PETROLEUM INDUSTRY: COMBUSTION PROCESS

SYNOPSIS SHEET

PREPARED IN THE FRAMEWORK OF EGTEI

1 Activity description and EGTEI contribution – summary

This sector covers emissions from **power plants in refineries** producing steam and/or electricity . Combustion engines and gas turbines are not included. Fired boilers and furnaces generate substantial SO_2, NO_x and particulate emissions, particulary when **heavy fuel oil** is used. **Gas**-fired boilers generate hardly any dust and low SO_2 emissions, when the refinery gases are cleaned in amine scrubbers. NO_x emissions are also much lower than those of oil-fired boilers.

This sector is considered as an individual sector in the previous NOx and SO_2 version of RAINS [2, 3], and EGTEI has been able to develop an approach for representing this sector and to estimate costs of reduction techniques. **The methodology for this sector was developed in close cooperation with CONCAWE and with experts from TOTAL, SHELL and ADEME.**

The representative unit used is the PJ fuel input. Two reference installations (RI) have been defined depending on the fuel burned. The first burns heavy fuel oil and the second natural gas.
EGTEI defines different abatement measures. However, as for dust, the group of experts agreed that **no dust abatement** techniques are installed in refinery boilers. For NOx abatement measures, **a low NOx burner and a secondary measure** allowing to achieve different abatement emission levels have been defined. For reducing the SO_2 emissions, **fuel switch and the use of a wet scrubber** are proposed.
EGTEI provides default emission factors (EF) with abatement efficiencies, investments and variable and fixed operating costs (OC) as well as unit costs (€/t pollutant abated and €/activity unit) for the different abatement measures.
National experts only need to collect **7 country specific parameters** (wages, electricity, ammonia price, catalyst cost, limestone cost and fuel prices) and **4 country and sector specific parameters** (activity level and the different pollutant emissions). EGTEI provides default costs for country and specific parameters which can be used if no better data exist. Knowing the 4 sector specific parameters then allows to properly describe the sector and to calculate the application rate of each abatement technique.

2 Representation of the sector in RAINS[1]

In the NOx and SO_2 RAINS models of the year 2003, which have been used for elaborating the background document, the RAINS sector “CON_COM” represented the fuel production and conversion. For the PM module, the refinery sector is aggregated in the RAINS sector “Fuel combustion in industrial boilers”.

3 Status of EGTEI

EGTEI has developed an approach for representing the Refinery sector and estimating costs of reduction techniques. The methodology used for this sector was developed in close cooperation with CONCAWE and with experts from TOTAL, SHELL and ADEME. EGTEI provided information on cost and for the Reference installation burning natural gas a range because of the lack of information. All new information delivered by experts are welcome to help the expert group to propose only one investment.

4 Methodology developed within EGTEI to represent the sector

4.1 Definition of reference installations

There are some 100 Refineries in Europe and each of those Refineries will have several heaters/furnaces; something of the order of a 1000. CONCAWE does not have information on all those heaters but has enough data to do a representative sample, a selection of 50. Their size varied from 7MW up to 386 MW. Here the range 30-150 MW was taken as representative. The heaters were geographically dispersed from Scandinavia to Italy.
According these statistics, the expert group choose a capacity of 50 MW_{th}.

[1]The latest modified versions of the RAINS modules have not been considered. Here we refer to the RAINS model of the year 2003

Table 4.1: Reference Installations

Reference Code	Technique	Fuel	Capacity [MWth]
01	Combustion unit	Heavy fuel oil	50
02	Combustion unit	Gas	50

4.2 Definition of emission abatement techniques and proposed techno-economic data

4.2.1 Dust abatement techniques

No dust abatement techniques are installed in refinery boilers.

Table 4.2.1.1: Abatement Measures for dust

Description	EF TSP [mg/Nm³] mean value	EF TSP [g/GJ fuel input] mean value
Reference Installation 01		
Uncontrolled	200-1000	56-280
Reference Installation 02		
Uncontrolled	5	1.35

Remark: An average conversion factor (F_{conv}) between concentrations of pollutants (in mg/Nm^3) and specific mass flows of pollutants (emission factor, in g per **GJ fuel input**) [4]
Concentration of pollutant emitted (in mg/Nm^3) x F_{conv} = Specific mass flow of pollutant emitted (in mg/GJ fuel input)

For liquid fuels: *F_{conv}= 280 Nm^3/GJ (3 % O_2, dry)*

For gaseous fuels: *F_{conv}= 270 Nm^3/GJ (3 % O_2, dry)*

4.2.2 NOx abatement techniques

For NOx abatement measures, a low NOx burner and a secondary measure allowing to achieve different abatement emission levels have been defined.

