
	CO2	1937	307	153.50	571	29.47	142.67	-43	-2
	HC	26	2	1.03	10	40.18	2.59	6	24
	NOx	19	2	1.17	7	35.29	1.66	2	10
	FC	731	107	53.53	229	31.37	57.36	15	2
MODEM	CO	201	18	8.85	81	40.23	20.25	46	23
	CO2	1955	295	147.49	574	29.35	143.46	-16	-1
	HC	23	2	1.00	9	37.85	2.22	5	21
	NOx	26	3	1.42	8	30.58	1.97	2	9
	FC	738	104	51.77	229	31.10	57.35	22	3
Vehicles detected		7	54 %		Errors of commission				
Vehicles with low benefit		2	15 %		N= 1		8 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: Idle



Short test parameters (left: total sample, right: random sample)

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: H-Idle

Total sample

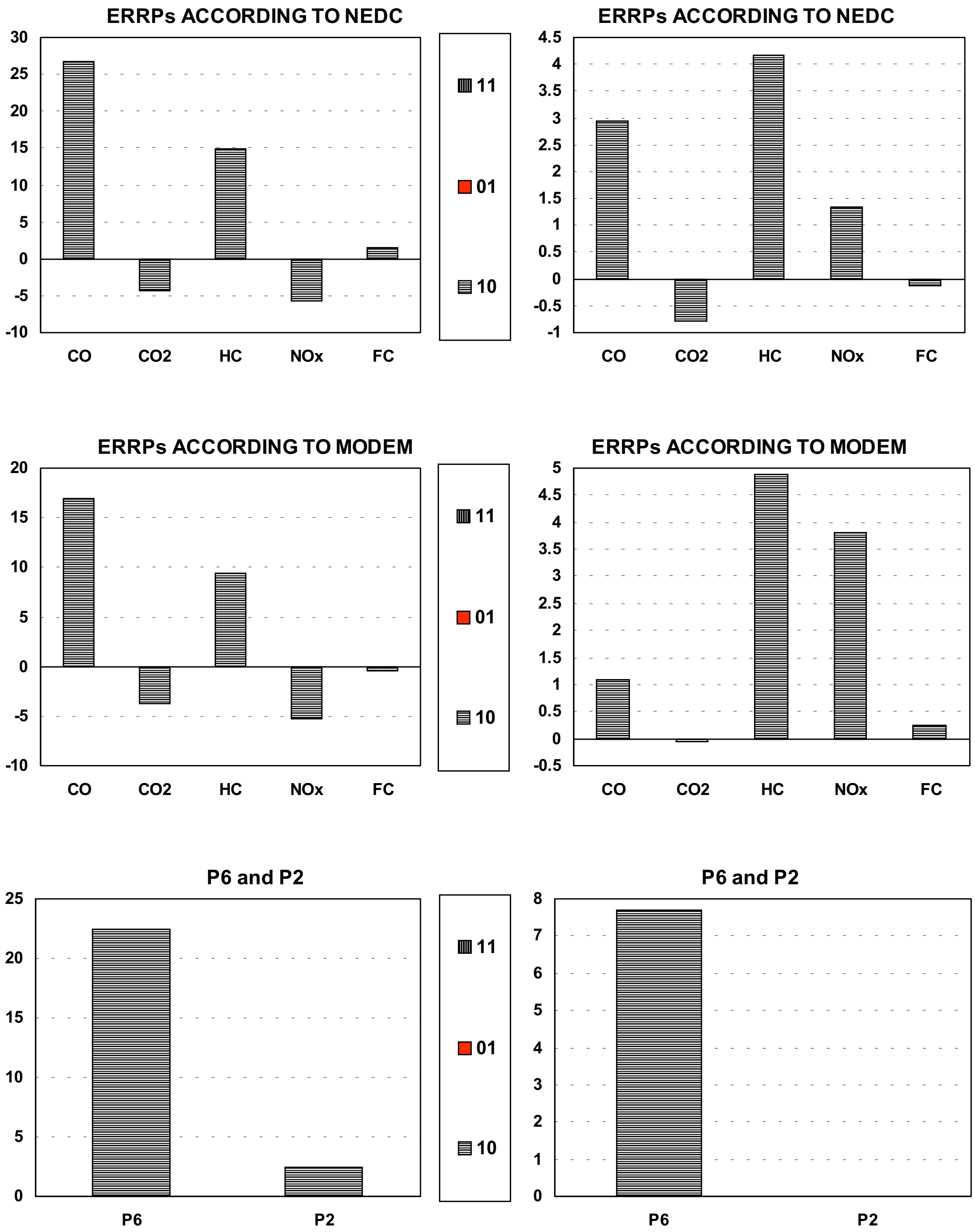
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 40 100 %			N= 4 10 %		N= 9 23 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	768	36	9.04	287	37.41	31.93	206	27
	CO2	5826	619	154.78	1137	19.52	126.37	-256	-4
	HC	86	4	1.10	23	26.27	2.51	13	15
	NOx	59	5	1.35	9	14.84	0.98	-3	-6
	FC	2299	217	54.31	522	22.71	58.00	33	1
MODEM	CO	641	42	10.44	203	31.59	22.50	109	17
	CO2	5805	598	149.53	1127	19.41	125.21	-219	-4
	HC	70	5	1.19	17	24.60	1.92	7	9
	NOx	79	8	1.88	13	16.27	1.42	-4	-5
	FC	2214	214	53.43	472	21.30	52.39	-9	0
Vehicles detected		16	40 %		Errors of commission				
Vehicles with low ben		6	15 %		N= 1		3 %		

