Vehicular Air Pollution Information Sytem (VAPIS)

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URBAN emissions .info

(UEinfo) was founded in 2007 with the vision to be a repository of information, research, and analysis related to air pollution. There is a need to scale-up research applications to the secondary and the tertiary cities which are following in the footsteps of the expanding mega-cities. Advances in information technology, open-data resources, and networking, offers a tremendous opportunity to establish such tools, to help city managers, regulators, academia, and citizen groups to develop a coordinated approach for integrated air quality management for a city.

UEinfo has four objectives: (1) sharing knowledge on air pollution (2) science-based air quality analysis (3) advocacy and awareness raising on air quality management and (4) building partnerships among local, national, and international airheads.

This report was conceptualized, drafted, and designed by the members of UEinfo.

All the working papers and more are accessible @ www.urbanemissions.info/publications

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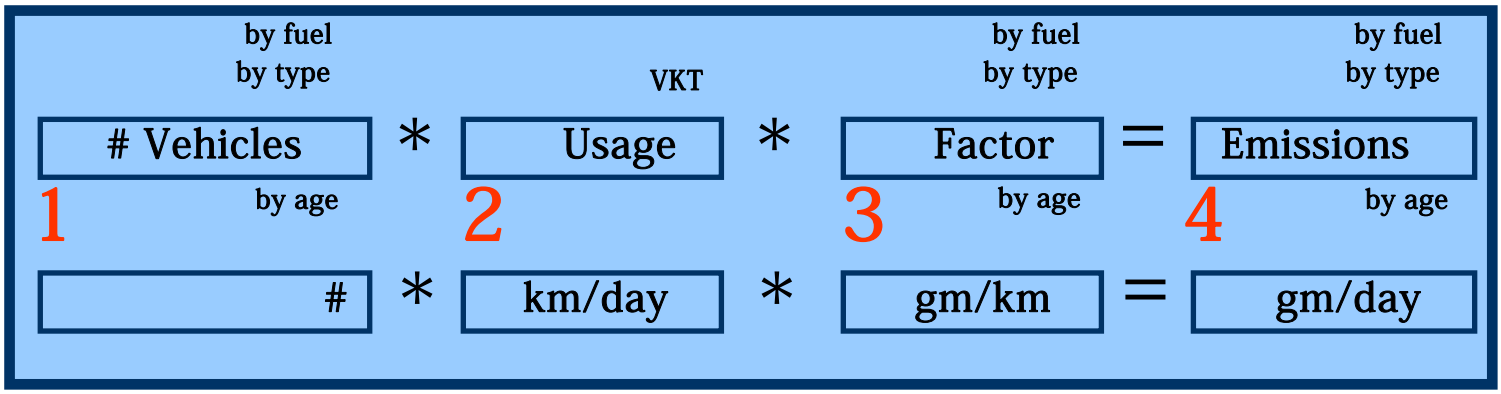
This working paper presents the description of the “Vehicular Air Pollution Information System” (VAPIS) tool.

The VAPIS tool was developed to establish the emission trends and evaluate possible management scenarios for one vehicle category, using minimum inputs for the user.

The tool can be replicated for multiple pollutants and multiple vehicle fleets, depending on the availability of the input data.

The fundamental equation for the calculations is based on the activity levels, which is the number of vehicles on road and number of kilometers traveled by the vehicle. The equation is represented in the box below.



The third (and an important) input is the emission factor, which depends on the make and age of the vehicle. An average set of factors in gm/km are presented below (**author’s interpretation, use with discretion)**.

For details and resources of available literature for emission factors, refer to the working paper SIM-02-2008, “Four equations to develop emissions inventory”. @ www.urbanemissions.info/simair/simseries.html

	Gasoline			Diesel				CNG			
	2Ws	3Ws	Cars	Cars	LDV	HDT	Bus	3Ws	Cars	LDV	Bus
PM_{10}	0.10	0.20	0.10	1.00	1.25	2.00	1.50	0.10	0.05	0.02	0.02
$PM_{2.5}$	0.05	0.08	0.03	0.60	0.50	1.00	0.80	0.05	0.02	0.01	0.01
SO_2	0.02	0.02	0.07	0.40	0.30	1.00	1.00	0.00	0.00	0.00	0.00
NO_x	0.15	0.10	0.20	1.25	2.00	10.0	10.0	0.35	0.20	3.50	2.50
CO	2.50	8.00	5.00	2.00	2.50	3.50	3.50	3.50	1.00	3.50	3.50
CO_2	40	80	200	250	500	850	850	70	100	450	450
HC	1.50	5.00	1.00	0.40	0.20	1.00	1.00	0.15	0.02	0.10	0.10

The tool allows for the development of trend functions for a 30 year horizon.

The emissions from the fleet depend on the mix of the vehicles on road, aka the age of the vehicles.

Based on the initial user input, the age mix of the fleet is progressively calculated at a five year interval, which is further used to calculate the effective emission factor of the fleet.

For the old fleet, the emission factors are deteriorated at an assumed rate.

A detailed mathematical description of the calculations is presented below.

