ON ROAD
MOPEDS AND MOTORCYCLES

Prepared in the framework of EGTEI

1. Activity description and EGTEI contribution - summary

The base case of the European Auto Oil Program AOP II had foreseen an increase of the share of VOC emissions emanated from Powered-Two-Wheelers (PTWs) from 4.1% in 1995 to 20% in 2020 of the total transport VOC emissions. This is due to the fact that stricter emission limits are implemented for on-road vehicles (e.g PC, LDV, HDV). That is why a new regulation was adopted in 2002 to strengthened motorcycle emission limits [1].

Mopeds and small motorcycles are generally equipped with 2-stroke engines whereas bigger motorcycle engines are 4-strokes. However, 2-stroke engines tend to be replaced by 4-stroke engines even for mopeds. This has a big importance because pollutants and abatement techniques are different for these two types of engines.

For *2-stroke engines*, NOx emissions are relatively low because of the natural exhaust gas recirculation (natural EGR) of these types of engines.

For *4-stroke engines,* VOC emissions are lowered because no intake mixture is directly routed to the exhaust but combustion peak temperature being higher than for 2-stroke engines, NOx emissions are higher.

SO_2 emission levels are proportional to the sulphur content of the fuel used. The only way to reduce SO_2 emissions is to reduce the gasoline sulphur content. TSP emissions are not a big issue for these types of engines. They are not considered in this document as no data has been found.

In RAINS [2], two sectors are considered separately: motorcycles gasoline 4-stroke engines (TRA_RD_M4-GSL) and motorcycles, mopeds or cars gasoline 2-stroke engines (TRA_RD_LD2-GSL). NOx emissions at a EU25 level (according to the RAINS model: version CP_CLE_Aug04(Nov04)) are about 1.3 kt for 2-stroke engines and 10.4 kt for 4-stroke (representing respectively 0.02 and 0.15% of total transport emissions). VOC emissions are respectively 308.3 and 103.6 kt (representing 8.3 and 2.8% of total transport emissions).

Mopeds and motorcycles are addressed by the European Directives 97/24/EC [3] and 2002/51/EC [1]. Gasoline is also regulated by the Directives 98/70/EC [4] and 2003/17/EC [5]. In order to be able to better represent these sub-sectors in terms of emission reductions and costs, they **have been considered as individual activities by EGTEI [6]**.

Activity is defined as the amount of gasoline consumed annually (PJ/year). Engines are distinguished according to the type of vehicle considered and to its size.

EGTEI provides default emission factors (EF) with abatement efficiencies, investments as well as unit costs (€/t pollutant abated) for the different measures. No information has been found concerning variable costs (corresponding to maintenance and repair and defined as a percentage (%) of investments in RAINS).

National experts have to collect engine specific parameters (annual mileage and annual consumption in GJ/engine) and fuel parameters (annual total fuel consumption from 2000 to 2020 and fuel costs according to the year).

EGTEI economic parameters have been introduced in RAINS to update data used in the previous version.

In the future, any new stage of the regulation should be considered with corresponding emission factors and costs.

2. European regulation

Two Directives regulate emissions from moped and motorcycle engines:

2.1 Directive 97/24/EC [3]

This Directive has been implemented to reduce two and three wheels vehicles air pollutant emissions: standards have been adopted in two steps for mopeds and one step for motorcycles. This Directive foresees that stricter standards (for motorcycles only) should be implemented in the two years following the date of compliance with stage I (i.e.: 1999).

Table 2.1.1: Emission standards [g/km]

Type of engine	Dates of Appliance	Stage	HC + NOx [g / km]	HC [g / km]	NOx [g / km]
Mopeds	17/06/1999	Stage I	3.0	-	-
Mopeds	17/06/2002	Stage II	1.2	-	-
Motorcycle 2-stroke	17/06/1999	Stage I	-	4.0	0.1
Motorcycle 4-stroke	17/06/1999	Stage I	-	3.0	0.3

2.2 Directive 2002/51/EC [1]

This Directive implements new standards for motorcycles only on the bases of researches on technical feasibility. Mopeds are not considered by this amendment because a stage II is already provided for in Directive 97/24/EC.

Standards are implemented in two phases as shown in table 2.2.1. No distinction is made between two-and four-stroke engines.