Random sample

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 13 100 %			N= 2 15 %		N= 1 8 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	196	17	8.44	14	7.26	14.20	6	3
	CO2	1937	307	153.50	138	7.15	138.42	-15	-1
	HC	26	2	1.03	2	8.15	2.10	1	4
	NOx	19	2	1.17	1	7.57	1.42	0	1
	FC	731	107	53.53	53	7.19	52.58	-1	0
MODEM	CO	201	18	8.85	11	5.49	11.05	2	1
	CO2	1955	295	147.49	147	7.50	146.57	-1	0
	HC	23	2	1.00	2	9.13	2.14	1	5
	NOx	26	3	1.42	2	9.32	2.40	1	4
	FC	738	104	51.77	54	7.27	53.63	2	0
Vehicles detected		3	23 %		Errors of commission				
Vehicles with low ben		2	15 %		N= 0		0 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: H-Idle



Short test parameters (left: total sample, right: random sample)

Conventional and Oxidation Catalyst Equipped Vehicles

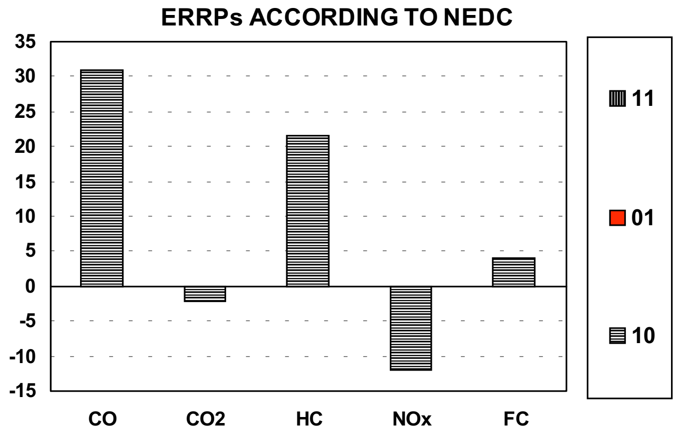
Short test: ga50-7

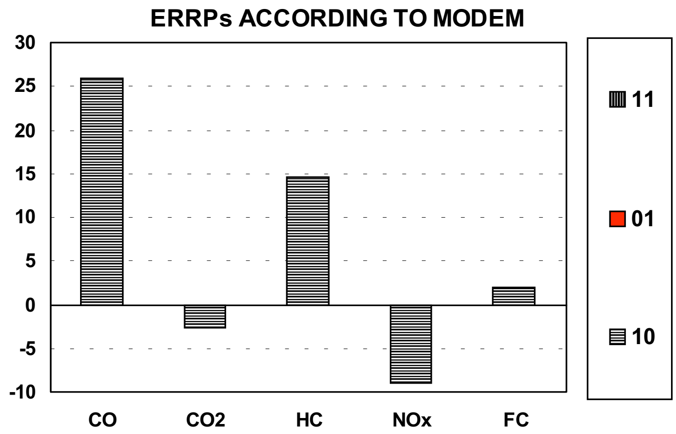
Total sample

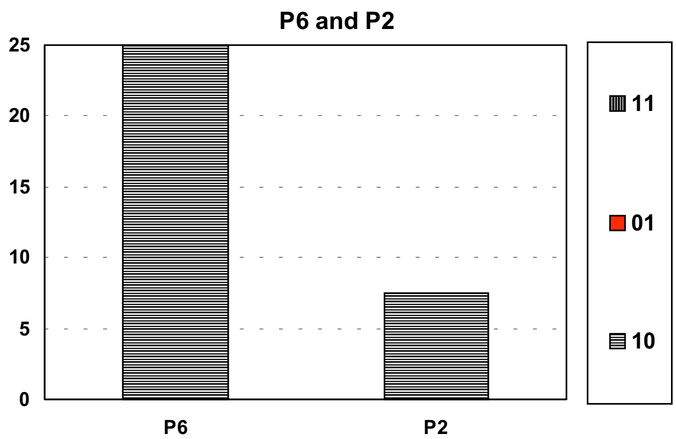
Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 40 100 %			N= 2 5 %		N= 10 25 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	768	18	8.81	326	42.39	32.56	238	31
	CO2	5826	286	142.78	1298	22.28	129.81	-130	-2
	HC	86	2	0.82	27	31.18	2.68	19	22
	NOx	59	4	1.84	11	18.93	1.13	-7	-12
	FC	2299	100	50.18	596	25.92	59.58	94	4
MODEM	CO	641	19	9.52	261	40.75	26.12	166	26
	CO2	5805	287	143.70	1286	22.16	128.64	-151	-3
	HC	70	2	0.97	20	28.33	1.99	10	15
	NOx	79	4	2.09	14	17.60	1.38	-7	-9
	FC	2214	102	50.98	553	25.00	55.34	44	2
Vehicles detected		16	40 %		Errors of commission				
Vehicles with low benefit		3	8 %		N= 3		8 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: ga50-7







Short test parameters (total sample)