$$NV_{t+1} = NV_{t} * (1 + growth)$$

$$NV_{total} = \sum_{age=1}^{age=n} NV_{age}$$

$$EF_{age} = ES_{new} * (1 + drate)^{\wedge age}$$

$$EF_{effective} = \sum_{age=1}^{age=n} EF_{age} * \frac{NV_{age}}{NV_{total}}$$

$$Emissions = NV_{total} * VKT * EF_{effective}$$

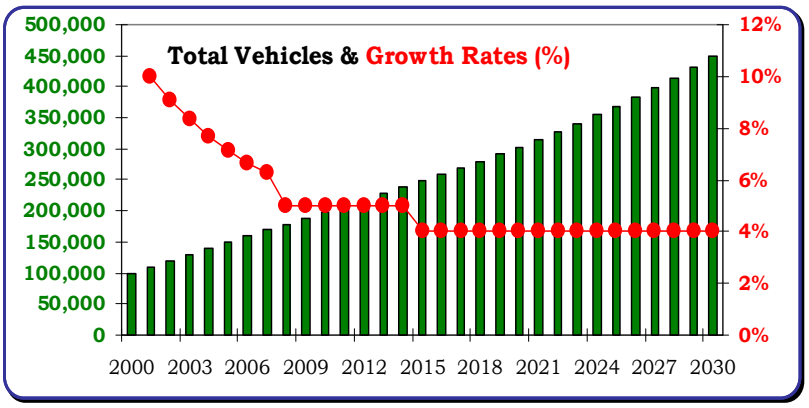
n = number of age groups

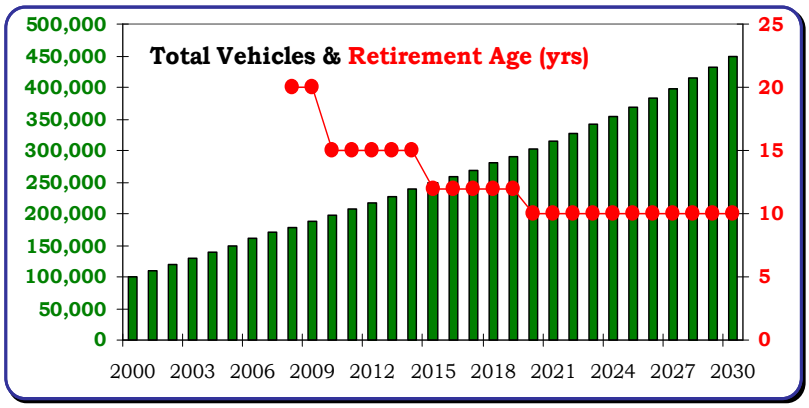
NV = number of vehicles

ES = emission standard

EF = emission factor

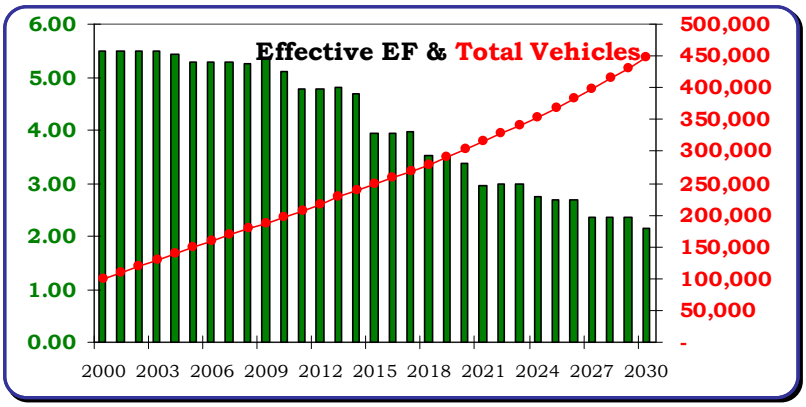
An illustration of calculations

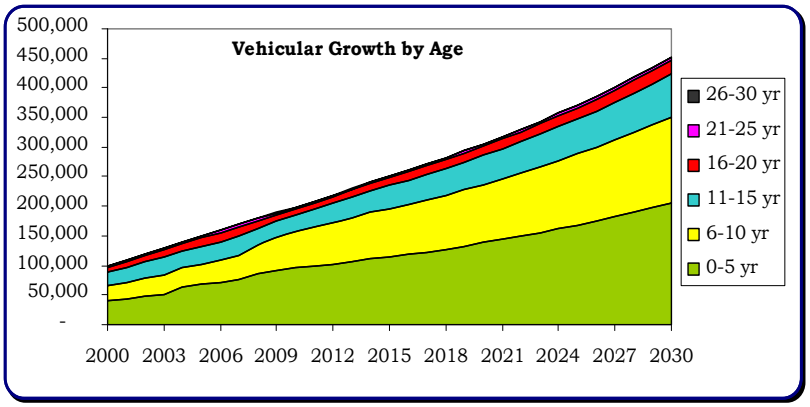




Total number of vehicles over 30 years, along with assumed growth rates and retirement rates

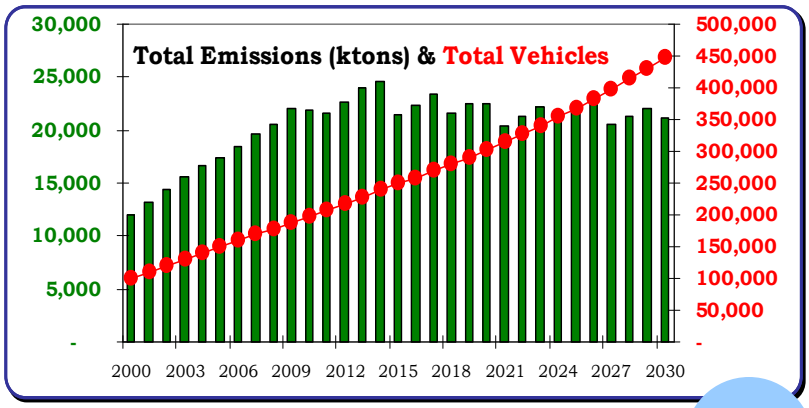
Effective emission factor of the fleet based on the age splits of the fleet →



