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Study on the Need for Modernization of Large Combustion Plants in the Contracting Parties of the Energy Community in the context of the implementation of Directive 2001/80/EC

FINAL REPORT

S.E.E.C.

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* This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo declaration of independence.

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The findings of the present report represent the views of the consultants contracted by the Energy Community Secretariat and are without prejudice to calculations, cost estimates and/or cost-benefit analyses of other entities or institutions.

Glossary of Abbreviations and Acronyms

AL	Albania
B	Benefit
BiH	Bosnia and Herzegovina
BAT	Best available techniques
BAU	Business as usual - existing status, "do nothing" scenario
BC	Brown coal
BF	Bag filter
C	Cost
CAFE	Clean Air for Europe
CBA	Cost-benefit analysis
CCGT	Combined Cycle Gas Turbine
CHP	Combined Heat and Power Plant
DCF	Discounted cash flow
$DeNO_x$	De-nitrification process
DO	Distillate oil
ECT	Energy Community Treaty
ELV	Emission limit value
EnC	Energy Community
ECS	Energy Community Secretariat
ESP	Electrostatic precipitator
EU	European Union
FGD	Flue gas desulphurization
FO	Fuel oil
FR	Final Report
GT	Gas turbine
HC	Hard coal
HR	Croatia
IED	Industrial Emissions Directive
IR	Inception Report
KO*	Kosovo*
L	Lignite
LCP	Large combustion plant
LCPD	Large Combustion Plants Directive
LNB	Low-NO_x burner
ME	Montenegro
MD	Moldova
MK	The former Yugoslav Republic of Macedonia
NID	Novel Innovation De-acidification
NG	Natural gas
NPV	Net present value
OFA	Over-fire air
PM	Particulate matter
RG	Refinery gas
PV	Present value
RS	Serbia
SCR	Selective catalytic reduction
SD	Spray drying
SNCR	Selective non-catalytic reduction

TPP	Thermal power plant
UA	Ukraine
VSL	Value of statistical life
VOLY	Value of life year
WL	Wet lime
WLS	Wet limestone scrubber

Executive Summary

Electricity and heat generation are major sources of air pollution all around Europe. To deal with the main air pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), dust - particulate matter (PM), the European Union (EU) had adopted Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants (LCP Directive) which entered into force on 27 November 2001. This Directive applies to combustion plants with a rated thermal input equal to or greater than 50 MW, irrespective of the type of fuel used (solid, liquid or gaseous). In December 2010, the EU adopted Directive 2010/75/EU on industrial emissions (Industrial Emissions Directive - IED) which entered into force on 6 January 2011 and had to be transposed into the national legislation of EU Member States by 7 January 2013.

All Contracting Parties to the Energy Community Treaty have undertaken to implement the LCP Directive by 31 December 2017, as it is set out by Article 16 and Annex II of the Energy Community Treaty. Implementing the LCP Directive in the Energy Community is a high priority politically and technically for all beneficiary parties as well as the EU. The main requirements of the LCPD and the IED are presented in Tables ES-1 and ES-2.

Table ES-1: Emission limit values for existing LCPs, LCPD

Pollutant	Rated thermal imput /MWth/	Emission limit values /mg/m^3/ per fuel used		
		Solid	Liquid	Gaseous
Dust (PM)	<500	100	50	5
	≥500	50		
NO_x	50-500	600	450	300
	>500	200	400	200
SO_2	50-100	2000	1700	35
	100-300	2000–400 Linear decrease	1700	
	300-500		1700–400 Linear decrease	
	>500	400	400	

