Convention on Long-Range Transboundary Air Pollution
49th Working Group on Strategies and Review
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Document for the determination of costs for activities of annexe V
Sector: New stationary engines
06/04/2011

Preamble: This document has been composed to fulfil the task of assigning cost parameters to options discussed in the light of revising the Gothenburg Protocol. Providing representative cost data for general use is challenging, as site issues and country-specific issues may affect investment and operating costs severely.

1 Options in the Gothenburg Protocol

The revised Annex V of the Gothenburg Protocol rules NO_x emissions from stationary engines.

Three options are provided for negotiations during WGSR 48 in April 2011 and WGSR 49 in September 2011.

Options are as follows:

The emission limit values in table below are proposed in 15 % reference oxygen content because this corresponds to the actual operational conditions of stationary engines.

The limit value of, for instance:

- *190 mg NO_x/Nm^3 in 15 % O_2 corresponds to the limit of 500 mg NO_x/Nm^3 in 5 % O_2,*
- *95 mg NO_x/Nm^3 in 15 % O_2 corresponds to 250 mg NO_x/Nm^3 in 5 % O_2 and*
- *225 mg NO_x/Nm^3 in 15 % O_2 corresponds to 600 mg NO_x/Nm^3 in 5 % O_2.*

Table 5. Suggested options for limit values for NO_x emissions released from new stationary engines

ENGINE TYPE, POWER, FUEL SPECIFICATION	*ELV 1 (a) (b) (c)*	*ELV 2(a) (b) (c)*	*ELV 3(a)*
GAS ENGINES > 1 MW_{th}			
Spark ignited (=Otto) engines	*35*	*95*	*190*
all gaseous fuels			
DUAL FUAL ENGINES > 1 MW_{th}			
In gas mode (all gaseous fuels)	*35 (e)*	*190(e)*	*380(e)*
In liquid mode (all liquid fuels)			
1-20 MW	*225*	*750*	*[1850] [2000]*
>20 MW	*225(e)*	*450*	*[1850] [2000]*
DIESEL ENGINES > 5 MW_{th} (compression ignition)			
Slow (< 300 rpm)/ Medium (300-1200 rpm)/ speed			
5-20 MW			
HFO and bio-oils	*225*	*[450] [750]*	*[1300] (d) [1600]*
LFO and NG	*150*	*190*	*[1300] (d) [1600]*
>20 MW			
HFO and bio-oils	*190*	*[225] [450]*	*[750] [1850]*
LFO and NG	*150*	*190*	*[750] [1850]*
High speed (>1200 rpm)	*[130] [150]*	*190*	*[750] _ [900]*

The oxygen reference content is 15%.

(a) These values do not apply to engines running less than 500 hours a year.

(b) Where SCR cannot currently be applied [for certain geographical areas, like remote islands] or the unavailability of good fuel or raw material quality not guaranteed, a transition period of [x] yrs can be granted. During this transition period the upper value of ELV3 can be applied.

(c) A flexibility option for engines running between 500 to1500 operational hours per year is to apply [the upper values of ELV3] [achievable with primary measures].

(d) Limit of primary measures under development (Currently only first laboratory tests done on some engine type.)

(e) A derogation from the obligation to comply with the emission limit values can be granted to combustion plants using gaseous fuel which have to resort exceptionally to the use of other fuels because of a sudden interruption in the supply of gas and for this reason would need to be equipped with a waste gas purification facility. The exception time period shall not exceed 10 days except where there is an overriding need to maintain energy supplies.

[Since engines running with higher energy efficiency consume less fuel and emit therefore less CO_2 and since higher efficiency of the engines can lead to higher temperatures and therefore to higher NO_X concentrations in the flue gases, a NO_X bonus using the formula [ELV x actual efficiency / reference efficiency] could be justified[1].]

[1] See e.g. U K "Environmental Protection Act 1990, part 1 (1995 revision), PG 1/5 (95): Secretary of state's Guidance-compression Ignition Engines, 20 – 50 MW Net rated Thermal Input" (prescribes efficiency correction from 40 %).

Technical Introduction

NOx abatement:

Primary measures and secondary measures are used according to the cases. The first draft of technical annex provides the following information.