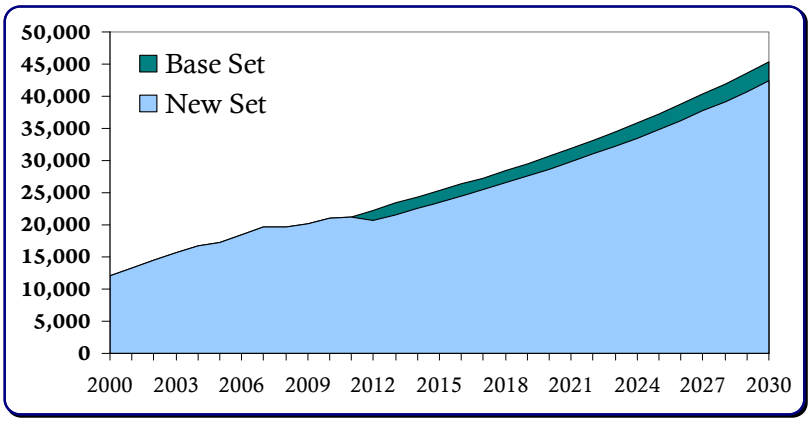


← Age splits of the fleet based on the initial input and assumed retirement age

Total emissions per year along with total number of vehicles →

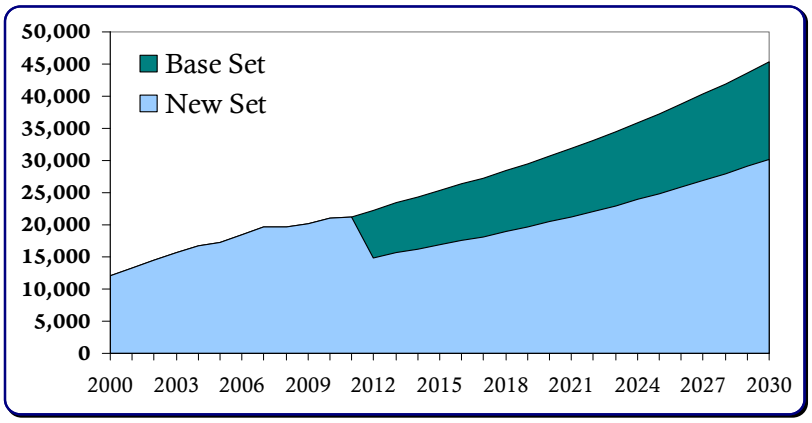


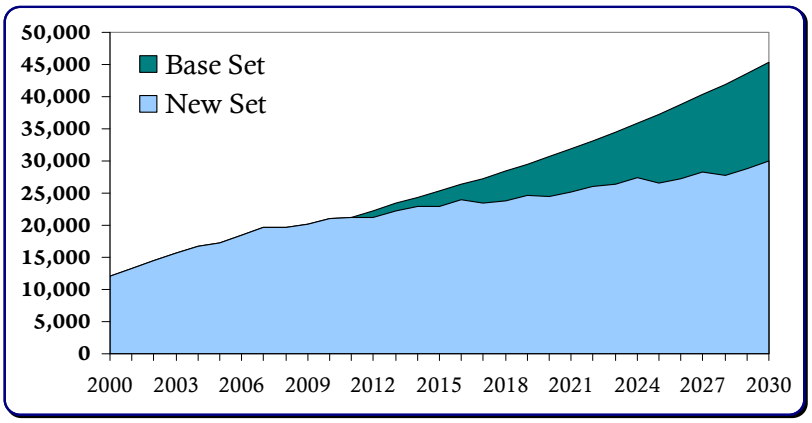
A combination of scenarios an be evaluated by exploring the parameters; below are some sample illustrations



← changing retirement age from 20 yrs to 10 yrs in 2012

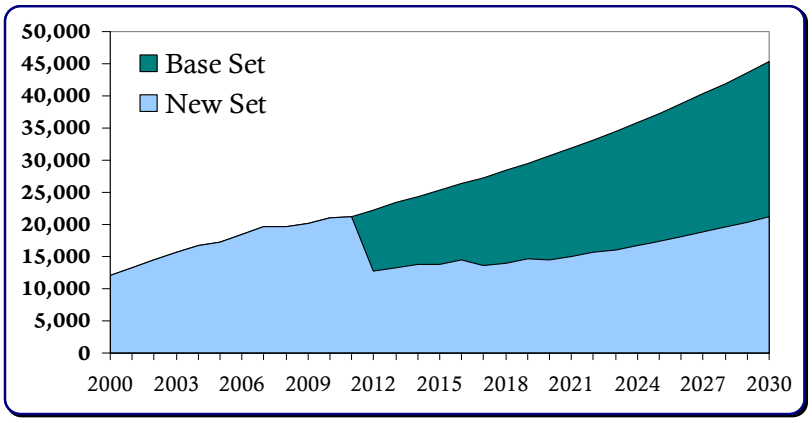
reducing the VKT by 30% from 60 km to 40 km in 2012→





← introducing newer emission standards in 2012 & 2017

.. or a combination of all the above →



The Input Sheet

Fill the cells in red to start the framework

Vehicular Category		Cars
Base Year		2007
Number of Vehicles in Base Year		100,000
Annual Growth Rate		3%
Age Split of the Vehicles	0 to 5 years	45%
	6 to 10 years	35%
	11 to 15 years	15%
	16 to 20 years	3%
	above 20 years	2%
Retirement age	in years	12
Vehicles Kilometers Traveled	km per day	60
New Emission Factor	gm/km	4.00
EF Deterioration %	0 to 5 years	0.5%
	6 to 10 years	1.0%
	11 to 15 years	2.0%
	16 to 20 years	3.0%
	above 20 years	4.0%

Enter the following to fill the sheet and start the calculations.

Vehicular category of user's choice. The calculator is set up to conduct calculations for one category ONLY, but allows for replication, as user sees it fit.

Base year for the calculations. This is extended to a 30 year horizon, starting with the base year.

Number of vehicles, is the in-use vehicle fleet number for the base year. This will be used to extend the calculations to 30 years using the **annual growth rate** (%).

The age splits are set at 5 year intervals. User should enter the **age splits of the vehicle fleet** (total should be 100%) for the five age categories.

The retirement function is introduced which uses the assumed **retirement age** of the vehicles. If there is not regulation for retirement for the vehicles, assume 20 years. The 20 years limit there due to the mathematical limitations in the retirement pre-calculated retirement functions, presented at the end of the VAPIS tool.

These functions are based the S3 Half Life functions.

If the retirement is set at 15 years, it doesn't mean that all the vehicles with 15 years of age are dropped from the inventory. It means that the probability of the vehicles with 15 years of age being out of the in-use fleet is high and calculated accordingly using the half life functions.

The activity levels that drive the emissions generation is the **vehicle kilometers traveled** (VKT). This cell represents a fleet average that can be adjusted later, if need be.

The emissions depend on the fleet **emission factors**. The cell represents the emission factor of the new vehicles.
NOTE: The user should enter the emission factors of the newer fleet (for example, the emission standards, above which the vehicles cannot emit)

For the older vehicles, the new emission rates are calculated accordingly using the **deteriorated rates** in the next set of cells. It is assumed that the older fleet deteriorates faster than the newer fleet.

These inputs are propagated through the remaining worksheets leading up to the total emissions and scenario comparisons.

