The European Association of Internal
Combustion Engine Manufacturers

EUROMOT

POSITION PAPER

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EUROMOT Position for WGSR 49

1 Background

Since 2002 EUROMOT has actively been following the UNECE Gothenburg Protocol and has been providing its expertise in the EGTEI working group and through numerous position papers /1 – 4/ showed the flaws of the old guidance paper /5/. The current Gothenburg Protocol includes an option (Article 3) to deviate from the limit values in the technical annexes IV, V and VI, but only few parties to the convention have used this possibility when ratifying the Protocol. As of today, many states have not ratified the Gothenburg Protocol. In spring 2008 the EGTEI subgroup "stationary engines" was formed "… ***to evaluate the present NOx limit values presented in the Gothenburgh Protocol Annex V table 4 as some Parties have had difficulties in applying these limit values. The target for the group was to recognize these problems and evaluate possible options to solve them***" /6/. In May 2009 the group finalized a new background paper /7/. Based on this background document new emission options were worked out /8A-B/ for new stationary engines. In spring 2010, Euromot issued a Position paper 2010 /9/ explaining the impact of the proposed different emission options for new stationary engines and made a recommendation based on the environmental quality need driven approach taking into account environmental, technical and economical aspects.

In the run-up to the WGSR 49, the secretariat published in June 2011 Draft Revised Annexes on the UNECE website. Furthermore, EGTEI provided cost data on new Stationary Engines. In this position paper will provide comments regarding these documents.

2 Draft Revised Annex V for WGSR 49

In Paragraph 9, Table 4 of Draft Annex V for WGSR 49 /10/, the limit values for **new stationary engines** are set out. EUROMOT is committed to improving the air quality in Europe and reducing emission from internal combustion engines. EUROMOT believes that the current proposal which now differentiates between different engine types in the categories of (spark-ignited) gas engines, dual fuel engines and diesel engines is an improvement compared to the 1999 Gothenburg Protocol. Nevertheless, EUROMOT continues to believe that some of the emission limit values (ELV) and rules proposed are inadequate for all circumstances and all parties to the convention.

Gas Engines (Spark ignited (=Otto) on all gaseous fuels):

Currently, option ELV 2 and 3 are proposed. EUROMOT wants to underline the importance of keeping option ELV 3 in the final version of Annex V. Two aspects are **important** to bear in mind when setting ELV for gas engines:

- We would like to reiterate that option ELV 2 while lowering NOx will lead to increases in fuel (gas) consumption and the lower flue gas temperature will reduce the amount of heat recovered for Cogeneration thus increasing corresponding CO2 emission compared to normal lean burn applications possible at ELV 3. Unburned gaseous emissions such as CO and HC emissions will also increase. **I.e. ELV 2 is not consistent with an Integrated Pollution Prevention and Control (IPPC) approach**!
- Furthermore, Table 4 in Annex V does not distinguish between “natural gas” and “other gases”. Therefore any limits for spark ignited engines would be applicable also for engines running on “other gases” such as biogas. Without an SCR, ELV 2 (95 mg/m3 (15 % O2)) can only be achieved with stable gases. On engines running e.g. on less stable biogas, SCRs would be necessary. However, as EGTEI concluded in the Guidance Document chapter on stationary engines, there is limited experience from SCR with the use of biogas at the moment and the systems are expensive. SCR for biogas therefore cannot be considered BAT and ELV 2 must not be applied to engines running on “other gases” such as biogas.

EUROMOT recommends keeping ELV 3 in the Table 4 for new stationary spark ignited (otto) gas engines as currently proposed.

Dual Fuel Engines:

This is **an engine type new to the Gothenburg Protocol** and **in the current Protocol no emission limits are set**. EUROMOT supports the introduction of separate emission limit values for dual fuel engines. However, it is EUROMOT’s view that the current proposal does not adequately take into account all aspects of this technology. The proposed ELV 2 (190 mg/Nm3 NOx at 15 % O_2) for gas mode without bigger detrimental effects is only achievable with a suitable gas quality[1].

Currently, the European Union is looking into harmonizing gas quality /14/ and the lower gas quality being discussed[2] will affect engine outputs (decrease) and emissions (raise). **ELV 3** is the **optimum** approach /8B/: *"..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*".

ELV2 can by enhanced lean burn approach be fulfilled but engine performance will not be at optimum conditions especially with natural gases with a Methane Number (MN) < 80, see above.