ANNEX: JUSTIFICATIONS FOR THE OPTIONS FOR "STATIONARY ENGINES"

TABLE 8. PROPOSED ELVs

ENGINE TYPE, POWER, FUEL SPECIFICATION	***ELV 1***	***ELV 2***	***ELV 3***
GAS ENGINES > 1 MW$_{th}$ *Spark ignited (=Otto) engines* *all gaseous fuels*	*35 – SCR with high efficiency*	*95 - enhanced lean burn*	*190 - lean burn*
DUAL FUAL ENGINES > 1 MW$_{th}$ *In gas mode (all gaseous fuels)* *In liquid mode (all liquid fuels)* *1-20 MW*	*35 - SCR with high efficiency* *225 - SCR with high efficiency*	*190 - enhanced lean burn* *750 - SCR with moderate efficiency*	*380 - lean burn* *[1850] [2000] with primary measures depending on fuel and engine design*
>20 MW	*225 - SCR with high efficiency*	*450 – SCR with moderate efficiency*	*[1850] [2000] – with primary measures depending on fuel and engine design*
DIESEL ENGINES > 5 MW$_{th}$ (compression ignition) *Slow (< 300 rpm) / Medium (300-1200 rpm)/ speed* *5-20 MW* *HFO and bio-oils*	*225 SCR with high efficiency*	*[450] [750] SCR with moderate efficiency*	*[1300] (d) [1600] primary measures*
LFO and NG	*150 SCR with high efficiency*	*190 SCR with high efficiency*	*[1300] (d) [1600] primary measures*
>20 MW *HFO and bio-oils*	*190 SCR with high efficiency*	*[225] SCR with high efficiency* *[450] SCR with moderate efficiency*	*[750] SCR [1850] primary measures*
LFO and NG	*150 SCR with high efficiency*	*190 SCR with high efficiency*	*[750] SCR [1850] primary measures*
High speed (>1200 rpm)	*[130] [150] SCR with high efficiency*	*190 SCR with high efficiency*	*[750] [900] primary measures*

GAS ENGINES

SG-type engine

ELV1

The emission limit value of 35 mg NO_x/Nm^3 is based on the best available technical measures (cost not in main focus) to reduce NO_x emissions from new stationary engines. The new emission limit for the spark ignition engine requires the use of SCR and an availability of a fuel of an adequate quality. The driving force for application of SCR is often the need to improve local air quality especially in severely degraded air-sheds, to comply with the high reduction targets of NO_x emissions. In application of SCR on gas engines caution should be taken especially on part loads in order not to overheat ("destroy") the SCR.

ELV2

The proposed NO_x ELV of 95 mg /Nm^3 for SG-type gas engines is consistent with the use of enhanced lean burn principle (primary measures) and is a part of BAT. For a spark ignition engine (SG) enhanced lean burn can cause an increase in fuel consumption (up to 3% in fuel consumption and corresponding CO_2 emission), and unburned gaseous emissions such as CO emissions and a lower flue gas temperature (detrimental for CHP applications) compared to "normal" lean burn. Certain gas (e.g. some bio gases) compositions set also limitations on the achievable NO_x-level to 95 mg NO_x/Nm^3 (15 % O_2) but possible fluctuations of gas composition and contaminations may have to be considered when defining emission limit values if achievable or not.

ELV3

The proposed ELV of 190 mg NO_x/Nm^3 is consistent with the use of the lean burn principle (corresponding with primary measures), also representing BAT. This level can be achieved by standard lean burn engines. The proposed ELV of 190 mg/Nm^3 can also be achieved by rich burn engines equipped with a 3-way catalyst (NSCR).

DUAL FUEL ENGINES (DF)

<u>Dual fuel engines in gas mode</u>

ELV1

The emission limit value of 35 mg NO_x/Nm^3 is based on the best available technical measures (cost not in main focus) to reduce NO_x emissions from new dual fuel engines in gas mode. The proposed emission limit value requires the use of SCR and an availability of a fuel of an adequate quality. The driving force for application of SCR is often the need to improve local air quality especially in severely degraded air-sheds to comply with the high reduction targets of NO_x emissions. In application of SCR on DF-type of engines in gas mode caution should be taken especially on part loads in order not to overheat ("destroy") the SCR.

