INLAND WATERWAYS

SYNOPSIS SHEET

Prepared in the framework of EGTEI

1. Activity description and EGTEI contribution - summary

This document concerns new marine diesel engines rated at or above 37 kW. For most marine engines of less than 5,000 kW techniques are expected to be derived from land-based engines already regulated.

Three categories of engines are differentiated:

Category 1 engines are small engines used in recreational and light commercial applications.

Category 2 engines are medium-sized engines such as those used in tugboats.

Category 3 engines are the largest engines used primarily for propulsion in ocean-going.

Engines can be derived from the land-based non-road technologies, locomotives or are manufactured on a unique basis for propulsion of very large ocean-going vessels.

At a EU25 level for the year 2000 (according to the RAINS model: version CP_CLE_Aug04(Nov04)), NOx emissions were about 96.6 kt representing 1.4% of NOx emissions from mobile sources and 13.2 kt of NMVOC being about 0.3% of NMVOC emissions from mobile sources.

Inland waterways diesel engines are addressed by the European Directive 2004/26/EC [1], related to the reduction of air emissions from the use of diesel engines. Fuels used are also regulated by the Directives 98/70/EC [2], 99/32/EC [3] and 2003/17/EC [4]. In order to be able to better represent the impact of these Directives in term of emission reductions and costs, this sector **has been considered as an individual activity by EGTEI [5]**.

This sector was already considered separately in the previous RAINS version [6] but **EGTEI has been able to develop a specific approach defined on updated sources [7]**. **The methodology for this sector is based on the engine types considered in the Directive 2004/26/EC.** Presently, RAINS has been modified to integrate some of the EGTEI proposals concerning the cost definitions [8]. In the EGTEI background document, emission factors are based on emission limit values implemented by the Directive. **The new RAINS version was used for the modelling work carried out in the scope of the CAFÉ programme and the revision of the Gothenburg Protocol and national emission ceiling Directive.**

The representative unit used is the amount of fuel consumed annually (PJ/year). Engine's sizes are based on the definitions of the Directive. Five sizes are considered.

In the EGTEI document, only one stage is taken into account as in the regulation as no data was found on further abatement techniques.

EGTEI provides default emission factors (EF) with abatement efficiencies, investments as well as unit costs (€/t pollutant abated) for each engine's category. No information has been found concerning variable costs (corresponding to maintenance and repair and defined as a percentage (%) of the investment in RAINS).

National experts have to collect engine specific parameters (either load factor, yearly operating hours and lifetime for each category of engines or annual consumption in GJ/engine) and fuel parameters (annual fuel consumption from 2000 to 2020, fuel types and fuel costs according to the year).

Even if the representation of this sector in RAINS is only partly based on the EGTEI proposal (one average engine is defined to represent the whole sector), it is recommended to national experts to complete the Excel spreadsheet developed by EGTEI. Indeed, very few country specific data exist for off-road sectors and if more detailed data can be provided, more realistic data (in terms of emissions, costs and control strategy) will be used in RAINS.

In the future, any new stages of the regulation or new technical improvements should be considered in EGTEI with corresponding emission factors and costs. In RAINS, 6 stages are defined so it would be interesting to develop specific investments and abatement efficiencies for these technologies.

2. European regulation

Directive 2004/26/EC [1] has been adopted to treat, among other types of engines, the diesel inland waterways engines. Emission limit values, according to the size of the engine considered, are defined in table 2.1 bellow.

Table 2.1: Emission limit values

Category	Displacement (liters/cylinder)	NOx + HC (g/kWh)	PM (g/kWh)
1	Power > 37 kW Disp. < 0.9	7.5	0.4
	0.9 < disp. < 1.2	7.2	0.3
	1.2 < disp. < 2.5	7.2	0.2
	2.5 < disp. < 5.0	7.2	0.2
2	5.0 < disp. < 15	7.8	0.27
	15 < disp. < 20 Power < 3300 kW	8.7	0.5
	15 < disp. < 20 Power > 3300 kW	9.8	0.5
	20 < disp. < 25	9.8	0.5
	25 < disp. < 30	11.0	0.5

Off-road fuels are most commonly supplied as heating oil quality with dye/marker, at a lower duty rate than road fuels. In some countries, road fuel quality is supplied to part or all of the non-road mobile machinery fuel market. Sulphur contents in the different fuel types are defined in the following Directives:

Table 2.2: Regulations on sulphur content of fuels

Directive References	Scope	Exemptions
98/70/EC [2] 2003/17/EC [4]	Quality of petrol and diesel fuels	-
99/32/EC [3]	Sulphur content of fuels : gas-oil and heavy fuel	Diesel and gasoline as defined in the Directive 98/70/CE

Table 2.3: Sulphur content of fuels: standards (ppm) implemented by the Directives

Fuels	2000	2005	2010
Diesel	350	50	10
Gas-oil and heavy fuels	2,000	2,000	1,000

3. Methodology developed within EGTEI to represent the sector

3.1 Definition of reference engines

Nine engine categories are defined in the European Directive. In the EGTEI background document [5], only five categories are considered as investments are not different between the 9 categories.