EUROMOT urges WGSR to add a new footnote d) for dual fuel engines:

"Where the gas quality available has a Methane Number below 80 following emission limit value may be applied for dual fuel engines during:

- **Dual Fuel Engines: max. 380 mg/Nm3 in gas mode (The reference oxygen content is 15% O_2).**

Diesel Engines:

With regards to liquid fired engines the current Emission Limit Values are the option chosen in the Draft Annex V for the WGSR 49 – values which EUROMOT for many years has **tried to correct.** It is important to note that these Emission Limit Values for new stationary diesel engines are not based on a corresponding BAT Associated Emission Level as the BREF for Large Combustion Plants ($\geq$ 50 MWth) does not provide any. Furthermore, in the UNECE Gothenburg Protocol the threshold for diesel engine units was set to > 5 MWth and for gas engines > 1 MWth for other prime movers (such as boilers and gas turbines) the thresholds are for > 50 MWth plants. This leads to the situation that contrary to the approach taken for most other technologies the ELVs for liquid fired engines are set at a level which the experts of EGTEI described as a "ELV 1" (HFO (Heavy Fuel Oil), liquid bio-fuel fired diesel and all liquid fired DF engines) or "ELV 2" (LFO (Light Fuel Oil), natural gas fired diesel engines) level. ELV1 is the strictest option – a level which is technically feasible if the existing infrastructure is good but does **not take into consideration the cost** necessary to achieve this high level of reduction. ELV 2 is also technically demanding but pays some attention to costs. For slow/medium speed diesel engine >5 MWth **a high efficiency SCR and**

[1] This aspect is also described in the UNECE Draft Revised Technical Annex V on NOx Emission Options from Stationary Sources /8B/ (page 13) which states: *"The limit value of 380 mg NOx/Nm3 (15 % O2) for DF engines in gas mode has following additional advantages (besides those listed above) compared to the limit value of 190 mg NOx/Nm3: …higher flue gas temperature, easier to tune at site (DF engine is sensitive to differences in gas compositions). "*

[2] For a more in-depth treatment on the impact of introducing the EASEE Gas Specifications on gas engines please see http://www.euromot.org/download/ec4913cb-48f7-45ad-8aae-b5f5fe69cc10/GAS%20QUALITY%20euromot%20position%202011_05.pdf

accompanying infrastructure is needed to comply with ELV 1 / ELV 2 (to comply with ELV 2, high speed diesel engines also need to apply SCR), EUROMOT has severe doubts this is an appropriate general Emission Limit Value for all parties and to the convention, especially for countries in economic transition and remote areas / small islands. A discussion of costs of aftertreatment follows in a separate chapter below.

EUROMOT strongly urges WGSR 49 to reconsider its proposition regarding diesel engines running on HFO, LFO/NG and bio-oils in the categories 5-20 MWth and above 20 MWth. Ditto approach is needed for Dual Fuel Engine > 1 MWth in liquid mode and high speed diesel engines. Adopting the ELV 3 (upper limit) would offer a cost-effective reduction of NOx more suitable for many parties to the convention. States and regions with degraded air sheds would still have the opportunity to introduce the higher reduction levels where necessary.

Footnotes to Table 4:

a) EUROMOT supports footnote "a"

b) In footnote "b" a derogation regarding the use of SCR is proposed. This allows the use of option ELV 3 for technical and logistical reasons or where sufficient amounts of high quality fuel cannot be guaranteed a transition period of 10 years after entry into force of the Protocol.

EUROMOT supports the derogation in footnote "b". However, it is impossible to forecast whether 10 years will be enough time for remote areas and small islands to overcome the challenges of introducing more demanding ELVs. Therefore, EUROMOT recommends to make this derogation not time bound and to review periodically (e. g. every five years after the first 10 year period) whether the advancement of infrastructure, logistics and abatement technologies make the adoption of stricter ELVs possible.

c) EUROMOT supports footnote "C" as this will enable a higher penetration of renewable energies (e.g. wind and solar energy) while maintaining grid stability in a balanced cost-effective and environmentally sound way.

e) In the latest draft of Annex V, footnote e) offering derogation for the case of sudden interruption of gas supply to internal combustion engines has been marked as "deleted". This is problematic as in the current wording the general section "5.1 (a)" (on page 2) which grants derogation to other technologies for such cases is not open to internal combustion engines.

EUROMOT urges WGSR to include stationary engines into the derogation regarding gaseous fuel supply interruption. This could be easily achieved by transforming section 5.1 a) into a paragraph covering all combustion technology independently of paragraph 5.1 which refers to paragraph 7. For example this could be a new paragraph 6.