ELV2

The emission limit value of 190 mg NO_x/Nm^3 for dual fuel (DF) gas engines in gas mode, can be complied with the enhanced lean-burn principle (primary measures) of the engine, representing BAT.

ELV 3

The emission limit value of 380 mg NO_x/Nm^3 for dual fuel (DF) gas engines in gas mode, can be complied with the lean-burn principle (primary measures) of the engine with optimum fuel consumption and lowest unburned gaseous emissions of CO, etc., which is according to the IPPC principle and have been considered to represent also BAT for DF engines in gas mode. The limit value of 380 mg NO_x/Nm^3 (15 % O_2) for DF engines in gas mode has following additional advantages (besides those listed above) compared to the limit value of 190 mg NO_x/Nm^3: … higher flue gas temperature, easier to tune at site (DF engine is sensitive to differences in gas compositions).

<u>Dual fuel engines in liquid mode</u>

ELV1

A dual fuel engine has been developed for countries where natural gas is available. It is optimized for gaseous operation (has a lower compression ratio in comparison to a modern diesel engine) and has therefore in the liquid mode/back-up mode, higher NO_x emissions compared to a modern diesel engine.

The dual fuel engines are usually only operated by liquid fuels in special cases like in the interruption of gas supply. They can however also be operated for a longer time in liquid mode (e.g. at a power plant when there is immediate power need before a gas terminal or a gas pipe line is ready). The proposed emission limit value of 225 mg NO_x/Nm^3 for long time main operation use of liquid fuels are used as the main fuel for a longer period of time, can be achieved by the use of a SCR (cost not in main focus) with an efficiency of near 90 %.

ELV2

The emission limit values of 750 mg NO_x/Nm^3 for the smaller DF engines in liquid mode (< 20 MW_{th}) can be achieved by the use of a SCR with an efficiency of 60 to 65 %.

The emission limit values of 450 mg NO_x/Nm^3 for the larger DF engines in liquid mode (> 20 MW_{th}) can be achieved by the use of a SCR with an efficiency of 75 to 80 %.

ELV 3

The emission limit values of 1850 and 2000 mg NO_x/Nm^3 for DF engines in liquid mode are achievable with primary measures like an optimized low-NO_x engine depending on fuel and engine design. Application of the limit value of 1850 mg NO_x/Nm^3 means higher fuel consumption and loss of efficiency compared to the ELV of 2000 mg NO_x/Nm^3.

DIESEL ENGINES

For diesel engines the ELVs are proposed by taking into account the capacity of the engine.

ELV1

<u>Slow (< 300 rpm) / Medium (300-1200 rpm)/ speed diesel engines</u>

When using heavy oil and bio-oils the emission limit value of 225 mg NO_x/Nm^3 for diesel engines <u>from 5 to 20 MW</u> and 190 mg NOx/Nm^3 for diesel engines of <u>more than 20 MW</u> can only be achieved by the use of a SCR ((cost not in main focus) with an efficiency of respectively about 85 % and 90% depending on the engine type.

When using light fuels oil and natural gas the emission limit value of 150 mg NO_x/Nm^3 can only be achieved by the use of a SCR (cost not in main focus) with an efficiency of more than 90%.

<u>High speed (>1200 rpm) diesel engines</u>

The emission limit value of 130 and 150 mg NO_x/Nm^3 for high speed diesel engines can only be achieved by the use of a SCR (cost not in main focus) with an efficiency of respectively more than 85% and more than 80 %.

ELV2

<u>Slow (< 300 rpm) / Medium (300-1200 rpm)/ speed diesel engines</u>

<u>5-20 MW</u>

For the smaller engine capacities (5 - 20 MW) the ELVs of 450 mg/Nm^3 or 750 mg/Nm^3 when heavy fuel oil and bio-oils are used, assume the application of a SCR with an efficiency of respectively more than 70 % and more than 50 %. When light fuel oil and natural gas is used, the ELV of 190 mg/Nm^3 can only be achieved with a SCR having a reduction efficiency of 85 to 90 %.