Conventional and Oxidation Catalyst Equipped Vehicles

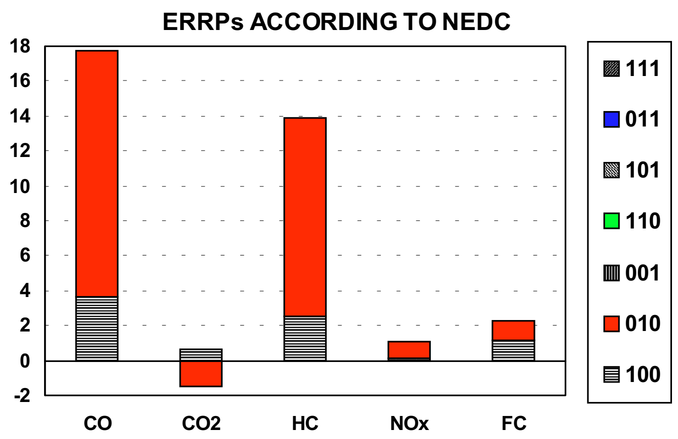
Short test: la50-7

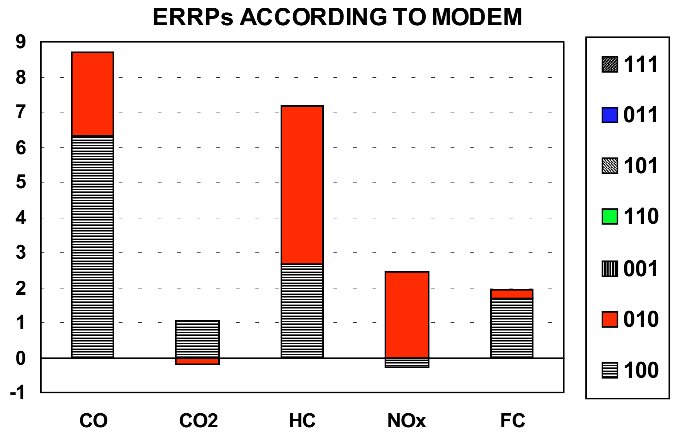
Total sample

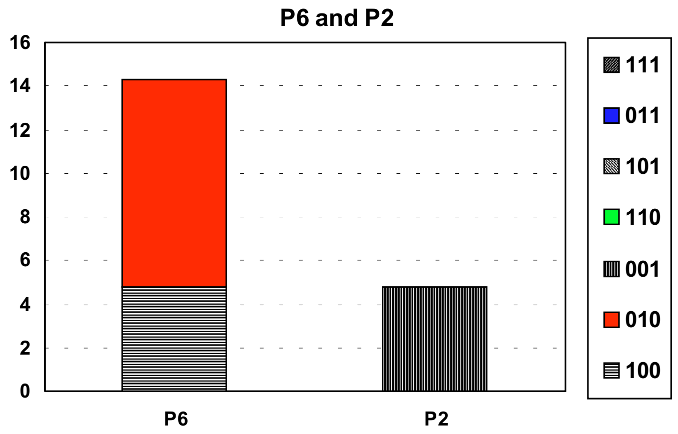
Vehicles measured			Low Polluters		Vehicles to be sent to maintenance				
N= 21 53 %			N= 4 19 %		N= 3 14 %				
		E	E	EF	E	P	EF	ERP	ERRP
NEDC	CO	361	34	8.57	90	24.86	29.93	64	18
	CO2	3297	600	150.04	422	12.82	140.83	-28	-1
	HC	38	3	0.87	8	20.90	2.62	5	14
	NOx	36	6	1.46	5	13.14	1.59	0	1
	FC	1255	210	52.41	185	14.77	61.81	28	2
MODEM	CO	287	38	9.60	54	18.74	17.92	25	9
	CO2	3301	592	147.93	472	14.29	157.29	28	1
	HC	32	4	1.00	5	16.57	1.76	2	7
	NOx	44	7	1.72	6	13.79	2.04	1	2
	FC	1214	209	52.37	180	14.87	60.15	23	2
Vehicles detected		7	33 %		Errors of commission				
Vehicles with low benefit		3	14 %		N= 1		5 %		

Conventional and Oxidation Catalyst Equipped Vehicles

Short test: la50-7







Short test parameters (total sample)

Directive 92/55/EEC

Total sample - 50% above standard

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 177 100 %			N= 78 44 %		N= 23 13 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	1218	144	1.84	726	59.60	31.57	684	56