Table 4.2.2.1: NOx abatement measures

Description	EF NO_x [mg/Nm³] mean value	EF NO_x [g/GJ fuel input] mean value	NO_x abatement efficiency [%]
Reference Installation 01			
Uncontrolled	600	168	-
Low NO_x Burner	420	118	30
SNCR(1)	170	48	60
SCR(1)	65	18	85
Reference Installation 02			
Uncontrolled	200	54	
Low NO_x Burner	100	27	50
SNCR(1)	40	11	60
SCR(1)	15	4	85

(1): after having installed the low NO_x burner technology .

Table 4.2.2.2: Investments and Operating costs for NOx abatement measures

Description	Investment (k€)	Fixed Operating costs (%/a)	Variable Operating costs (k€/t)	Total Operating costs (k€/t)	Cost per tonne of NOx abated (€/t) (1)	Cost per PJ fuel input (k€/PJ) (1)
Reference Installation 01						

Low NOx burner	636	4	0	83	1,600	83
Secondary measure	4,250	4	63.7	470	5,300	529
Reference Installation 02						
Low NOx burner	400	4	0	83	1,940	52
Secondary measure	3,850	4	44.2	341	20,800	481

(1): Case of France

Remark: Only one issue of debate persists concerning the description of one abatement measure (the SCR technology) for one pollutant. Two sets of data have been delivered to EGTEI respectively put forward by EGTEI. For modelling purposes only one set can be used. EGTEI proposes to keep the set delivered by CONCAWE, and as soon as new information on cost for this abatement measure may become available, the data set should be up-dated.

4.2.3 SO_2 abatement techniques

The SO_2 abatement techniques are fuel switch and wet scrubber.

Table 4.2.3.1: SO_2 abatement measures

Description	EF SO_x [mg/Nm³] mean value	EF SO_x [t/PJ fuel input] mean value
Reference Installation 01		
Uncontrolled	3,400*	950
Fuel switch HF-GAS	20	5.4
Scrubber (η=90 %)	340	95
Reference Installation 02		
Reference level	20	5.4

Table 4.2.3.2: Investments and Operating costs for SO_2 abatement measures

Description	Investment (k€)	Fixed Operating costs (%/a)	Variable Operating costs (k€/t)	Total Operating costs (€/t)	Cost per tonne of SO_2 abated (€/t) (1)	Cost per PJ fuel input (€/PJ) (1)
Reference Installation 01						
Uncontrolled	-	-	-	-	-	-
Fuel switch HF-GAS	0	4	X(2)	X(2)	X(2)	X(2)
Scrubber (η=90 %)	4,000	4	433	450	1,038	883
Reference Installation 02						
None	-	-	-	-	-	-

(1): Case of France
(2: depending on country specific data

5 Country specific data to be collected

Different types of country specific data have to be collected to give a clear picture of the situation in each Party. EGTEI proposes default values for the economic parameters which can be modified by the national expert if better data are available.
For the refinery sector, country specific economic parameters are used to calculate variable operating costs. They are presented in table 5.1 as default costs proposed by EGTEI (these costs are entered only once in the ECODAT database tool).

Table 5.1: Country specific costs

Parameters	Default costs provided by EGTEI	Country specific costs
Electricity [€/kWh]	0.0569	To be provided by national experts
Wages [€/h]	37,234	To be provided by national experts

Ammonia price [€/t_{NH3}]	400	To be provided by national experts
Catalyst cost [k€/m³]	15	To be provided by national experts
Limestone cost [€/$t_{limestone}$]	100	To be provided by national experts
Gas price [€/GJ]	To be provided by national experts	
Heavy fuel oil price [€/GJ]	To be provided by national experts	

Default data have been used to calculate variable and annual abatement costs presented in tables 4.2.1.2; 4.2.2.2, 4.2.3.2.
Information concerning activity levels from 2000 to 2020 as well as the description of the control strategy is also necessary (these data can be directly entered in the database ECODAT). A full specification of the work to be done by national experts is provided in the general EGTEI methodology.

In order to make collection of data as easy as possible, a methodology is described in the background document, based on the consumption of fuel [5].