The NO_x value of 750 mg/Nm^3 (15 % O_2) is in line with emission ruling in several EU states (e.g. Italy, France), this value will give a better economic performance of the SCR. Major part of the operational cost of the SCR is due to the reagent consumption, i.e. a lower NOx limit means also a higher reagent consumption need and thus a higher cost.

<u>> 20 MW</u>

For the larger engine capacities (> 20 MW) when heavy fuel oil and bio-oils are used, the ELV of 225 mg NO_x/Nm^3 assumes the application of a SCR with a reduction efficiency of more than 85 % and the ELV of 450 mg NO_x/Nm^3 can be achieved with a SCR with a lower reduction efficiency of more than 75 % (and reagent need and thus lower operational cost). When light fuel oil and natural gas is used, the ELV of 190 mg NOx/Nm^3 can only be achieved with a SRC having a reduction efficiency of 90 %.

High speed (>1200 rpm) diesel engines

The emission limit value of 190 mg NO_x/Nm^3 for high speed diesel engines can only be achieved by the use of a SCR with a moderate reduction efficiency of near 80 %.

ELV3

Slow (< 300 rpm) / Medium (300-1200 rpm)/ speed diesel engines

5-20 MW

When using heavy fuel oil, bio-oils, light fuel oil or natural gas the emission limit value of 1 300 and 1600 mg NO_x/Nm^3 for diesel engines from 5 MW to 20 MW can be reached by using primary measures like an optimized low-NO_x engine.

The NO_x level of 1300 mg/Nm^3 (an efficient "dry" primary method is needed for the future international markets) is an option that allows the use of primary measures, such as "wet methods" or advanced Miller concept. Diesel manufacturers (EUROMOT) have in some preliminary laboratory tests seen that by introducing a new extreme Miller concept that NO_x-levels of 1300 mg/Nm^3 with a lower fuel consumption (and as a consequence lower CO_2 emissions) could be achieved but a lot of engine testing and development work still to be done in order to get this to a commercial level.

> 20 MW

When using heavy fuel oil, bio-oils, light fuel oil or natural gas the emission limit value of 750 mg NO_x/Nm^3 for diesel engines of more than 20 MW can only be complied with the use of a SCR with a reduction efficiency of 60 %, and the ELV of 1850 mg NOx/Nm^3 can be reached by using primary measures like an optimized low-NO_x engine.

High speed (>1200 rpm) diesel engines

The high-speed engines can comply with emission limit values of 750 and 900 mg NOx/Nm^3 by primary measures where the engine is optimized. The value of 900 mg NO_x/Nm^3 (15 % O_2) corresponds to current US Tier 2 requirements. Engineering work would be necessary to achieve an emission limit value of 750 mg NO_x/Nm^3 without secondary measures, which will result in an increase of specific fuel consumption.

The distinction between small and large engine plants is justified since the smaller engines are often installed in sectors which are economically less viable compared to the larger engines installed by the large electricity producers. The cost of SCR with lower efficiencies is less, since the cost of a SCR is mainly determined by the cost of NH_3 or urea (operational cost). To avoid odour emissions of NH_3 the operation of a SCR needs good control and maintenance, which is more easily to be enforced on the larger engine plants.

The application of SCR means for diesel engines that fuels with good quality (like fuels with low sulphur content) are needed and some restrictions to use have to be taken into account. The costs for application of SCR are plant specific and operational and maintenance costs are dependent on the NO_x reduction rate. The impact of applying NO_x emission limit values on fuel consumption quality needs to be considered taking into account the currently rising fuel prices.

The proposed exemptions for new diesel engines operating in isolated areas can be justified because exemptions are meant to be used mainly on islands or remote areas where

1) *there is no possibility so far to replace diesel engines with gas engines,*
2) *the application of SCR in diesel engines using heavy fuel oil is not technically or economically feasible or*
3) *the application is not feasible due to the peak-load operation and varying loads of engines or other infrastructural reasons (lack of needed reagents, etc).*

The exemption is allowed for transitional period of [x] years or until the moment when certain conditions are met to apply SCR, for instance, when low–sulphur fuels and a good infrastructure for SCR, or natural gas are available.