Table 2.2.1: Emission standards [g/km]

Type of engine	Dates of Appliance	Stage	HC [g / km]	NOx [g / km]
Motorcycle < 150cc (cubic centimeter)	01/04/2003	Stage II	1.2	0.3
Motorcycle > 150cc			1.0	0.3
Motorcycle < 150cc	01/01/2006	Stage III *	0.8	0.15
Motorcycle > 150cc			0.3	0.15

* In 2006 a new test cycle will be used to be more representative of real emissions.

The Commission shall consider a new set of limit values (stage III) for mopeds, including particulate emissions in accordance with the results of technical studies, to be applied from 2006.The provisions on durability requirements and the obligation to measure specific CO_2 emissions in type approval will also be applied to mopeds.

Only gasoline is used in these engines. Gasoline sulphur content is regulated by Directives 98/70/EC [4] and 2003/17/EC [5] relating to the quality of gasoline and diesel fuels.

Table 2.2.2: Gasoline sulphur content: standards (ppm) implemented by the two Directives

Dates of compliance	2000	2005	2008
Sulphur content in petrol (ppm)	150	50	10

3. Methodology developed within EGTEI to represent the sector

3.1 Definition of reference engines

Reference engines are defined to determine costs incurred by the reduction of emissions in the different countries. Five different reference engines are described according to the techniques used and the different engine sizes.

Table 3.1.1: Reference engines

Reference engine codes (REC)	Description
01	Moped engine < 50 cc
02	Motorcycle 2-stroke > 50 cc
03	Small motorcycles 4-stroke 50-150 cc
04	Medium motorcycles 4-stroke 150-400 cc
05	Large motorcycles 4-stroke > 400 cc

3.2 Definition of emission abatement techniques

Abatement techniques are defined according to the type of engine considered and to the technique used.

Mopeds: to comply with stage I standards, oxidation catalysts (OC) have been used.

For the second stage of the regulation, three approaches are possible: either the use of a more efficient catalyst with second air injection (SAI) or the use of electronic fuel injection (EFI) with a catalyst or the use of a 4-stroke engine.

The completion with a potential stage III could be obtained with the use of direct injection (DI) technology. This potential stage is not yet considered in the European regulation.

Motorcycles: standards of stage I have been reached with engine modifications (EM).

Three technologies have been used to reduce further 4-stroke engine emissions:
- Secondary air injection (SAI) with efficiency on VOC emissions of about 25%.
- Oxidation catalysts (OC) with or without SAI with efficiency on VOC emissions of about 50-60%.
- Closed loop three way catalyst (TWC) with efficiency on VOC emissions of about 60-80%. Only this technique makes it possible to reduce NOx emissions.

For *2-stroke motorcycle engines*, the oxidation catalyst (OC) and the direct injection (DI) are technically feasible. With the use of DI, VOC emissions have been reduced to the level achieved with 4-stroke engines (reduction of 70% of VOC emissions). This technique also reduces fuel consumption. The only drawback is the increase in NOx emissions. DI will probably be the only technique allowing 2-stroke engines to comply with Stage III requirements (2006).

Table 3.2.1: Techniques used to reach the standards

REC	Stage I	Stage II	Stage III
01	OC	EFI	DI
02	EM	DI	DI/OC
03	EM	OC	SAI/OC
04	EM	SAI/OC	TWC
05	EM	SAI/OC	TWC

Table 3.2.2: Aggregated abatement techniques

Measure Code (MC)	Description
00	Pre-control stage
01	Stage I
02	Stage II
03	Stage III

4. Country specific data to be collected

Data to be provided are:
- the number of each type of vehicles,
- the annual distance (km/y) driven per vehicle in 1990 and 2000 (and the change in activity per engine from 2005 to 2020 relative to the base year 2000),
- the annual fuel consumed (GJ/y) per vehicle in 1990 and 2000 (and the fuel efficiency improvement for individual engine sizes from 2005 to 2020 relative to the base year 2000).

As emission factors are given in g/km, it is possible to calculate unit costs if annual distances driven are known. Table 4.1 shows European average figures from documents provided by [7].

Table 4.1: Default values used to calculate abatement costs

REC	Annual distance driven (km/y)	Lifetime (years)
01	1,500	10
02	5,200	10
03	5,200	10
04	5,200	10
05	5,200	10

5. Default emission factors and cost data defined with the EGTEI methodology

Table 5.1.1 gives an overview of all data provided by EGTEI: default emission factors (EF), investments as well as unit costs per t pollutant abated.