Table ES-2: Emission limit values for existing LCPs, IED

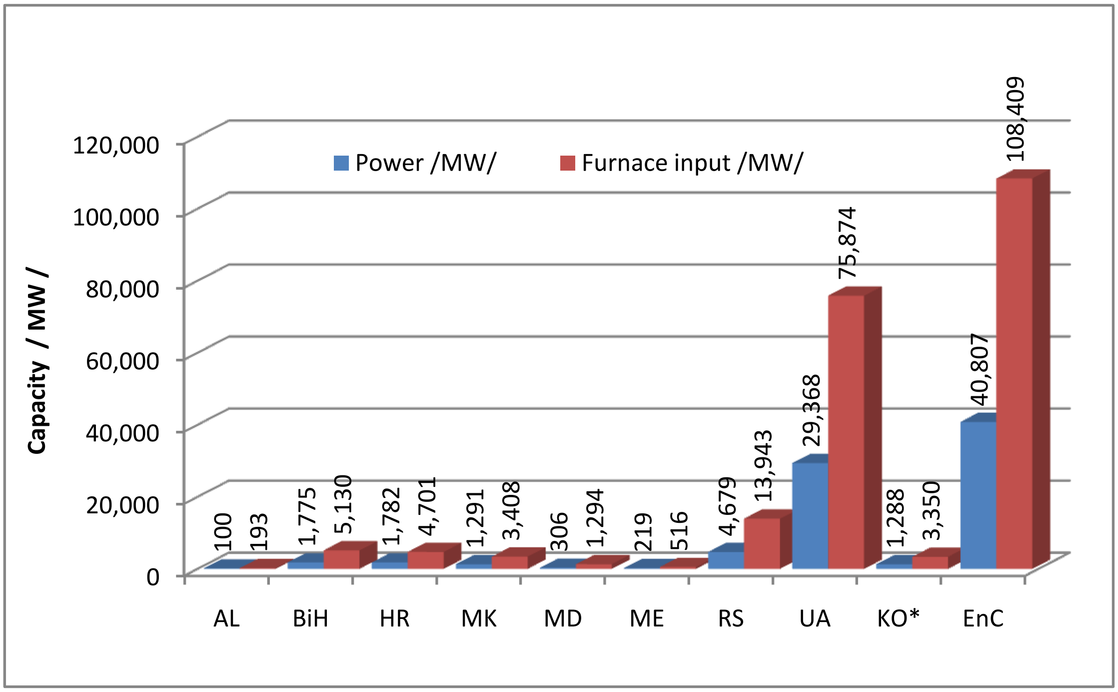
Pollutant	Rated thermal imput /MWth/	Emission limit values /mg/m^3/ per fuel used		
		Solid	Liquid	Gaseous
Dust (PM)	50-100	30	30	5
	100-300	25	25	
	>300	20	20	
NO_x	50-100	450	450	100
	100-300	200	200	
	>300	200	150	
SO_2	50-100	400	350	35
	100-300	250	250	
	>300	200	200	

During the inception phase of this project, an inventory of LCPs with a rated thermal input equal to or greater than 50 MW for each Contracting Party had been established. This inventory contains a list and general information on LCPs with a rated furnace capacity equal to or greater than 50 MW, as well as technical data on the LCP units. Also, additional information on measures needed to meet the requirements of the LCPD and the IED related to the emission limit values (ELVs) for the existing and the associated costs had been collected.

The summary of these data are presented in Table ES-3 and Graph ES-1. There are 183 LCP units, with a total power capacity of 40,807 MW and with a net power output of 38 GW. The largest capacity of TPPs is installed in Ukraine, with 113 units and a total power output of 29.4 GW. The total furnace inputs for all Contracting Parties are nearly 108 GW and the total yearly power output is 149 TWh/year.

Table ES-3: Total capacities in EnC Contracting Parties

No	EnC Contracting Party	Number of units	Power gross MW	Power net MW	Furnace capacity MW	Energy production GW/year
1	Albania	1	100	97	193	722
2	Bosnia and Herzegovina	9	1,775	1,616	5,130	10,044
3	Croatia	17	1,782	1,682	4,701	10,464
4	FYR Macedonia	7	1,291	1,194	3,408	6,364
5	Moldova	8	330	285	1,294	1,463
6	Montenegro	1	219	200	516	1,489
7	Serbia	22	4,679	4,247	13,943	26,605
8	Ukraine	113	29,368	27,493	75,874	88,669
9	Kosovo*	5	1,288	1,169	3,350	3,951
Total		183	40,807	37,982	108,409	149,405



Graph ES-1: LCP capacities in EnC Contracting Parties

Environmental protection measures have only been applied in certain units. Since with a few exceptions, the LCP units are over 30 years old, a large majority of them would need to undergo significant environmental improvements to meet the emission limit values of either the LCPD or the IED.

To estimate the investment costs for the measures proposed according to the different scenarios for each Contracting Party for the period 2014–2018, appropriate cost-benefit tools had been used[1].

Furthermore, impacts of electricity and heat production on human health and the environment has been estimated as external costs having in mind that they are not included in the current pricing system. The external costs have been calculated by using software tools that had been developed in the framework of the ExternE[2] and NEEDS[3] projects.

The ranking of the average estimated external costs of SO_2, NO_x and dust emissions in the Contracting Parties in 2014 is presented in Table ES-4 and Graph ES-2. The calculation is based on the pollutants emission concentration, flue gas volume and fuel consumption for the present power production (in 2012), while the external costs have been estimated for the year 2014.

Table ES-4: Average estimated external costs of SO_2, NO_X and dust emissions in 2014

Rank	EnC Contracting Party	Power MW	Energy GWh/a	Emission - BAU Pollutants emissions, t/year			External costs - BAU Total costs, million €/year				Unit cost
				Dust (PM)	NO_x	SO_2	Dust (PM)	NO_x	SO_2	Sum	€c/kWh
1	Montenegro	219	1,489	221	3,322	44,295	0.2	28.8	369.4	398.3	26.7
2	Bosnia and Herzegovina	1,775	10,044	6,407	24,334	296,060	3.1	187.0	2,054.7	2,244.7	22.3
3	FYR Macedonia	1,291	6,362	13,222	18,642	99,953	18.4	480.9	3,052.6	3,551.9	13.5
4	Serbia	4,679	26,240	22,551	55,536	366,060	6.1	89.2	566.8	662.1	10.4
5	Ukraine	29,368	88,669	336,517	291,830	996,765	435.9	1,555.8	7,062.9	9,054.6	10.2
6	Kosovo*	1,288	3,951[4]	8,582	17,952	14,768	7.0	155.5	123.2	285.6	7.2
7	Croatia	1,782	10,464	1,977	16,747	61,090	1.7	176.9	524.9	703.5	6.7
8	Moldova	330	1,580	0	734	0	0.0	5.3	0.0	5.3	0.4
9	Albania	100	722	2	98	70	0.0	0.5	0.5	1.0	0.1
	Energy Community	40,807	149,405	388,262	427,551	1,869,566	472.4	2,679.9	13,754.9	16,907.2	11.3