It is expected that more grid stability power plants will be needed due to large increase in renewable energy production (e.g. wind and solar power). These "grid stabilization" plants are expected to operate up to 1500 hr/year, a grid stabilization plant will typically have frequent start-up/shut-down periods and operate on varying loads (therefore SCR is not recommended, see BREF document for more info). Therefore leaner NO_x-emission limits should be justified for these plants operating typically 500-1500 h/year.

For more information on primary measures and SCR, refer to the guidance document, chapter 7.42[2] and the background document[3].

[2] Guidance document - No. 1: Draft Guidance document on control techniques for emissions of Sulphur, Nox, VOCS, dust from stationary sources – Informal document – 45th WGSR september 2009

[3] Background document on revision of technical annexes of the unece CLRTAP Gothenburg protocol - annex V, table 4 – 2009 – Prepared by EGTEI

2 Investment and operating costs

Investment and operating costs have been estimated for different sizes of diesel engines using heavy fuel oil and gas engines. Costs for medium distillate engines will be provided later.

Operating costs take into account the urea water 40 wt-% solution consumption (Urea water 40 wt-% solution is many times preferred to ammonia due to safety aspects), the electricity consumption and wages.

Costs are expressed in Euros/ton of NOx abated but also in % of increase of the produced electricity cost and incremental Euro/MWhe cost due to the SCR cost. Electricity price is indeed a key parameter for the economy of an engine and for the operator. The SCR additional Euro/MWhe cost is of consequently of big interest. An average cost of 70 Euros/MWhe of produced electricity is taken into account as reference.

Gas engine are mostly used in combined heat and power (CHP) plants.

Diesel engines using heavy fuel oil, are used to generate electricity in remote lands and islands. As location and transportation costs might be major contributors to the price depending on location, for diesel engines, two cases are presented: a standard case and a case corresponding to an engine installed in a remote area. Investment can be larger in that case (a ratio of 20 % of the initial investment is used on average but this ratio can be larger according to the cases) and urea which is about 300 Euros/ton can more than double. A case with 750 Euros/ton is developed for remote area.

2.1 Diesel engines, low and medium speed

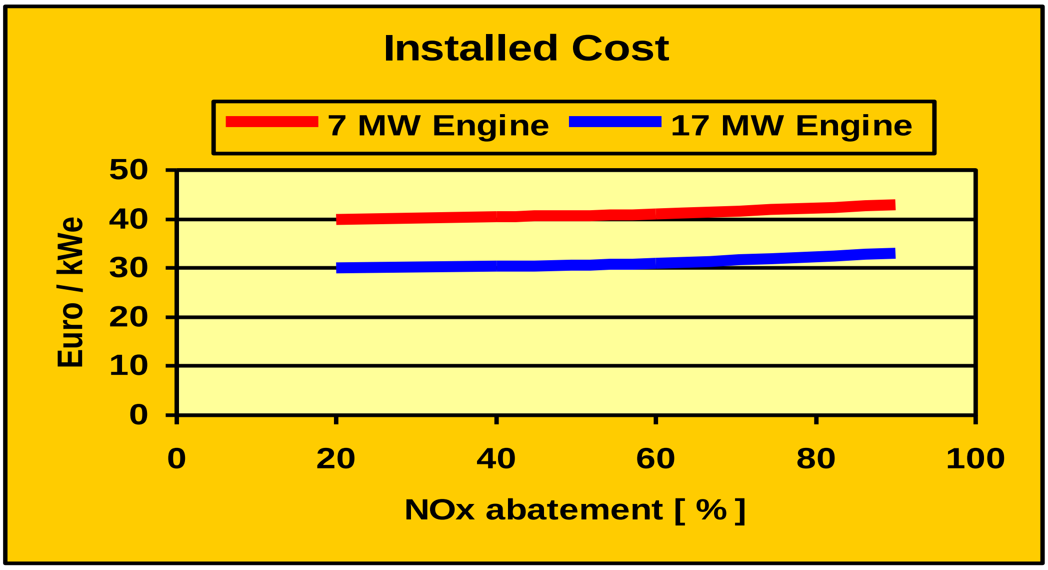
In EU main land, oil fired diesel engines are mainly used for short term peaking/emergency purposes. In some EECCA countries diesel engines are used besides as emergency plants but are also used in remote areas with harsh climates especially during winter season (heating season, thus often CHP plants). The engine plant is often the main power source for the isolated grid. (It has to be kept in mind, that in recent years, liquid fired bio-oil engine plants have become popular in some EU countries, due to the green certificate need in electrical production. In these bio-oil plants, a fast deactivation of the SCR element has been noticed. It is suspected that the phosphorous content of the bio oil plays a big role in the seen deactivation, investigations are still in progress. For this type of plants, operating costs can be larger than those presented here after).