Calculations – Vehicles

Year	Vehicle Number	Growth Rate	Retirement Age
2007	100,000		
2008	103,000	3.0%	12
2009	106,090	3.0%	12
2010	109,273	3.0%	12
2011	112,551	3.0%	12
2012	115,927	3.0%	12
2013	119,405	3.0%	12
2014	122,987	3.0%	12
2015	126,677	3.0%	12
2016	130,477	3.0%	12
2017	134,392	3.0%	12
2018	138,423	3.0%	12
2019	142,576	3.0%	12
2020	146,853	3.0%	12
2021	151,259	3.0%	12
2022	155,797	3.0%	12
2023	160,471	3.0%	12
2024	165,285	3.0%	12
2025	170,243	3.0%	12

Similarly for the retirement age.

Default is the value entered in the input sheet for all the years. However, the user can also change the retirement age values, individually for each of the years.

Cells with yellow background are from the input sheet.

Rest of the cells for the total number of vehicles is calculated, up to 30 years from the base year, using the growth rate from the input sheet.

However, the user can also change the growth rates, individually for each of the years. See example below.

Default value is the input value for all the cells.

Year	Vehicle Number	Growth Rate	Retirement Age
2007	100,000		
2008	106,000	6.0%	20
2009	112,360	6.0%	20
2010	119,102	6.0%	20
2011	125,057	5.0%	15
2012	131,310	5.0%	15
2013	136,562	4.0%	15
2014	142,024	4.0%	15
2015	147,705	4.0%	15
2016	153,614	4.0%	15
2017	158,222	3.0%	15
2018	162,969	3.0%	15
2019	167,858	3.0%	15
2020	172,893	3.0%	12
2021	178,080	3.0%	12
2022	181,642	2.0%	12
2023	185,275	2.0%	12
2024	188,980	2.0%	12
2025	192,760	2.0%	12

Calculations – Age Splits

Year	Vehicular Split by Age				
	0-5 yr	6-10 yr	11-15 yr	16-20 yr	> 20 yr
2007	45,000	35,000	15,000	3,000	2,000
2008	56,426	31,877	12,485	2,008	204
2009	58,847	34,437	11,048	1,621	136
2010	60,014	36,464	11,266	1,419	110
2011	61,415	37,807	11,810	1,423	96
2012	63,150	38,916	12,280	1,485	97
2013	65,051	40,034	12,675	1,544	101
2014	67,022	41,215	13,050	1,595	105
2015	69,042	42,449	13,435	1,643	108
2016	71,114	43,724	13,836	1,692	112
2017	73,247	45,037	14,251	1,742	115
2018	75,444	46,388	14,679	1,794	118
2019	77,707	47,780	15,119	1,848	122
2020	80,038	49,213	15,573	1,903	126
2021	82,439	50,690	16,040	1,961	129
2022	84,912	52,210	16,521	2,019	133
2023	87,460	53,777	17,017	2,080	137
2024	90,084	55,390	17,528	2,142	141
2025	92,786	57,052	18,053	2,207	146
2026	95,570	58,763	18,595	2,273	150
2027	98,437	60,526	19,153	2,341	155

In this page, the user input is minimum. The user can play with the retirement functions, but the most is interlinked with the functions in the last sheet.

Table to the left is based on the inputs on “first table” on Page 7.

Table to the right is based on the inputs on “second table” on Page 7.

The age split calculations depend on the retirement age specified and the calculations are automated.

Year	Vehicular Split by Age				
	0-5 yr	6-10 yr	11-15 yr	16-20 yr	> 20 yr
2007	45,000	35,000	15,000	3,000	2,000
2008	44,942	36,306	18,685	5,097	970
2009	46,054	36,998	20,829	6,831	1,648
2010	49,016	37,800	22,054	8,022	2,209
2011	61,298	37,204	19,183	5,932	1,440
2012	65,958	41,414	17,941	4,931	1,065
2013	67,234	45,264	18,702	4,477	885
2014	68,908	47,688	20,103	4,523	804
2015	71,234	49,533	21,328	4,798	812
2016	74,017	51,326	22,320	5,090	861
2017	75,499	53,258	23,209	5,342	914
2018	77,559	54,784	24,101	5,566	959
2019	79,883	56,316	24,876	5,784	999
2020	94,887	53,908	20,293	3,412	393
2021	98,690	58,050	18,459	2,650	232
2022	98,863	61,289	18,945	2,364	180
2023	100,028	62,843	19,853	2,390	161
2024	101,882	63,966	20,473	2,496	162
2025	103,968	65,133	20,912	2,577	170
2026	108,020	66,401	21,312	2,635	175
2027	111,506	68,403	21,725	2,686	179

Calculations – Emission Factors

Year	New EF	Emission Factor Deterioration Rate				
	(gm/km)	0-5 yr	6-10 yr	11-15 yr	16-20 yr	> 20 yrs
2007	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2008	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2009	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2010	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2011	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2012	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2013	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2014	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2015	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2016	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2017	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2018	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2019	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2020	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2021	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2022	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2023	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2024	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2025	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2026	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2027	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2028	4.00	0.50%	1.00%	2.00%	3.00%	4.00%

Cells with yellow background are from the input sheet.

Default value is the input value for all the cells.

However, the user can change the emission factors for new vehicles, individually for each of the years.

See example below.

Similarly, for the deterioration rates. Defaults are from the input sheet, but the user can change them over the years.

These represent the inspection & maintenance of the vehicles. Better the program, lesser the deterioration of the emission factors.