5.1 Reduction of VOC and NOx

Technical and economic parameters are all derived from documents from the European Motorcycle Industry Association [7]. The document has been reviewed and commented by experts from this association.

To calculate unit costs, annual emissions per engine are first calculated by multiplying annual driven distances given in paragraph 4 by emission factors provided in table 5.1.1. Then, total investments are annualised (taking into account lifetimes shown in table 4.1 and an interest rate of 4%) to calculate unit costs for the two pollutants.

Emission factors given in table 5.1.1 are based on average data found in the literature: they are not country specific. They were not available in the EGTEI background document [6] as they might slightly vary from country to country: emission factors are usually defined at a country level by using COPERT equations (as indicated in the EGTEI background document [6]). They are only provided in table 5.1.1 to calculate unit costs but have to be handled with care.

When the technique does not reduce a pollutant, no abatement cost is calculated.

Table 5.1.1: Emission factors (EF), investments and unit costs for each combination

REC MC	VOC EF [g/km]	NOx EF [g/km]	Investment [€/engine]	Unit cost [€/ t. VOC abated]	Unit cost [€/ t. NOx abated]
01 00	5	0.03	1,200	-	-
01 01	2.25	0.03	1,248	1,435	-
01 02	1.1	0.01	1,296	2,023	392,568
01 03	0.5	0.003	1,440	4,384	730,613
02 00	10	0.1	2,800	-	-
02 01	4	0.1	2,870	277	-
02 02	1.2	0.2	2,996	528	-
02 03	0.8	0.15	3,133	858	-
03 00	5.1	0.3	3,250	-	-
03 01	3	0.3	3,300	565	-
03 02	1.2	0.3	3,373	748	-
03 03	0.8	0.15	3,488	1,312	37,620
04 00	5.1	0.3	4,500	-	-
04 01	3	0.3	4,560	677	-
04 02	1	0.3	4,699	1,151	-
04 03	0.3	0.15	4,860	1,778	56,904
05 00	5.1	0.3	8,000	-	-
05 01	3	0.3	8,105	1,185	-
05 02	1	0.3	8,360	2,082	-
05 03	0.3	0.15	8,608	3,003	96,104

* Only investments are taken into account in the calculations

5.2 Sulphur content of fuels

The different fuel type costs have to be entered only once in ECODAT in the table “Fuel characteristics”. Additional investment and refinery operating costs associated with lowering the sulphur content from a maximum of 50 ppm to a maximum of 10 ppm are defined in the report [8]. EGTEI proposes two sets of default costs for EU North and EU South. According to reference [8], the main driver of cost difference between north and south EU is the crude oil quality (in particular the sulphur content) handheld in refineries.

Table 5.2.1: Costs of lowering the sulphur content of gasoline [8]

	Min. (€/l)	Max. (€/l)	Average (€/l)
EU. North	0.001	0.003	0.002
EU. South	0.002	0.003	0.0025

6. Relevance of EGTEI information for Integrated Assessment Modelling (IAM)

Only EGTEI economic data have been introduced in RAINS to update investments already used in the previous version. In RAINS, only two types of engines are defined (2- and 4-stroke) as very few country specific data are available. More detailed information is thus needed from national experts to have a better representation of this sector.

7. Perspective for the future

In the future, any new technology development should be considered by EGTEI in the background document to continuously improve the representation of the sector. This is crucial to well represent this sector in RAINS.

8. Bibliography

[1] Directive 2002/51/EC of the European Parliament and of the Council of 19 July 2002 on the reduction of the level of pollutant emissions from two- and three-wheel motor vehicles and amending Directive 97/24/EC.

[2] Review of data used in RAINS model: http://www.iiasa.ac.at/web-apps/tap/RainsWeb/

[3] Directive 97/24/EC of the European Parliament and of the Council of 17 June 1997 on certain components and characteristics of two or three-wheel motor vehicles.

[4] Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC [Official Journal L 350, 28.12.1998].

[5] Directive 2003/17/EC of the European Parliament and of the Council of 3 March 2003 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels.

[6] EGEI background document. http://www.citepa.org/forums/egtei/two_wheels_311003.pdf

[7] ACEM Associations des Constructeurs Européens de Motocycles. http://www.acembike.org/html/start.htm

[8] The costs and benefits of lowering the sulphur content of petrol & diesel to less than 10 ppm. Prepared by Directorate-General Environment. 9 September 2001.