Table 3.1.1: Reference engines

Reference engine code (REC)	Power range
01	100 representing the range 37-225 (MARPOL)
02	400 representing the range 225-560 (MARPOL)
03	750 representing the range 560-1,000 (MARPOL)
04	1,500 representing the range 1,000-2,000 (MARPOL)
05	3,000 representing the range 2,000-5,000 (MARPOL)

3.2 Definition of emission abatement techniques

The USEPA [7] supposes that to meet the new emission limit values, Category 1 engine manufacturers will have to conduct basic engine modifications, upgrade fuel systems and improve after cooling systems.

For Category 2, manufacturers are expected to redesign combustion chambers, improve high-pressure fuel injection systems and upgrade or add turbo charging and after cooling.

Measures are defined as a mix of techniques to reach the stage I emission limit values defined in the Directive.

Table 3.2.1: Aggregated measures

Measure codes MC	Description
00	None
01	Mix of technologies to reach Stage I emission limit values

4. Country specific data to be collected

National experts do not have to calculate emissions per engine category. Calculations will be done in RAINS. However, experts are requested to provide country-specific data for calculations. The formulas used and the appropriate coefficients are presented below (2 options are available):

- Option I: annual NOx, VOC and TSP emissions per engine can be calculated with the following equation:

$$E\ [t/y] = \text{Load Factor} \times \text{Power [kW]} \times \text{Annual use [h/y]} \times \text{Emission Factor [g/kWh]} / 10^6$$

Country specific data (engine characteristics) are required for each Reference Engine:

- Load factor (<1 : gives the average power delivered by the engine),
- Annual use (h/y),
- Operating lifetime (year).

Option II (consumption method): emission factors are expressed in g of pollutant/GJ using the engine's efficiency. This method is used to estimate emissions in RAINS because it is a simplified approach.

According to CIAM [6], engine's efficiency is considered to be about 40% for diesel engines. Currently, no better data have been provided.

$$E\ [t/y] = \text{Fuel consumption [GJ/y]} \times \text{Emission Factor [g/GJ]} / 10^6$$

In this case, only the total fuel consumption and the operating lifetime per size of engines have to be provided.

Default values for all types of use are based on reference [7]. They are presented hereafter.

Table 4.1: Default values to calculate emissions per engine

Reference engine code REC	Load factor	Annual use (h/y)	Operating lifetime (years)
01	60	2,270 – 2,350	16
02	72	3,240 – 3,770	16
03	79	4,500	16
04	79	4,500	16
05	79	4,500	23

These data have been used to calculate annual emissions per engine and then unit costs presented in table 5.1.

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, NOx and TSP

To calculate unit costs, annual emissions per engine are first calculated with the equation given in paragraph 4. Then, total investments are annualised (taking into account lifetimes given in table 4.1 and an interest rate of 4%) to calculate abatement costs for the three pollutants.

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

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

REC MC	VOC EF [g/outp.kWh]	NOx EF [g/outp.kWh]	TSP EF [g/outp.kWh]	Invest. [€/engine]	Unit costs [€/t VOC]*	Unit costs [€/t NOx]*	Unit costs [€/t TSP]*
01 00	0.27	10-11	0.4-0.9	0	-	-	-
01 01	0.20	7.3	0.4	2,106	18,629	408	5,216
02 00	0.27	10.0	0.3	0	-	-	-
02 01	0.20	7.0	0.3	3,743	4,546	106	-
03 00	0.27	10.0	0.3	0	-	-	-
03 01	0.20	7.0	0.2	29,622	13,621	318	9,535
04 00	0.27	13.0	0.3	0	-	-	-
04 01	0.20	7.0	0.2	26,618	6,120	71	4,284
05 00	0.27	13.0	0.3	0	-	-	-
05 01	0.20	7.6-10.8	0.27-0.5	63,211	5,699	105	13,298

* Only investments are taken into account in the calculations

When an emission factor range is given, the average figure is used for the calculations.

Unit costs for VOC and TSP are high because the most important pollutants concerned by the Directive are the NOx. Unit costs vary significantly from one reference engine to another according to default data given in table 4.1.

5.2 Sulphur content of fuels

Fuels used have to be defined with their sulphur content and their cost from 2000 to 2020.

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

In the previous RAINS version [6], diesel inland waterways engines were already considered as a separate sector. The new RAINS version [8] takes into account some of the EGTEI proposals (especially on cost issues). Six abatement measures are defined in RAINS instead of one in the EGTEI document.

A simplified approach is used in RAINS due to a lack of country specific data. Detail information for off-road sectors is very difficult to find: only one engine category is considered to represent this sector (an average engine rated between REC01 and REC 02 is considered). Data are then used in two different sectors: inland waterways and rail because it is assumed in RAINS that these engines are very similar in terms of size.

Uncontrolled emission factors are the same than for other diesel off-road engines, and efficiencies for the 6 stages defined in RAINS are based on those of large diesel engines.