	CO2	34690	15939	204.35	4102	11.82	178.35	-598	-2
	HC	86	20	0.25	37	42.75	1.60	31	36
	NOx	73	19	0.24	14	19.52	0.62	9	12
	FC	11920	5249	67.30	1703	14.28	74.03	155	1
MODEM	CO	1209	153	1.96	715	59.14	31.09	670	55
	CO2	35330	16199	207.68	4348	12.31	189.06	-428	-1
	HC	59	9	0.12	31	52.08	1.33	28	47
	NOx	102	23	0.30	20	20.14	0.89	14	13
	FC	12091	5327	68.30	1768	14.62	76.88	197	2
Vehicles detected		37	21 %		Errors of commission				
Vehicles with low benefit		2	1 %		N= 12		7 %		

Random sample - 50% above standard

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 126 71 %			N= 67 53 %		N= 3 2 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	391	120	1.79	17	4.41	5.75	12	3
	CO2	25069	13746	205.16	487	1.94	162.48	-128	-1
	HC	38	17	0.25	1	2.79	0.35	0	1
	NOx	47	16	0.24	2	5.22	0.81	2	4
	FC	8391	4544	67.82	163	1.94	54.27	-41	0
MODEM	CO	366	122	1.81	11	3.00	3.66	6	2
	CO2	25263	13922	207.80	495	1.96	164.95	-129	-1
	HC	21	7	0.11	1	2.47	0.17	0	1
	NOx	64	19	0.28	4	5.51	1.18	3	4
	FC	8424	4593	68.56	161	1.92	53.80	-44	-1
Vehicles detected		11	9 %		Errors of commission				
Vehicles with low benefit		0	0 %		N= 8		6 %		