Year	New EF	Emission Factor Deterioration Rate				
	(gm/km)	0-5 yr	6-10 yr	11-15 yr	16-20 yr	> 20 yrs
2007	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2008	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2009	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2010	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2011	4.00	0.50%	1.00%	2.00%	3.00%	4.00%
2012	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2013	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2014	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2015	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2016	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2017	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2018	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2019	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2020	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2021	3.00	0.50%	1.00%	2.00%	3.00%	4.00%
2022	2.00	0.50%	1.00%	2.00%	3.00%	4.00%
2023	2.00	0.50%	1.00%	2.00%	3.00%	4.00%
2024	2.00	0.50%	1.00%	2.00%	3.00%	4.00%
2025	1.00	0.50%	1.00%	2.00%	3.00%	4.00%
2026	1.00	0.50%	1.00%	2.00%	3.00%	4.00%
2027	1.00	0.50%	1.00%	2.00%	3.00%	4.00%
2028	1.00	0.50%	1.00%	2.00%	3.00%	4.00%

Calculations – Emission Factors

Emission Factor					Effective
0-5 yr	6-10 yr	11-15 yr	16-20 yr	21-25 yr	EF
4.10	4.20	4.42	4.64	4.87	4.22
4.10	4.20	4.42	4.64	4.87	4.18
4.10	4.20	4.42	4.64	4.87	4.18
4.10	4.20	4.42	4.64	4.87	4.18
4.10	4.20	4.42	4.64	4.87	4.18
4.10	4.31	4.64	5.12	5.64	4.24
4.10	4.31	4.64	5.12	5.64	4.24
4.10	4.31	4.64	5.12	5.64	4.24
4.10	4.31	4.76	5.38	6.23	4.26
4.10	4.31	4.76	5.38	6.23	4.26
4.10	4.31	4.76	5.38	6.23	4.26
4.10	4.31	4.76	5.52	6.55	4.26
4.10	4.31	4.76	5.52	6.55	4.26
4.10	4.31	4.76	5.52	6.55	4.26
4.10	4.31	4.76	5.52	6.71	4.26
4.10	4.31	4.76	5.52	6.71	4.26
4.10	4.31	4.76	5.52	6.71	4.26
4.10	4.31	4.76	5.52	6.71	4.26
4.10	4.31	4.76	5.52	6.71	4.26
4.10	4.31	4.76	5.52	6.71	4.26
4.10	4.31	4.76	5.52	6.71	4.26
4.10	4.31	4.76	5.52	6.71	4.26

This table is calculated using the “new emission factor” and the “deterioration rates” entered and described in Page 9.

The table to the left, is the result of input from Table 1 on Page 8.

The effective emission factor is sum product of fleet % by age and the calculated emission factor of the age mix.

The table to the right presents results using input from Table 2 on Page 9.

Introduction of stringent emission factors in the future fleet, reduces the effective emission factor of the fleet an thus the emissions.

Emission Factor					Effective
0-5 yr	6-10 yr	11-15 yr	16-20 yr	21-25 yr	EF
4.10	4.20	4.42	4.64	4.87	4.22
4.10	4.20	4.42	4.64	4.87	4.22
4.10	4.20	4.42	4.64	4.87	4.24
4.10	4.20	4.42	4.64	4.87	4.24
4.10	4.20	4.42	4.64	4.87	4.21
3.08	4.31	4.64	5.12	5.64	3.78
3.08	4.31	4.64	5.12	5.64	3.78
3.08	4.31	4.64	5.12	5.64	3.79
3.08	3.23	4.76	5.38	6.23	3.46
3.08	3.23	4.76	5.38	6.23	3.47
3.08	3.23	4.76	5.38	6.23	3.47
3.08	3.23	3.57	5.52	6.55	3.31
3.08	3.23	3.57	5.52	6.55	3.31
3.08	3.23	3.57	5.52	6.55	3.24
3.08	3.23	3.57	4.14	6.71	3.20
2.05	3.23	3.57	4.14	6.71	2.64
2.05	3.23	3.57	4.14	6.71	2.65
2.05	3.23	3.57	4.14	5.03	2.65
1.03	2.16	3.57	4.14	5.03	1.73
1.03	2.16	3.57	4.14	5.03	1.72
1.03	2.16	3.57	4.14	5.03	1.72
1.03	1.08	2.38	4.14	5.03	1.23

Calculations – Emissions

Year	Total Vehicles	VKT per day	Effective EF	Emissions tons
2007	100,000	60	4.22	9,233
2008	103,000	60	4.18	9,436
2009	106,090	60	4.18	9,703
2010	109,273	60	4.18	9,993
2011	112,551	60	4.18	10,294
2012	115,927	60	4.24	10,772
2013	119,405	60	4.24	11,095
2014	122,987	60	4.24	11,428
2015	126,677	60	4.26	11,816
2016	130,477	60	4.26	12,171
2017	134,392	60	4.26	12,536
2018	138,423	60	4.26	12,918
2019	142,576	60	4.26	13,306
2020	146,853	60	4.26	13,705
2021	151,259	60	4.26	14,116
2022	155,797	60	4.26	14,540
2023	160,471	60	4.26	14,976
2024	165,285	60	4.26	15,425
2025	170,243	60	4.26	15,888
2026	175,351	60	4.26	16,365
2027	180,611	60	4.26	16,856
2028	186,029	60	4.26	17,361

Emissions = total number of vehicles * vehicle kilometers traveled * effective emission factor

The default for VKT is the input value and copied to all the years.

The example to the left shows the results using the table 1's on Pages 7 to 10.

The example calculations to the right shows the results using the table 2's on Pages 7 to 10.

See the change in effective emission factors, based on the change in the new emission factors.

Year	Total Vehicles	VKT per day	Effective EF	Emissions tons
2007	100,000	60	4.22	9,233
2008	106,000	60	4.22	9,807
2009	112,360	60	4.24	10,426
2010	119,102	60	4.24	11,066
2011	125,057	60	4.21	11,542
2012	131,310	60	3.78	10,860
2013	136,562	60	3.78	11,314
2014	142,024	60	3.79	11,793
2015	147,705	60	3.46	11,204
2016	153,614	60	3.47	11,663
2017	158,222	60	3.47	12,029
2018	162,969	60	3.31	11,796
2019	167,858	60	3.31	12,154
2020	172,893	60	3.24	12,263
2021	178,080	60	3.20	12,474
2022	181,642	60	2.64	10,500
2023	185,275	60	2.65	10,733
2024	188,980	60	2.65	10,948
2025	192,760	60	1.73	7,295
2026	198,543	60	1.72	7,483
2027	204,499	60	1.72	7,693
2028	210,634	60	1.23	5,675

Calculations – Emissions

Year	Total Vehicles	VKT per day	Effective EF	Emissions tons
2007	100,000	60	4.22	9,233
2008	103,000	60	4.18	9,436
2009	106,090	60	4.18	9,703
2010	109,273	60	4.18	9,993
2011	112,551	60	4.18	10,294
2012	115,927	60	4.24	10,772
2013	119,405	60	4.24	11,095
2014	122,987	60	4.24	11,428
2015	126,677	60	4.26	11,816
2016	130,477	60	4.26	12,171
2017	134,392	60	4.26	12,536
2018	138,423	60	4.26	12,918
2019	142,576	60	4.26	13,306
2020	146,853	60	4.26	13,705
2021	151,259	60	4.26	14,116
2022	155,797	60	4.26	14,540
2023	160,471	60	4.26	14,976
2024	165,285	60	4.26	15,425
2025	170,243	60	4.26	15,888
2026	175,351	60	4.26	16,365
2027	180,611	60	4.26	16,856
2028	186,029	60	4.26	17,361

Emissions = total number of vehicles * vehicle kilometers traveled * effective emission factor

For VKT's the default value is from the input sheet copied to all the subsequent years. In the example t the left, 60 km/day is used for all years.