It appears that in the present status of TPPs (BAU status), the emission rate is very high namely 388,000 t/year of dust, 428,000 t/year of NO_x and 1,870,000 t/year of SO_2 (Table ES- 3). Therefore, it appears that the external costs of power production are very high, ranging from 0.1 €c/kWh, which is rather low, to the extremely high value of 26.7 €c/kWh. The average amount of external costs in Energy Community parties is 11.3 €c/kWh, which can be considered as a very high value.

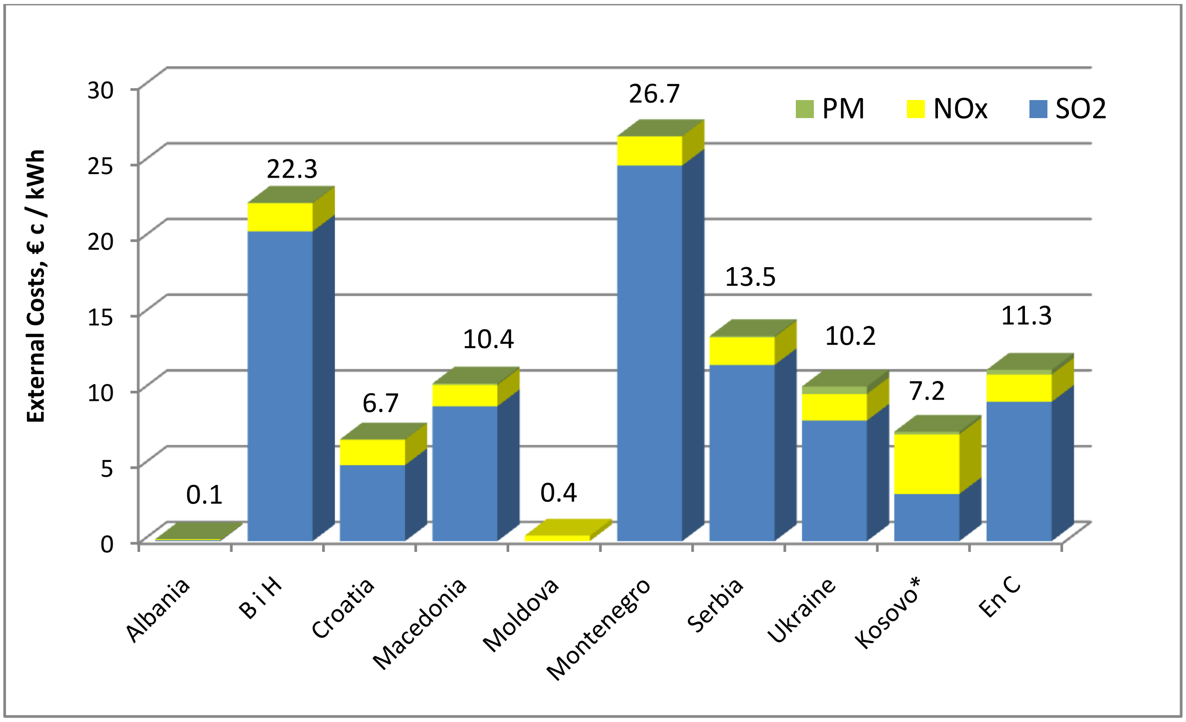
The estimated average external costs are different in the EnC Contracting Parties (Graph ES 2). For all EnC Contracting Parties, with the exception of Albania and Moldova, the biggest shares of external costs are those related to SO_2 emissions.

[1] Methodology for the Cost-Benefit analysis for CAFE Programme - Volume 1: Overview of Methodology (2005): http://europa.eu.int/comm/environment/air/cafe/ and www.cafe-cba.org

[2] http://www.externe.info/externe_2006

[3] http://www.needs-project.org

[4] The latest statistics show that total power output for both Kosovo A and B was 5,384 GWh in 2012, within which 36% comes out of Kosovo A and 74% was produced in Kosovo B



Graph ES-2: External costs per unit of power generation in BAU status

A very high level of external costs has been estimated in Montenegro mostly because of the environmentally complex situation related to the production of electricity and heat from lignite, which is the energy source used in the TPP Pljevlja. This is also the case in Bosnia and Herzegovina's TPPs Ugljevik and Kakanj which also resulted in high estimated external costs. The level of external costs in FYR Macedonia is high because of the conditions of lignite usage in TPP Bitola and TPP Oslomej. A similar situation can be observed in Serbia due to the conditions of lignite usage in TPPs Kostolac A and Kostolac B as well as in TPP Kolubara A. In Ukraine, high external costs are related to almost all TPPs which are using coal for electricity and heat production. In Kosovo*, average external costs are relatively smaller due to the better conditions of lignite usage for electricity production. In Croatia, external costs are high related to electricity and heat production from oil fuel and in some cases by a combined use of oil and natural gas in the vicinity of urban areas. In Moldova and Albania, external costs are low, the main reason of which is the dominant use of natural gas for electricity production.