3 Cost Data

In May 2011, EGTEI provided additional cost data (document /11/). Beside the commonly cited benchmark "Euro/NOx ton removed" it also estimates the additional cost impact factor "Euro/MWhe" on the produced electricity of the usage/installation of the secondary NOx reduction technique. The "**Euro/MWhe" cost factor is the primary cost which electricity consumers, operators and owners of the stationary engine plant will face** and in EUROMOT's opinion this should be taken into account when making policy decisions. For example using the EGTEI cost data, the Euro/MWhe criterion shows that adopting option ELV 1 for stationary diesel engines could lead to a **huge increase** in the cost of producing electricity on small islands by almost 25% (see Table 3 below) due to SCR and reagent costs.

SCR and Reagent Costs

The only available secondary abatement technique to reach low NOx levels for a (especially for a liquid fired) stationary engine is SCR (Selective Catalytic Reduction, note restrictions: on flue gas temperature, etc. issues on page 244 /7/). SCR needs a reagent to reduce NOx and the most commonly used reagent is a 40- 45 wt-% urea water solution[3] or less commonly a 25 wt-% aqueous ammonia solution or pure (100 %) ammonia.[4]

During the last years the price of urea has seen high fluctuations following closely the price of energy (similar trend as for the oil price) with a peak in year 2008. More recently the urea price was rising again. Due to the high volatility on the urea market after the financial crisis it is difficult to forecast the reagent prices for years to come and therefore cautious estimates are needed.

It is important to not that the price of the urea solution depends on many factors and cannot be derived directly from the bulk urea price found on world markets. Other **major contributor's to local urea prices are logistics, infrastructure and transportation** – making urea solution prices heavily dependent on the power plant's location. Furthermore, the reagent price an operator has to pay also depends on the consumption at the plant due to rebates: A big coal fired plant can expect to get a better price on the needed reagent than a stationary engine plant. The calculation was done with the small, medium sized stationary engine plant in focus. Taking these factors into account, different scenarios where calculated based on a long term price level of 300 Euro/ton of the 40 wt-% urea water solution for "main land based" stationary engine plant and a higher reagent price of 750 Euro/ton for a remote area.

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[3] The urea used in the SCR has to be of good "technical grade" which is of a more expensive quality with strict composition requirements on impurities such as biuret, heavy metals, etc.

[4] In some places the more demanding on-site production is necessary leading to higher investment costs. For simplification reasons the option "ready" urea water solution with a lower up front equipment investment was chosen for the cost estimates which in most Central European applications is the preferred option.

Operating Costs

In the operating costs are included: needed reagent (see above), electricity consumption and spare parts of the SCR system and wages. In the cost is also included besides operating cost the depreciation period of the investment (10 year time) and interest rate for investment is 4 %. **A 10 year depreciation period is rather long** for a plant in the manufacturing industry, where shorter periods such as typically 3-5 years are used.

SCR Costs for Diesel engines

The costs of the proposed three emission options (ELV1, ELV2 and ELV 3) for the 5 - 20 MWth and > 20 MWth diesel engine cases operating on heavy fuel oil (HFO) for:

- 4000 h/year case operation of stationary diesel engine plant and
- 2500 h/year operation of stationary engine plants is shown in tables 1 and 2 below (Source: EGTEI document /11/ on page 15).

In main land operations, the case of 2500 operational hours per annum is more realistic due to currently high oil prices.

Table 1: SCR costs for diesel engine in main land operation, case 4000 h/year, urea solution price 300 Euro/ton.

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	k€			286	293	307
Total annual cost	k€/year			162	191	214
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	k€		527	544	577	594
Total annual cost	k€/year		404	480	538	549
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: SCR costs for diesel engine in main land operation, case 2500 h/year, urea solution price 300 Euro/ton.

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	k€			286	293	307
Total annual cost	k€/year			128	146	161
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	k€		527	544	577	594
Total annual cost	k€/year		296	344	383	370
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%**

For remote islands a case with a higher (as stated above logistics and transportation cost are major contributors to final price) was calculated (urea solution price 750 euro/ton) (page 16 /11/), see table 3 below.

Table 3: SCR costs for diesel engine in remote area, case 4000 h/year, urea solution price 750 Euro/ton. Case 4000 h/tyear.

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	k€			343	352	368
Total annual cost	k€/year			292	363	418
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/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	k€		632	653	692	713
Total annual cost	k€/year		553	1 014	1 156	1 180
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%**

SCR costs for boiler plants

To illustrate the cost factor Euro/MWhe and to enable comparison with other combustion technology, a cost calculation case for a boiler plant is made below.

Table 4: SCR cost for a (coal) boiler plant. Yearly operation 5000 h.[5] Source: LCP BREF 2006

In the next table costs were estimated for an SCR unit treating a flue-gas volume of 200000 m^3/h, 500000 m^3/h and 1000000 m^3/h with a raw gas concentration of 500 mg/Nm^3 (attained by primary measures) and 350 mg/Nm^3 (attained by primary measures and an SNCR respectively). Clean gas concentration is, in both cases, assumed to be 100 mg/Nm^3.