Then, the annual fuel consumption per engine (GJ/year) is defined enabling calculating unit costs for each pollutant. This parameter is different for inland waterways and rail engines so unit costs will be different for these 2 categories. Control strategies can also be defined separately as regulations are not the same.

Data provided by national experts at a more detail level (as defined in the EGTEI background document) will help defining more precisely the situations in each country. If national experts have more specific data, they can be used in RAINS to redefine average power rates (which will have an influence on costs) and annual fuel consumptions. The control strategy in each country has also to be defined as it has a great influence on emissions.

If national experts have more data, they can also review emission factors used in the RAINS model as they are calculated with an engine efficiency of 40%. This factor has a big influence on total emissions.

This is then very important for national experts to fill in EGTEI spreadsheet with detail information to facilitate the discussion during the bilateral consultations with CIAM.

7. Perspective for the future

In the future, any new stage should be considered by EGTEI in the background document to continuously improve the representation of the sector. As presented above, 6 stages are defined in RAINS. New specific data should be developed to update the document.

8. Bibliography

[1] Directive 2004/26/EC of the European Parliament and of the Council of 21 April 2004 amending Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery.

[2] 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].

[3] Council Directive 1999/32/EC of 26 April 1999 relating to a reduction in the sulphur content of certain liquid fuels and amending Directive 93/12/EEC [Official Journal L 121, 11.05.1999].

[4] 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.

[5] EGEI background document. http://citepa.org/forums/egtei/inland_waterways_270603.pdf

[6] Z. KLIMONT; J. COFALA ; I. BERTOK ; M. AMANN ; C. HEYES and F. GYARFAS. Modelling Particulate Emissions in Europe. A Framework to Estimate Reduction Potential and Control Costs. Interim Report. IR-02-076. IIASA. 2002.

[7] Final Regulatory Impact Analysis ; Control of Emissions from Marine Diesel Engines. EPA. Engine Programs and Compliance Division. Office of Mobile Sources. EPA420-R-99-26.November 1999.

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

ANNEXE: Example of data collection and use of EGTEI data – Case of France

A. Country specific data collection and scenarios developed

Activity levels are derived from the French national statistics on fuel consumption per sector (after a pre-treatment of the data). Fuel consumption is defined for diesel inland waterways.

Fuel consumption forecasts are based on a scenario developed by France in June 2004. This exercise is under revision for the CAFÉ programme so data presented in table A.1 are provisional. These figures have not been validated by the French expert yet. For the years 2005 and 2015, average figures are taken into account.

Table A.1: Fuel consumption (PJ / y)

Activity	2000	2005	2010	2015	2020
Diesel [PJ]	2.8	2.9	3.0	3.25	3.5

Fuel parameters for 2000 are based on annual data provided by the French Petroleum association (UFIP).

Table A.2: Fuel parameters

	2000	2005	2010	2015	2020
Diesel sulphur content (%)	0.2	0.2	0.1	0.1	0.1
Heat value of diesel [GJ/t]	42	42	42	42	42

Fuel costs should be provided by the French Ministry of economy and industry (MINEFI).

French specific data are available at different level of detail according to the sub-sector:

The number of each engine type is known from an enquiry realised for a study concerning inland waterways emissions in France (CITEPA-2000). The activity shares per engine's category are presented in table A.4. They are assumed to remain constant between 2000 and 2020.

Table A.4: Activity levels per category of engine (% of total activity)

RIC	2000 - 2020
01	45.3
02	41.2
03	9.5
04	3.7
05	0.3
Total	100

The control strategy presented in table A.5 is calculated by considering an average engine size (this can be done because REC 01 + REC 02 + REC 03 represent 96% of total activity). Assuming an average lifetime of 16 years for these engines, 6.25% of the fleet is replaced each year: engines replaced after the end of 2006 have to comply with the stage I emission limit values.

Table A.5: Application rates of stage I (% of activity)

REC	2000	2005	2010	2015	2020
None	100	100	75	43.75	12.5
Stage I	0	0	25	56.25	87.5
Total	100	100	100	100	100

At the end of 2010, 25% of the activity will comply with stage I (this corresponds to 4 years x 6.25%).

B. Trends in emission factors and emissions

Emissions are calculated with a simplified approach by considering average emission factors (table B.1) and the control strategy defined in table A.5. Average emission factors and emissions are presented bellow.

Table B.1: Emission factors evolving with the control strategy

REC	2000	2005	2010	2015	2020
NMVOC (g/GJ)	112	112	104.7	95.6	86.5
NOX (g/GJ)	1,012	1,012	928.5	824.1	719.8
TSP (g/GJ)	107	107	97.1	84.7	72.4
SO_2 (g/GJ)	95	95	48	48	48

Emissions are given in table B.2.

Table B.2: Emissions from 2000 to 2020

REC	2000	2005	2010	2015	2020
NMVOC (kt)	0.3	0.3	0.3	0.3	0.3
NOX (kt)	2.8	2.9	2.8	2.7	2.5
TSP (kt)	0.30	0.31	0.29	0.27	0.25
SO_2 (kt)	0.27	0.28	0.14	0.16	0.17