External costs related to the emissions of SO_2, NO_x and dust are not internalised in the power and heat generation systems of any EnC Contracting Party. Moreover, these external costs are still not adequately reflected in energy and heat prices.

Internalisation of external costs in the power and heat generation sector has to be an important policy instrument towards the sustainable development of energy production in all EnC Contracting Parties. The emissions generated in the process of electricity and heat production can cause substantial damages to human health and the environment, which may vary widely depending on the fuels used, the location of the generation capacities as well as the technology used. Our objective is therefore to assess the external costs associated with electricity and heat production and to combine them with environmental taxes and economic instruments. This is relevant in assessing progress towards internalising external costs or, in other words, to define indicative prices that would reflect those external costs.

The investment costs of the environmental upgrade systems for thermal power plants in the case of the different scenarios (reaching compliance with the LCPD and IED, respectively) are estimated for each Contracting Party. Having in mind that there are many different techniques offering a wide range of solutions for emission reduction and with a large variation in their respective investment costs, the Consultant made a separate review of best available techniques (BAT) and their costs, which are presented in the annexes to the study. The investment cost estimates for the environmental upgrade systems are based primarily on data obtained from the Contracting Parties on already completed projects as well as on their feasibility studies for some TPPs and also on separate studies of international consultants for TPPs in the region, performed within the last decade. The investment costs are used with the same level in all beneficiary countries, taking into account the variations in fuel characteristics, pollutants emission, plant capacity, fuel consumption, etc.

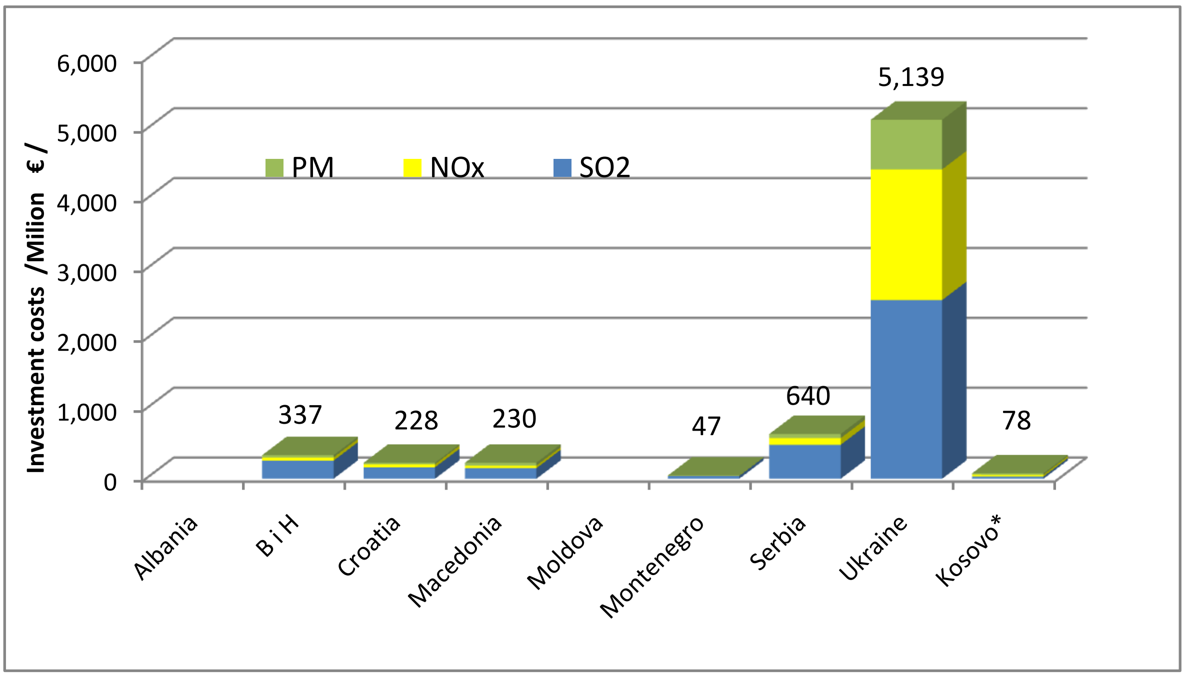
The common characteristics of all EnC Contracting Parties are that they have only one type of domestic fuel appropriate for electricity production. Albania does not have its own fuel sources and uses distillate oil with low sulphur content. Moldova does not have domestic sources of primary energy and it produces electricity in several gas-fired CHPs and imports electricity for the most of its needs. Ukraine is one of the biggest exporters of high quality coal. It has a developed system for gas transport, but due to the major difference between gas and coal prices it uses presently only coal as a fuel in TPPs and all its gas-fired TPPs are temporarily in reserve. In Bosnia and Herzegovina, Montenegro and Serbia lignite is the main source for electricity and heat production. In Croatia, the main sources are gas, oil and coal.