Parameter	Unit	Flue-gas volume (Nm^3/h)		
		200000	500000	1000000
NO_X-concentration to be reduced	g/Nm^3		0.25 – 0.4	0.25 – 0.4
Operating hours	h/yr	5000	5000	5000
Reduced load	t/yr	250 – 400	625 – 1000	1250 – 2000
Investment costs	EUR million	4.86	9.23	15.0
Yearly repayment [1]	EUR million/yr	0.50	0.95	1.54
Operating costs (including costs for electr. energy,. catalysts,. reducing agents,. maintenance, and wear and tear)	EUR million/yr	0.25 – 0.29	0.60 – 0.69	1.17 – 1.34
Yearly costs	EUR million/yr	0.75 – 0.79	1.56 – 1.64	2.72 – 2.88
Yearly specific costs	EUR/t NO_X	1968 – 3016	1638 – 2488	1442 – 2175
Note 1: basis 15 years with a 6% interest rate				

Table 3.13: Cost estimations for SCR units after power plants as a function of the flue-gas volume

Cost estimates based on above table:

With coal as fuel the typical emission reduction rate in order to reach the above clean gas concentration the NOx reduction is about 75 - 80 % of the SCR (raw emission from a boiler equipped with low NOx burners is about 500 mg/Nm^3 (6 % O_2) NOx). The 500,000 Nm^3/h flue gas flow is representative for an about 170 MWe coal fired power plant with 41 % electrical net efficiency. I.e:

- **Euro / ton NOx removed: 2488 (from table above)**
- **Euro/MWhe: about 1.9**

In "old" source (document /12/) costs for a coal fired power plant are about in the same range as above figures.

[5] The cost data for the boiler plant is taken from the EU LCP BREF document /13/ page 112 table 3.13, see table 5 below.

It is important to note (can be seen from above calculations) that **the diesel engine (expected similar impact on the liquid fired DF engine) cases differ considerably** from the boiler plant. **The additional cost "Euro/MWhe" the operator/owner of the stationary diesel (or liquid fired DF) engine plant will face due to the NOx-limitations is about 3 to 9 times higher than for the above calculated boiler case!**

4 Conclusion

In order to get the full picture of the cost NOx reduction the **factor "Euro/MWhe" needs to be taken into consideration as otherwise the impact on important parts of society (e.g. plant operators and consumers) will be missed**.

Above tables show that the strictest emission option ELV1 has significant adverse economic impact on the operation of especially the **liquid fired stationary engine** plant and on the consumers they serve. To a lesser degree this is also true for ELV 2. It is EUROMOT's opinion that option ELV 1 which is close to the lowest technically achievable emission level should only be applied in certain highly polluted areas. ELV 1 (or ELV 2) is not adequate for the area covered by the Gothenburg Protocol as a whole.

Considering that according to EU statistics only about 0.24 - 0.26 % of total NOx emissions in Europe is due to stationary engine plant (see document /3/), the benefits of reducing NOx seem small while the economic impact on communities dependent on electricity from stationary diesel engines will be severe as the cost of producing electricity will increase up to 24.8% due to the introduction of SCR.

For gas fired dual fuel engines and "spark ignited gas engines" emission option ELV2 will increase the fuel gas consumption (as a consequence more CO_2 emissions) and unburned gaseous emissions (CO, etc.) and decrease the flue gas temperature which is not according to the IPPC principle. Some engine types face additional operational challenges with the ELV2 option: such as spark ignited gas engines in context with (non-stable) "other gases" and dual fuel engines with natural gases with a Methane Number < 80, see text above for more information.

Based on the discussion above, Euromot is of the opinion that ELV3 (upper level) is the preferable limit in general. Only for certain special areas ELV2 or ELV1 could be applied where there is an urgent need to achieve low emissions due to a constrained air quality. The cost-effective environmental quality need representing a balance between costs and environmental aspects should be taken into consideration and the sole focus should not lie on technical feasibility alone.

5 Sources

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/4/ “Euromot Proposal for the proceeding in the revision process of the technical annexes in the Gothenburgh Protocol, The Euromot Final position”; July 2008 at: http://www.euromot.org/download/95fc5e0f-3d3a-4ec9-91fd-fa97f3b78c54/UNECE%20CLRTAP%202008%2006.pdf

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/11/ “Update of cost data for LCP, Stationary Engines, ..Sectors”, May 2011 at http://www.citepa.org/forums/egtei/4-Secretariat-costs-WGSR48.pdf

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