In EU islands, oil fired diesel engines are used in power production due to the special characteristics which match the peculiarities of the electricity demand on the islands. The installations operate at full capacity for a short period of time each year, namely the tourist season (for approximately 2 months or sometimes longer). For the rest of the year the year the installations operate at a small part of their capacity (approximately ¼). Characteristics of the electricity demand determine configuration of plant, i.e. multi engine units are needed due to the electrical fluctual needs. The plant has to be flexible for quick start ups, shut downs and frequent and quick load variations, low partial loads and black-start capability. These features of the diesel engine provide means to reach a satisfactorily efficiency and reliability in electricity production.

In the scope of EGTEI, in order to provide comparable cost data with other sectors, 10 years are taken into account to calculate annual costs, with an interest rate of 4% (However, it has to be kept in mind that a diesel plant in remote areas, islands might have 10 years pay back, but small plants on main land are often private with a much shorter payback period of maximum 5 years. Costs can be larger in that case).

Investment costs are provided using information available in the guidance document, chapter 7.42. They are as follows:

Figure 1: typical costs of SCR as a function of NO_x reduction rate, heavy fuel oil fired medium speed diesel engine power plant, reagent handling not included.



Costs estimated are as follows :

- Costs for an engine located in main land with an urea cost of 300 Euros/t for 4000 operating hours – table 1;
- Costs for an engine located in main land with an urea cost of 300 Euros/t for 2500 operating hours – table 2.
- Costs for an engine located in remote area with an urea cost of 750 Euros/t for 4000 operating hours – table 3.

Investments increase with the efficiency of the SCR required to reach the ELV.

Costs expressed in Euro per reduced ton of NOx are quite low but additional total costs due to SCR expressed in Euro/MWhe are on the other hand much higher compared to other activities. The additional cost of electricity produced range from 7 to 11 % in main land and from 11 to 25 % in remote area.

Table 1: costs of a SCR for diesel engines in main lands (urea cost 300 Euros/t). Case 4000 h/year

Diesel engines		**OPTION 3**		**OPTION 2**		**OPTION 1**
From 5 to 20 MWth						
	mg NOx/Nm^3 at 15 %	**1600**		**750**	**450**	**225**
Based on an engine of 16 MWth (7 MWe) heavy fuel oil						
SCR efficiency required				53%	72%	86%
Investment	€			286 300	293 756	307 235
Total annual cost	€/year			162 197	191 256	214 022
Cost of removed NOx	**€/t NOx abated**			**1 014**	**884**	**827**
Additional cost of electricity produced	**€/MWhe**			**5.8**	**6.8**	**7.6**
Additional cost of electricity produced	**%**			**8.28%**	**9.76%**	**10.9%**
From 20 to 50 MWth						
	mg NOx/Nm^3 à 15 %	**1850**	**750**	**450**	**225**	**190**
Based on an engine of 38 MWth (17 MWe) heavy fuel oil						
SCR efficiency required			59%	76%	88%	90%
Investment	€		527 087	544 666	577 244	594 244
Total annual cost	€/year		404 624	480 000	538 924	549 561
Cost of removed NOx	**€/t NOx abated**		**751**	**700**	**677**	**676**
Additional cost of electricity produced	**€/MWhe**		**6.0**	**7.1**	**7.9**	**8.1**
Additional cost of electricity produced	**%**		**8.5%**	**10.1%**	**11.3%**	**11.5%**

Table 2: costs of a SCR for diesel engines in main lands (urea cost 300 Euros/t). Case 2500 h/year