Apart from the prime environmental compliance scenarios with the LCPD and the IED, alternative scenarios have been considered, aiming to achieve the same emission standards as it is required by the LCPD, albeit with different technical solutions. In that respect, the absence of fuel diversity in the Contracting Parties undermines the possibility to choose alternative scenarios which would include a change of fuel. Small power systems in most beneficiary countries also limit the options for different scenarios. In scenarios which include the replacement of existing TPP units, the new TPP units will use the same kind of fuel and the only characteristic to achieve their financial viability is high plant efficiency. The evidence of such options can be approved by analysing their long-term operation results and financial feasibility.

Compliance with LCPD in the EnC Contracting Parties has been analyzed unit by unit. According to the obtained information, regarding the technical parameters and emission concentrations, the best available techniques have been determined for every LCP unit. For these techniques the investment cost is estimated, which is summarized in Table ES-5 and in Graph ES-3.

Table ES-5: Investment costs of TPPs/CHPs for compliance with LCPD (million €)

No	EnC Contracting Party	Pollutant			Total
		Dust (PM)	NO_x	SO_2	
1	Albania	0	0	0	0
2	Bosnia and Herzegovina	31.9	45.8	259.5	337.2
3	Croatia	20.4	43.6	164.0	228.0
4	FYR Macedonia	41.8	36.0	151.9	229.7
5	Moldova				
6	Montenegro	0.0	4.9	42.0	46.9
7	Serbia	58.6	95.4	486.4	640.4
8	Ukraine	709.5	1,871.2	2,557.9	5,138.5
9	Kosovo*	20.0	26.0	32.0	78.0
Total		882.1	2,122.9	3,693.7	6,698.7



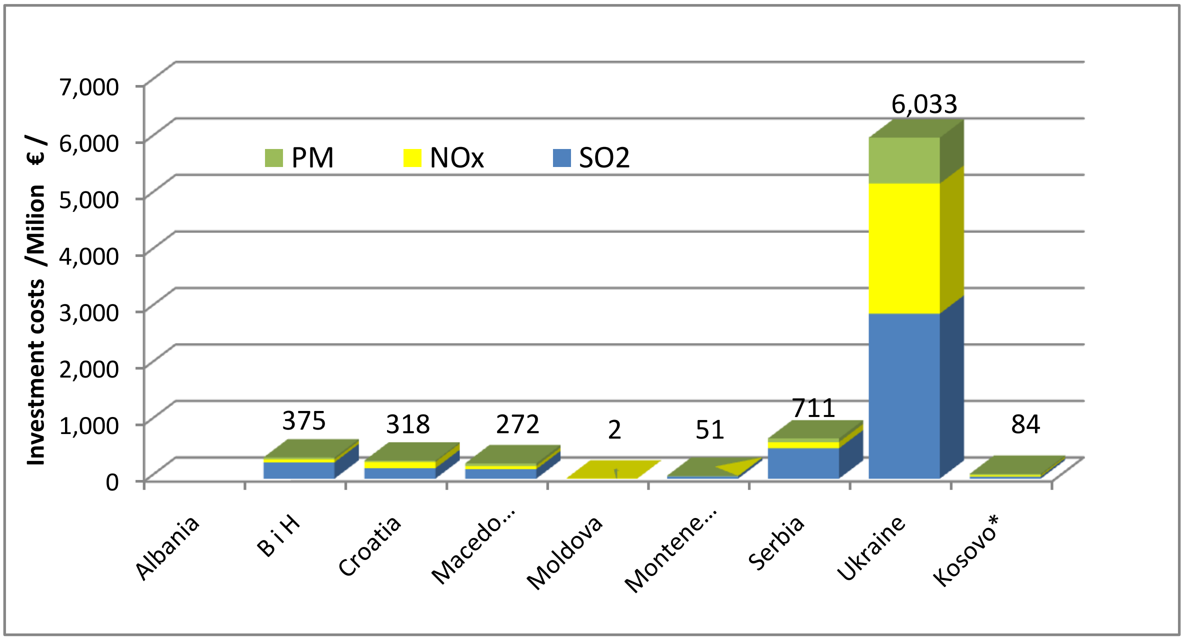
Graph ES-3: Investment cost estimate for the compliance with LCPD

The total required investment costs of the environmental upgrade systems amount to 6.7 billion €, out of which Ukraine has the largest share with 5.14 billion € (77%). Regarding the investment cost expenditure per pollutant, SO_2 abatement techniques account for 55%, NO_x reduction for 32% and dust reduction for 13% out of the total estimated amount of costs.