The example calculations to the right shows the results using the table 2's on Pages 7 to 10, along with a reduction in the VKTs in the coming years.

Year	Total Vehicles	VKT per day	Effective EF	Emissions tons
2007	100,000	60	4.22	9,233
2008	106,000	60	4.22	9,807
2009	112,360	60	4.24	10,426
2010	119,102	60	4.24	11,066
2011	125,057	60	4.21	11,542
2012	131,310	50	3.78	9,050
2013	136,562	50	3.78	9,428
2014	142,024	50	3.79	9,827
2015	147,705	50	3.46	9,337
2016	153,614	50	3.47	9,719
2017	158,222	50	3.47	10,024
2018	162,969	50	3.31	9,830
2019	167,858	50	3.31	10,128
2020	172,893	50	3.24	10,219
2021	178,080	40	3.20	8,316
2022	181,642	40	2.64	7,000
2023	185,275	40	2.65	7,155
2024	188,980	40	2.65	7,299
2025	192,760	40	1.73	4,863
2026	198,543	40	1.72	4,989
2027	204,499	40	1.72	5,129
2028	210,634	40	1.23	3,783

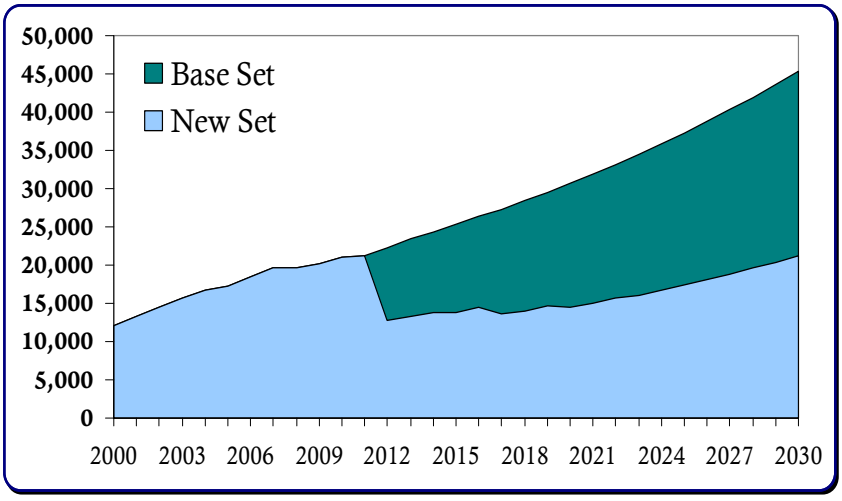
See the change in VKTs, could be based on introduction of new public transport systems, assuming that the category in analysis is Cars.

Notice the dramatic drop in emissions due to drop in VKTs.

Calculations – Comparisons

Copy Current Emissions as Base Set

Use this button on “Emissions” worksheet to copy the current set of calculations as a base set. Any calculations made after will be assumed as a new scenario and displayed as presented in **Page 4**.



The user can change any number of the parameters, listed in the calculations, to introduce scenarios and compare the “what if” scenarios. For example,

1. Changing the emission factors of the new fleet to represent improving fuel and vehicle standards
2. Reducing the deterioration rates to represent better inspection and maintenance programs
3. Reducing the vehicle kilometers traveled to represent alternative mode of transports
4. Changing the growth rates to represent vehicle taxing reforms
5. Reducing the vehicle kilometers traveled to represent economic incentives such as congestion fees
6. Introducing institutional standards for phasing out old vehicles to keep the fleet fresh and clean
7. Changing the emission factors to represent alternative fuels for the fleet

The user for replicate the tool for multi-pollutant and multi-fleet mode. Details @ www.urbanemissions.info/simair/vapis.html

Average Emission Factors for Indian Fleet (gm/km)

Vehicle Type	CO	HC	NOx	CO2	PM
Scooter 2-St Post 2005 >80cc	0.16	0.86	0.02	38.5	0.057
Scooter 4-St Post 2005 >100cc	0.40	0.15	0.25	42.1	0.015
MC 2-St Pre 2000 >80cc	2.96	2.44	0.05	24.2	-
MC 4-St Post 2000 <100cc	1.65	0.61	0.27	25.0	0.035
MC 4-St Post 2000 >100cc	1.48	0.50	0.54	24.8	-
MC 4-St Post 2005 >200cc	0.72	0.52	0.15	45.6	0.013
3W 2-St Post 2000 <200cc	1.37	2.53	0.20	62.4	0.045
3W 2-St Post 2005 <200cc	1.15	1.63	0.16	71.5	0.043
3W 4-St Post 2000 <200cc	1.97	0.84	0.40	62.7	0.030
3W 4-St Post 2005 <200cc	2.29	0.77	0.53	73.8	0.015
3W Diesel Post 2000 <500cc	2.09	0.16	0.69	173.9	0.347
3W Diesel Post 2005 <500cc	0.41	0.14	0.51	131.6	0.091
3W CNG-4S Post 2000 <200cc	1.00	0.26	0.50	77.7	0.015
3W CNG-2S Post 2000 <200cc	0.69	2.06	0.19	57.7	0.118
3W LPG-2S Post 2000 <200cc	1.70	1.03	0.04	68.2	0.130
P.Car Petrol Pre 2000 <1000cc	4.83	0.58	0.65	98.6	0.019
P.Car Petrol Post 2000 <1000cc	1.30	0.24	0.20	126.4	0.004
P.Car Petrol Post 2000 >1400cc	2.74	0.19	0.21	142.9	0.006
P.Car Petrol Post 2005 >1400cc	0.84	0.12	0.09	172.9	0.002
P.Car Diesel Pre 2000 <1600cc	0.87	0.22	0.45	129.1	0.145
P.Car Diesel Post 2000 <1600cc	0.72	0.14	0.84	156.8	0.190
P.Car Diesel Post 2005 <1600cc	0.06	0.08	0.28	148.8	0.015
P.Car Diesel Pre 2000 >1600cc	0.66	0.25	0.61	166.1	0.180
P.Car CNG Pre 2000 <1000cc	0.85	0.79	0.53	149.4	0.001
P.Car CNG Post 2000 <1000cc	0.06	0.46	0.74	143.5	0.006
P.Car LPG Pre 2000 >1000cc	6.78	0.85	0.50	130.9	0.001
P.Car LPG Post 2000 >1400cc	2.72	0.23	0.20	140.0	0.002