Diesel engines		OPTION 3		OPTION 2		OPTION 1
From 5 to 20 MWth						
	mg NOx/Nm³ at 15 %	**1600**		**750**	**450**	**225**
Based on an engine of 16 MWth (7 MWe) heavy fuel oil						
SCR efficiency required				53%	72%	86%
Investment	€			286 300	293 756	307 235
Total annual cost	€/year			128 335	146 841	161 694
Cost of removed NOx	**€/t NOx abated**			**1 284**	**1 086**	**1 000**
Additional cost of electricity produced	**€/MWhe**			**7.3**	**8.4**	**9.2**
Additional cost of electricity produced	**%**			**10.5%**	**12.0%**	**13.2%**
From 20 to 50 MWth						
	mg NOx/Nm³ à 15 %	**1850**	**750**	**450**	**225**	**190**
Based on an engine of 38 MWth (17 MWe) heavy fuel oil						
SCR efficiency required			59%	76%	88%	90%
Investment	€		527 087	544 666	577 244	594 244
Total annual cost	€/year		296 744	344 667	383 001	370 950
Cost of removed NOx	**€/t NOx abated**		**882**	**805**	**770**	**730**
Additional cost of electricity produced	**€/MWhe**		**7.0**	**8.1**	**9.0**	**8.7**
Additional cost of electricity produced	**%**		**10.0%**	**11.6%**	**12.9%**	**12.5%**

Table 3: costs of a SCR for diesel engines in remote areas (Urea cost 750 Euros/t). 4000 h/year

Diesel engines		**OPTION 3**		**OPTION 2**		**OPTION 1**
From 5 to 20 MWth						
	mg NOx/Nm^3 at 15 %	**1600**		**750**	**450**	**225**
Based on an engine of 16 MWth (7 MWe) heavy fuel oil						
SCR efficiency required				53%	72%	86%
Investment	€			343 560	352 507	368 682
Total annual cost	€/year			292104	363556	418313
Cost of removed NOx	**€/t NOx abated**			**1826**	**1680**	**1617**
Additional cost of electricity produced	**€/MWhe**			**10.4**	**13.0**	**14.9**
Additional cost of electricity produced	**%**			**14.9%**	**18.5%**	**21.3%**
From 20 to 50 MWth						
	mg NOx/Nm^3 à 15 %	**1850**	**750**	**450**	**225**	**190**
Based on an engine of 38 MWth (17 MWe) heavy fuel oil						
SCR efficiency required			59%	76%	88%	90%
Investment	€		632 504	653 599	692 693	713 093
Total annual cost	€/year		553 982	1 014 363	1 156 451	1 180 319
Cost of removed NOx	**€/t NOx abated**		**1 539**	**1 480**	**1 454**	**1 452**
Additional cost of electricity produced	**€/MWhe**		**12.2**	**14.9**	**17.0**	**17.4**
Additional cost of electricity produced	**%**		**17.4%**	**21.3%**	**24.3%**	**24.8%**

2.2 Diesel engines, high speed

To be completed later.

2.3 Gas (lean burn) engines

In EU main land, gas engines are operated mainly during a part of the year (heating season) typically up to 3500 - 4000 h/year. Customer segment is both industry and utility. In plant applications with varying load conditions, care should be taken to avoid overheating ("cracking") of the SCR catalysts.

In ECCA countries, many gas engines are also used in CHP (Combined Heat and Power) plants.

Costs have been defined for an engine of about 20 MWth or 8,7 Mwe and 4000 h/y. In the scope of EGTEI, in order to provide comparable data with other sectors, 10 years are taken into account to calculate annual costs, with an interest rate of 4% (However, it has to be kept in mind that a diesel plant in remote areas, islands might have 10 years pay back, but small plants on main land are often private with a much shorter payback period of maximum 5 years. Costs can be larger in that case).

Table 4: costs of a SCR for gas engines (Urea cost 300 Euros/t) and 4000 h/year

Gas engines		**OPTION 3**	**OPTION 2**	**OPTION 1**
Natural gas	mg NOx/Nm^3 at 15 %	**190**	**95***	**35**
Based on an engine of 20 MWth (8.7 MWe)				
SCR efficiency required				82%
Investment	€			356 700
Total annual cost	€/year			84 070
Cost of removed NOx	**€/t NOx abated**			**2 395**
Additional cost of electricity produced	**€/MWhe**			**2.42**
Additional cost of electricity produced	**%**			**3.45%**

*Additional costs are due to the increase of fuel consumption.