Similar analyses are performed for the second scenario. The results of the investment assessment concerning the environmental upgrading of LCPs with a view to reach compliance with the requirements of the IED are presented in Table ES-6 and Graph ES-4 per Contracting Party.

Table ES-6: Investment cost of TPPs/CHPs for compliance with IED (million €)

No	EnC Contracting Party	Pollutant			Total
		Dust (PM)	NO_x	SO_2	
1	Albania	0.0	0.0	0.0	0.0
2	Bosnia and Herzegovina	33.5	52.9	288.3	374.7
3	Croatia	22.7	110.6	184.9	318.2
4	FYR Macedonia	47.0	57.6	167.0	271.6
5	Moldova	0.0	1.9	0.0	1.9
6	Montenegro	0.0	4.9	46.0	50.9
7	Serbia	64.7	109.5	536.5	710.7
8	Ukraine	811.7	2,300.9	2,920.6	6,033.2
9	Kosovo*	23.0	26.0	35.2	84.2
Total		1,002.6	2,664.3	4,178.5	7,845.4



Graph ES-4: Investment cost estimate for the compliance with IED

As the IED requires lower emission limit values for pollutants, the investment cost requirements will be increased to 7.85 billion €, which is 17% higher from the LCPD scenario. Ukraine has also the largest part in it, with a budget sum of over 6 billion €. The other EC beneficiary countries have much lower investment needs, with the exception of Albania, which has already complied with IED standards. Within the required investment cost estimates, the desulphurization plants need 53%, while the nitrogen oxides reduction and dust removal systems require 34% and 13%, respectively.

The third scenario, an alternative scenario to Scenario 1 (with LCPD requirements), includes the replacement of some old TPP units and the environmental upgrading for the rest in the case of need. The main characteristics of this scenario is that the new TPP units, apart from the required environmental standards, will have higher energy efficiency factors, fuel savings, O&M cost reduction and lower green-house gases emissions. The rest of the TPP units would have to implement technical measures for the compliance with the LCPD standards. For this scenario the following investment costs are estimated:

- Bosnia and Herzegovina 945 million €
- Croatia 704 million €
- FYR Macedonia 1,367 million €
- Montenegro 370 million €
- Serbia 2,776 million €
- Kosovo* 1,090 million €

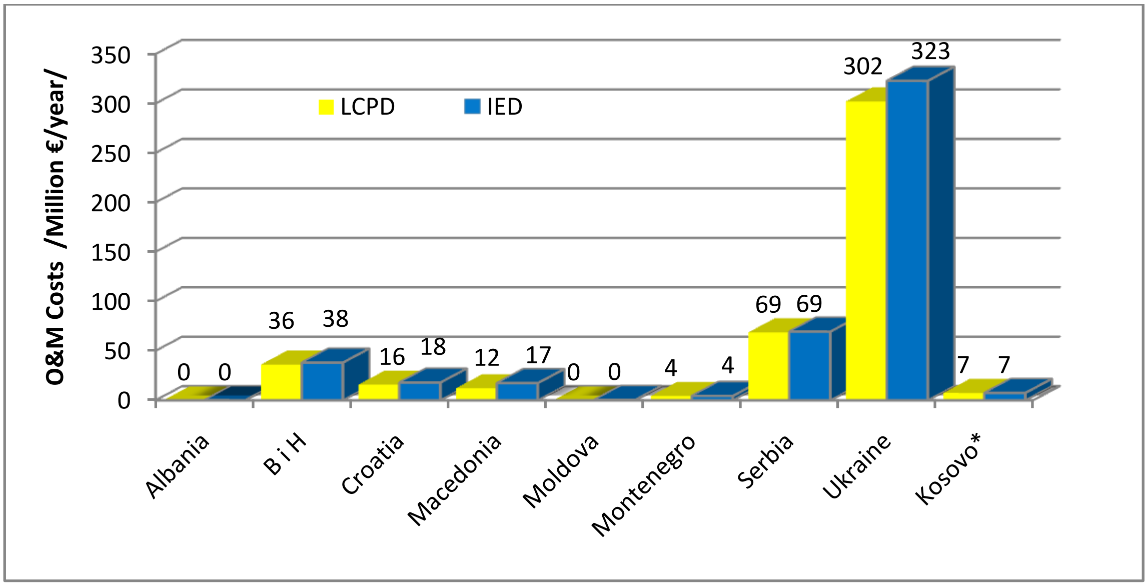
These scenarios would have to be analysed on a plant by plant basis, taking into account fixed assets of the existing TPP units, the technical characteristics of new units, fuel savings, revenue, etc. in order to obtain conclusions on the financial viability of the proposed projects.

Ukrainian thermal power plants generally operate at a very low load factor (36.8%) and capacity use (3,224 h/year). Therefore, the power system has a major surplus of generating capacity. One of the possible scenarios analysed in this study, is the temporary conservation of all gas fired TPP units along with the mothballing of the oldest coal fired units (with a total capacity of 9,441 MW). Following this scenario, the average load factor could be increased up to 54.2 %. The necessary investment for the environmental upgrade of the remaining TPPs would amount to 3,843 million €, which is a temporary reduction in investment costs of 1,277 million €. The cost savings for the environmental upgrading for this scenario shall be reinvested later on, if and when the electricity demand increases.