This dataset is compiled by the Central Pollution Control Board, India. Detailed report is available @ http://cpcb.nic.in/Source_Apportionment_Studies.php

Average Emission Factors for Bangkok Fleet (gm/km)

		Average Speed				Average Speed				Average Speed		
		10	20	30		10	20	30		10	20	30
		Light Duty Vehicles				Heavy Duty Buses				Heavy Duty Trucks		
HC	Pre-1994	0.52	0.32	0.25	Pre-1995	2.35	1.31	0.93	Pre-1995	1.46	0.93	0.71
CO		1.88	1.32	1.07		10.17	6.59	5.11		13.12	10.35	9.02
NOx		2.97	2.34	2.03		19.68	12.00	8.98		15.02	10.44	8.44
CO2		415	318	272		1299	843	655		1164	921	804
PM		0.22	0.19	0.17		1.32	0.96	0.80		2.45	1.86	1.58
HC	1994-96	0.36	0.24	0.20	1996-97	1.81	1.10	0.82	1996-97	1.65	1.18	0.96
CO		1.51	1.09	0.90		17.40	16.02	15.26		4.24	3.46	3.08
NOx		3.37	2.60	2.24		22.45	13.30	9.80		14.24	10.88	9.30
CO2		410	322	280		1318	1000	851		1186	981	878
PM		0.15	0.16	0.16		1.93	1.76	1.67		0.93	0.88	0.85
HC	1997-99	0.34	0.21	0.16	1997-2000	0.85	0.46	0.32	1997-2000	1.83	1.22	0.97
CO		1.83	1.08	0.79		18.21	15.42	13.99		4.24	3.46	3.08
NOx		2.87	2.23	1.93		19.68	12.00	8.98		15.02	10.44	8.44
CO2		438	342	297		1789	1155	894		1401	1127	993
PM		0.17	0.17	0.16		0.84	0.62	0.52		1.28	0.93	0.76
HC	after 2000	0.27	0.19	0.16	after 2001	1.83	1.05	0.76	after 2001	0.83	0.55	0.43
CO		1.70	1.37	1.21		6.36	3.72	2.72		5.40	3.61	2.85
NOx		1.45	1.14	0.98		13.50	9.47	7.70		15.07	10.03	7.91
CO2		421	342	303		1475	1038	846		1438	1010	821
PM		0.14	0.15	0.15		1.12	0.98	0.91		0.45	0.41	0.39

This dataset is compiled from the emission factor tests conducted under the DIESEL (Developing Integrated Emission Strategies for Existing Land-transport) program in Bangkok, Thailand.

The dataset also includes functions to evaluate the dependence of change emission factors to the vehicle speed. For convenience, factors for only 10, 20, and 30 km/hr are presented here. On average, the emission factors improve by at least 20% for every 10 km/hr increase in the average vehicle speeds. A Detailed report is available

@ http://www.cleanairnet.org/caiasia/1412/article-48845.html

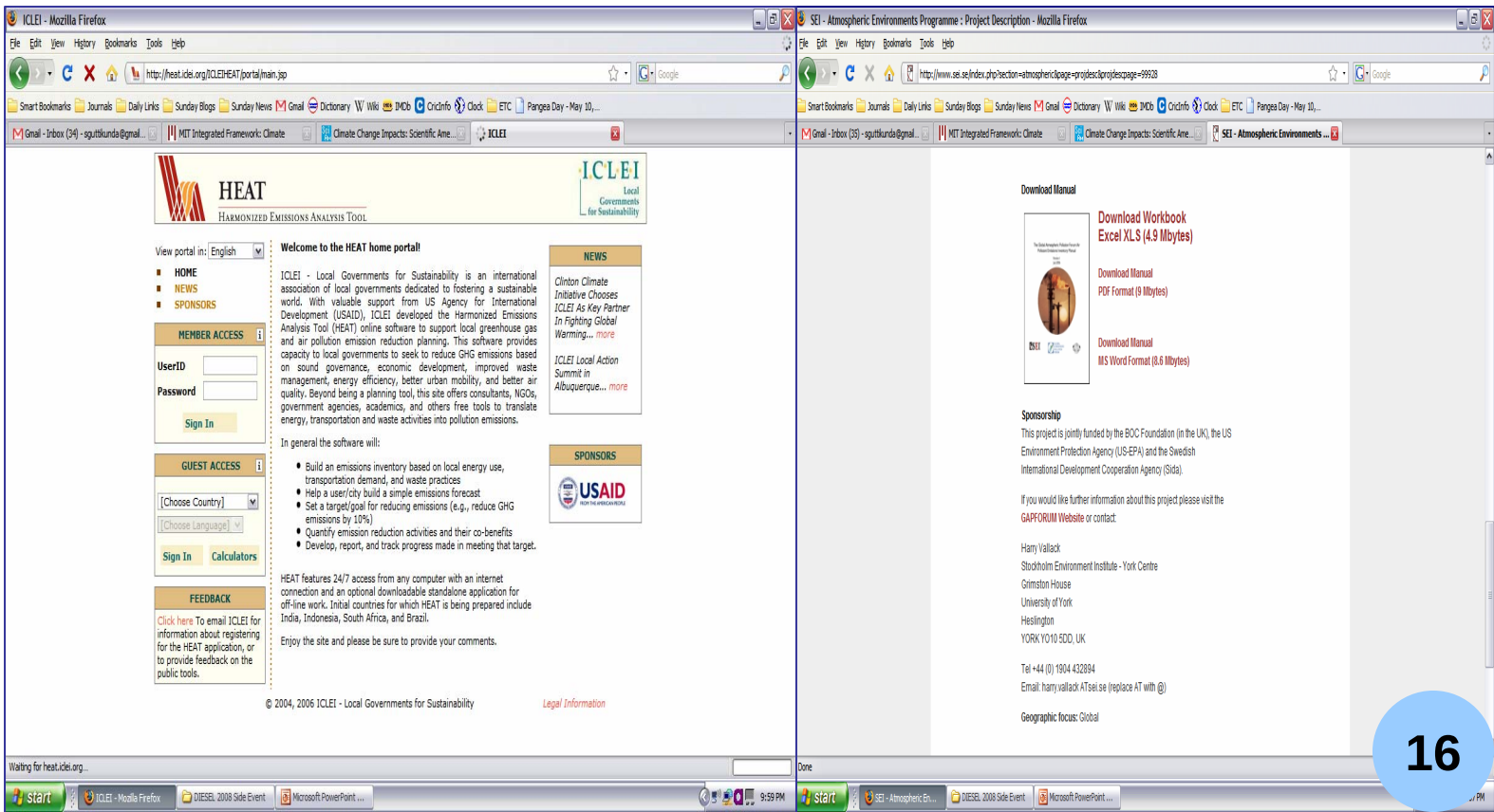
Average Emission Factors for Hanoi Fleet (gm/km)