Total sample - 0% above standard

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 177 100 %			N= 78 44 %		N= 31 18 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	1218	144	1.84	754	61.86	24.31	696	57
	CO2	34690	15939	204.35	5622	16.21	181.35	-713	-2
	HC	86	20	0.25	40	46.35	1.29	32	37
	NOx	73	19	0.24	18	24.44	0.57	10	14
	FC	11920	5249	67.30	2226	18.67	71.80	140	1
MODEM	CO	1209	153	1.96	745	61.62	24.04	685	57
	CO2	35330	16199	207.68	5816	16.46	187.62	-622	-2
	HC	59	9	0.12	33	55.54	1.05	29	49
	NOx	102	23	0.30	25	24.61	0.81	16	15
	FC	12091	5327	68.30	2276	18.82	73.41	159	1
Vehicles detected		37	21 %		Errors of commission				
Vehicles with low benefit		0	0 %		N= 6		3 %		

Random sample - 0% above standard

Vehicles measured			Low polluters		Vehicles to be sent to maintenance				
N= 126 71 %			N= 67 53 %		N= 6 5 %				
		E	E	EF	E	PE	EF	ERP	ERRP
NEDC	CO	391	120	1.79	29	7.40	4.82	18	5
	CO2	25069	13746	205.16	1045	4.17	174.22	-186	-1
	HC	38	17	0.25	2	4.84	0.31	0	1
	NOx	47	16	0.24	3	6.92	0.54	2	4
	FC	8391	4544	67.82	345	4.11	57.51	-62	-1
MODEM	CO	366	122	1.81	24	6.69	4.08	14	4
	CO2	25263	13922	207.80	973	3.85	162.17	-274	-1
	HC	21	7	0.11	1	5.13	0.18	0	2
	NOx	64	19	0.28	4	6.47	0.69	2	4
	FC	8424	4593	68.56	319	3.79	53.18	-92	-1
Vehicles detected		11	9 %		Errors of commission				
Vehicles with low benefit		0	0 %		N= 5		4 %		

Lambda Measurement

INRETS

$$\frac{1}{\lambda} = 1 + \frac{CO - 2 \cdot O_2}{21} \qquad (CO > O_2)$$

$$\frac{1}{\lambda} = 1 - \frac{O_2 - \frac{CO}{2}}{21} \qquad (CO < O_2)$$

CO and O_2 concentrations expressed in %.

TNO

$$\lambda = \frac{CO_2 + \frac{CO}{2} - \left(HC - \overline{C}\right)\left(3\frac{\frac{x}{4}}{\frac{CO}{kCO_2} + 1} - \frac{y}{2}\right) + O_2 + \frac{NO}{2}}{\overline{C} \cdot \left(1 + \frac{x}{4} - \frac{y}{2}\right)}$$

All concentrations expressed in % (HC as C1).

Fuel: CH_xO_y

$k = 3.5$

$\overline{C} = CO_2 + CO + HC$

LAT

$$\lambda = \frac{\left(A/F\right)}{\left(A/F\right)_{st}}$$

$$\frac{A}{F} = \frac{M_{air}}{M_f}\left[\frac{100 + HC - \frac{CO}{2} + \frac{3}{2}H_2O}{HC + CO + CO_2} - \frac{y}{2}\right] \qquad H_2O = 0.5y\frac{CO_2 + CO}{\frac{CO}{kCO_2} + 1}$$

$M_{air} = 28.96$

$M_f = 12.01 + 1.008y$

$k = 3.5$

$\left(A/F\right)_{st} = 14.6$

$y = H/C$ in fuel

All concentrations expressed in % (HC as C1).

TUEV

$$\lambda = \frac{CO_2 + \frac{CO}{2} + O_2 + \left(\frac{1.7261}{4}\cdot\frac{3.5}{3.5 + \frac{CO}{CO_2}} - 0.0088\right)\cdot\left(CO_2 + CO\right)}{\left(1 + \frac{1.7621}{4} - 0.0088\right)\cdot\left(CO_2 + CO + k1\cdot HC\right)}$$

All concentrations expressed in %.

The index k1 depends on the way HC is measured.