The valuation of different scenarios of the environmental upgrade of LCPs is performed by the use of the Cost-Benefit Analysis (CBA) methodology, which is undertaken from the point of view of the society. The CBA is the economic quantification of all costs and benefits, with regard to compliance with LCP and IE Directives, for every unit for which an environmental upgrade is required. The benefits are accounted as the monetization of the avoidance of external costs of pollutants emission, for each particular pollutant and for each TPP unit, for each EnC Contracting Party. The benefits are summarized by the appropriate social discount rate of 3% to the year of 2017, which is the implementation deadline for the LCPD. Similarly, the present values of all incurred costs are evaluated for the same year (2017). The costs comprise the investment costs for the environmental upgrade as well as the sum of discounted O&M costs for the environmental upgrade systems, over the period up to 2030.

The O&M yearly costs for the Contracting Parties are presented in Graph ES-5. The costs cover maintenance costs, material and power consumption costs, labour costs, insurance costs and waste disposal costs. Due to the characteristics of the O&M costs, they have a fixed part and a part proportional to the energy production. Generally speaking, O&M costs are very large. For all EnC Contracting Parties, they amount to 446 million €/year for LCPD and about 473 million €/year for IED. Within these figures Ukraine has the largest portion of that of 302 and 323 million €/year (see Graph ES-5), followed by Serbia with 69 million €/year, Bosnia and

Herzegovina with 36 to 39 million €/year, Croatia with 16-18 million €/year, FYR Macedonia with 12 to 17 million €/year, Kosovo* with 7 million €/year and Montenegro with 4 million €/year. Moldova will have about 0.4 million €/year for the IED scenario, while Albania will not have any of these expenses.



Graph ES-5: O&M costs of the LCPD and IED compliance systems

The Cost-Benefit analysis has been performed for every single TPP or CHP unit. The results of the CBA show that in most cases benefits significantly outweigh the costs and consequently the B/C ratio is far greater than 1. In the case of a few units, however, the B/C ratio drops down to 4.3 for LCPD scenario and as low as 1.4 for IED scenario. This justifies compliance with the emission limit values of both directives from an economic point of view, with regards to the interest of the society as a whole. The aggregated results per Contracting Party are presented in Tables ES-7 and ES-8.

Within the framework of this study, appropriate environmental abatement techniques are assessed for all LCPs in the EnC Contracting Parties, with a total capacity of 40,807 MW. Compliance with the standards of the **LCP Directive** will require 6,699 million €, amounting to an average of 164 €/kW. In addition, the O&M costs of the environmental upgrade systems will amount to 446 million €/year. The present value of all estimated costs is 11.4 billion € while the present value of all benefits is estimated at a level of 193 billion €. Although there is a variation of B/C Ratio from unit to unit in all considered cases the present value of benefits are much higher than the present value of costs.

Table ES-7: Cost-benefit analysis for compliance with the LCPD

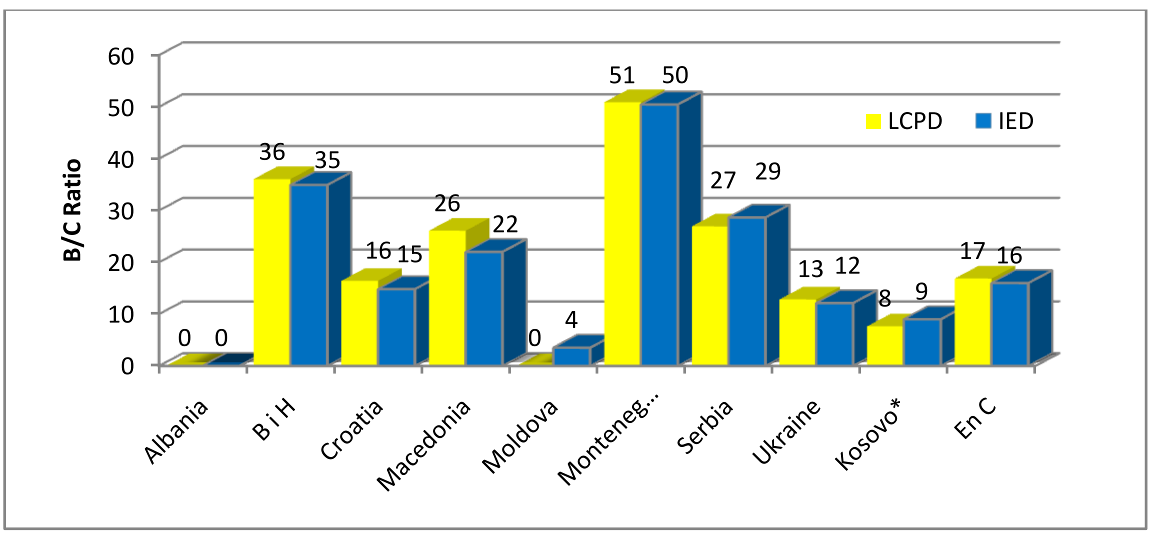
Code	EnC Contracting Party	MW	Costs		NPV			B/C
			Invest.	O&M	C	B	B-C	
			Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	
1	Albania	100	N/A	N/A	N/A	N/A	N/A	N/A
2	Bosnia and Herzegovina	1,775	337.2	36	720	25,974	25,254	36
3	Croatia	1,782	228	16	396	6,497	6,101	16
4	FYR Macedonia	1,291	230	12	358	9,350	8,992	26
5	Moldova	330	N/A	N/A	N/A	N/A	N/A	N/A
6	Montenegro	219	46.9	4.3	93	4,725	4,632	51
7	Serbia	4,679	640	68	1,368	36,825	35,458	27
8	Ukraine	29,368	5,138.5	302.1	8,351	108,243	101,448	13
9	Kosovo*	1,288	78	7	156	1194	1,038	8
	EnC	40,807	6,699	446	11,442	192,808	182,923	17