Vehicle Type	CO	HC	NOx	CO2	PM
1995					
Motorcycle	13.07	2.55	5.00	42	0.03
Car	4.60	0.40	1.06	234	0.11
Truck	18.47	4.50	32.80	1302	1.47
Bus	10.35	0.30	17.85	1402	0.38
2005					
Motorcycle	8.72	1.70	0.34	40	0.02
Car	3.07	0.27	0.71	205	0.07
Truck	18.00	4.90	31.60	1077	0.67
Bus	6.90	0.20	11.50	1277	0.25

This dataset is compiled by the World Resources Institute (WRI) under the Transport Emissions Analysis program for Hanoi (EMBARQ). A detailed report is available

@ http://www.embarq.org/en/city/hanoi-vietnam

HEAT & SEI Workbooks



For further research, emission factor databases

1. United States Environmental Protection Agency's AP-42 Handbook @ http://www.epa.gov/ttn/chief/ap42/
2. United States National Freight Transportation Trends & Emissions @ http://www.fhwa.dot.gov/environment/freightaq/chapter2.htm
3. MOVES (Motor Vehicle Emission Simulator) @ http://www.epa.gov/otaq/models/moves/index.htm
4. Emission Factor Database by National Atmospheric Emissions Inventory of UK @ http://www.naei.org.uk/emissions/index.php
5. Air Pollutant Inventory Program of SEI @ http://sei-international.org/gapforum/tools.php
6. Harmonizing Emissions Analysis Tool by ICLEI @ http://heat.iclei.org
7. COPERT by European Environmental Agency @ http://lat.eng.auth.gr/copert/
8. IPCC Guidelines for GHG Inventory @ http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
9. GAINS of IIASA @ http://www.iiasa.ac.at/rains/gains.html
10. TREMOVE for European Countries @ http://www.tremove.org/index.htm
11. EMEP Corinair Emissions Inventory Guidebook @ http://reports.eea.europa.eu/EMEPCORINAIR3/en/page011.html

Estimating Emission Factors from Emission Standards

Most often, for many reasons, local specific emission factors are hard to come by. In which case, an option is to estimate the emission factors based on the emission standards and following the equation on Page 2.

$$EF_{age} = ES_{new} * (1 + drate)^{\wedge age}$$

$$EF_{effective} = \sum_{age=1}^{age=n} EF_{age} * Frac_{age}$$

The deterioration rates can be based on existing studies (like on Page 15) for the fleet mix.

Emission Standards in Asia

Country	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
European Union	E1	Euro 2					Euro 3				Euro 4				Euro 5					E6
Bangladesh[a]											Euro 2									
Bangladesh[b]											Euro 1									
Hong Kong, China	Euro 1		Euro 2				Euro 3					Euro 4								
India[c]							Euro 1				Euro 2				Euro 3					
India[d]					E1		Euro 2				Euro 3				Euro 4					
Indonesia											Euro 2									
Malaysia			Euro 1											*Euro 2*			*Euro 4*			
Nepal						Euro 1														
Pakistan																				
Philippines									Euro 1				Euro 2							
PRC[a]							Euro 1			Euro 2			Euro 3			Euro 4				
PRC[e]							Euro 1		Euro 2			Euro 3		*Euro 4 Beijing only*						
Singapore[a]	Euro 1						Euro 2													
Singapore[b]	Euro 1						Euro 2					Euro 4								
Sri Lanka									Euro 1											
Taipei,China					US Tier 1								US Tier 2 for diesel [g]							
Thailand	Euro 1						Euro 2		Euro 3								Euro 4			
Viet Nam													Euro 2							

Source: CAI-Asia Center, Manila, Philippines

Sulfur Level Standards in Diesel in Asia (ppm)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Bangladesh							5000									
Cambodia					2000				1500							
Hong Kong, China		500					50					*10 - under consideration*				
India (nationwide)	5000				2500					500					350	
India (metros)	5000				2500	500				*350*					*50*	
Indonesia	5000										2000				*350*	
Japan[a]	500									50		10				
Malaysia	5000		3000				*500 - marketed*			500					*50*	
Pakistan	10000						5000			*1000*						
Philippines	5000					2000			500						*50*	
PRC (nationwide)	5000						2000			*500 - widely used*					*50*	
PRC - Beijing	5000						2000		500	350			*50*			
Republic of Korea	500								100			*15/10*				
Singapore	3000		500								50					
Sri Lanka	10000							5000	3000/ 500		*500*					
Taipei,China	3000			500			350		100						50	
Thailand	2500			500					350		150				50	
Viet Nam	10000							2500			500				*150*	
European Union					500					50/ 10			10			
United States	500										15					

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