Table 5.2: Activity level of each RI

PARAMETER	2000	2005	2010	2015	2020
Natural gas consumption [GJ]					
Heavy fuel oil consumption [GJ]					

Table 5.3: Fuel characteristics of each fuel burned in the sector

	S content [wt-%]	Lower heat value [GJ/t]
Gas		
Heavy fuel oil		

National experts can also modify - in a range of ± 10% - the default unabated emission factor proposed by EGTEI to represent the reference situation of the petroleum industry for all Parties.

Table 5.4: Unabated emission factor [g/GJ]

Pollutants	Default data mean	User input mean
Reference installation 1		
EF PM_{TSP}	56-280	To be provided by national expert
EF NO_x	168	To be provided by national expert
EF SO_2	950	To be provided by national expert
Reference installation 2		
EF PM_{TSP}	1.35	To be provided by national expert
EF NO_x	54	To be provided by national expert
EF SO_2	5.4	To be provided by national expert

6 Application rate and applicability of each abatement technique

The national experts are kindly asked to provide for each abatement technique its application rate and its applicability in 2000, 2005, 2010, 2015, 2020. If a national expert has this information at hand, he can fill in the different tables described in paragraphs 6.1, 6,2.
If not, a methodology is described in the background document [5].

Table 6: Input parameters needed to calculate application rates

PARAMETER	2000	2005	2010	2015	2020
Natural gas consumption [PJ]					
Heavy fuel oil consumption [PJ]					
E_{NOx} Emission of NOx [t]					
E_{SOx} Emission of SO2 [t]					

6.1 NOx abatement measures

Table 6.1: Application rate and applicability for NO_x abatement measures

Description	Application rate in 2000 [%]	Application rate in 2005 [%]	Applicability [%]	Application rate in 2010 [%]	Applicability [%]	Application rate in 2015 [%]	Applicability [%]	Application rate in 2020 [%]	Applicability [%]
Reference installation 1									
None									
Low NOx burner			100		100		100		100
Secondary technologies			100		100		100		100
Reference installation 2									
None									
Low NOx burner			100		100		100		100
Secondary technologies			100		100		100		100

6.2 SO_2 abatement measures

Table 6.2: Application rate and applicability for SO_2 abatement measures

Description	Application rate in 2000 [%]	Application rate in 2005 [%]	Applicability [%]	Application rate in 2010 [%]	Applicability [%]	Application rate in 2015 [%]	Applicability [%]	Application rate in 2020 [%]	Applicability [%]
Reference installation 1									
None									
Fuel switch HF-GAS			100		100		100		100
Wet scrubber			100		100		100		100

Remark:
For this specific pollutant, the regulatory constraints introduced by the LCP directive have to be introduced. The refinery sector uses the *bubble* concept which refers to air emissions of SO_2. This concept is a regulatory tool applied in several EU countries. The bubble approach for emissions to air reflects “a virtual single stack” for the whole refinery. In the revisions of the LCP Directive, the SO_2 emission limit values VEL for new and existing refineries are respectively 600 and 1000 mg/Nm³.

7 Relevance of EGTEI information for Integrated Assessment Modelling (IAM)

EGTEI now provides an approach to consider the combustion sector in refinery. The approach has been developed in close cooperation with industry but needs more information on costs for the SCR installation to deliver to IAM only one data and not a range. For the other pollutants, IAM can use the information to improve their modules.

8 Perspective for the future

For this specific sector, more input from experts is welcome in order to find a consensus on the investment of SCR.
In the future, new production technologies which could gain relevant market shares should be considered by EGTEI in the background document to continuously develop the representation of the sector.

9 Bibliography

[1] Reference document on best available techniques for mineral oil and gas refineries, IPPC, Sevilla, 2001.
[2] Nitrogen oxides emissions, abatement technologies and related cost for Europe in the RAINS model database, IIASA, 1998. http://www.iiasa.ac.at/~rains/reports/noxpap.pdf
[3] Sulfur emissions, abatement technologies and related cost for Europe in the RAINS model database, IIASA, 1998. http://www.iiasa.ac.at/~rains/reports/so2-1.pdf
[4] Modelling Particulate Emissions in Europe, A framework to Estimate Reduction Potential and Control Costs, IIASA, 2002. http://www.iiasa.ac.at/rains/reports/ir-02-076.pdf
[5] Background document on the sector of the petroleum industry prepared in the framework of EGTEI, http://www.citepa.org/forums/egtei/egtei_doc-Proc-Refinery.htm