Table ES-8: Cost-benefit analysis for compliance with the IED

Code	EnC Contracting Party	MW	Costs		NPV			B/C
			Invest.	O&M	C	B	B-C	
			Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Albania	100	N/A	N/A	N/A	N/A	N/A	N/A
2	Bosnia and Herzegovina	1,775	375	38.0	779	27205	26426	35
3	Croatia	1,782	318	18	508	7,524.9	7,017.1	15
4	FYR Macedonia	1,291	272	17	456	10,035	9,579	22
5	Moldova	330	2.1	0.4	6.5	22.7	16.2	4
6	Montenegro	219	51	4.3	96.8	4,886	4,789	50
7	Serbia	4,679	704	67	1,419	40,668	39,248	29
8	Ukraine	29,368	6,033	323	9,467	114,860	107,283	12
9	Kosovo*	1,288	84	7	163	1,462	1,299	9
	EnC	40,807	7,846	473	12,836	205,432	194,487	16

Compliance with the **IED** requires higher investment costs amounting to 7,845 million € which results in an average of specific investments of 192 €/kW. The present value of all estimated costs is 12.8 billion € while the present value of all benefits is estimated to be over 205 billion €. The B/C ratio is very highn the case of IED, which justifies the environmental upgrading, from the point of view of the society as a whole.

The average B/C ratio per Contracting Party is in the range of 8 to 51 for the LCPD, with an EnC average value of 17. In case of IED, the B/C ratio varies from 4 to 50, with an average value of 16 (see Graph 6).



Graph ES-6: Benefit/cost ratio of compliance with the LCPD and IED

The EnC Contracting Parties, with the exception of Croatia, who joined the European Union on 1 July 2013, do not apply adequate measures to reduce emissions of NO_x, SO_2 and dust from large combustion plants. Taking into account fuel characteristics, Albania is already ready to implement both the LCPD and the IED and Moldova only has to carry out minor additional efforts in order to implement the requirements of the IED. Other Contracting Parties, namely Bosnia and Herzegovina, the Former Yugoslav Republic of Macedonia, Montenegro, Serbia, Ukraine and Kosovo* face serious challenges to implement the two directives.

In the past two decades major changes have occurred in the social and economy sectors in the Energy Community Contracting Parties. As a consequence of those changes, a steady decline of industrial production could have been observed resulting in the decline of electricity demand as well. As a consequence, in most of the Contracting Parties no new power generation sources have been constructed for more than twenty years. Therefore, it can be concluded that there is a strong general need for the modernization of this sector as a whole.

1. Introduction

Electricity and heat generation are main sources of air pollution in the EnC Contracting Parties together with transport, industry and agriculture. All these sectors emit a variety of air pollutants – sulphur dioxide (SO_2), nitrogen oxides (NO_x), dust - particulate matter (PM), ammonia (NH_3) and volatile organic compounds (VOCs). Many of these pollutants interact with others or with each other to form new pollutants. These are eventually deposited and have a whole range of adverse effects on human health and environment.

Air pollution results in a high number of premature deaths of citizens in the EnC Contracting Parties each year, as well as increased hospitalization costs, the costs of additional medication and millions of lost working days. Furthermore, environmental damages caused by the acidification of ecosystems and damage to crops and forests are substantial.

Dust (particulate matter) consists of "primary" particles emitted directly into the atmosphere from certain processes and "secondary" particles (or "aerosol"). Particulates in the ambient air are classified according to their size: PM10 and PM2.5 refer to all particles with diameter less than 10 micrometres (the "coarse" fraction) and 2.5 micrometres (the "fine" fraction) respectively. Fine particles tend to originate more from human activities than coarse particles. The scope of this study covers particulate mater between 2.5 and 10 micrometres (PM10), referred to as dust throughout this document. The emissions of gaseous pollutants, such as sulphur dioxide (SO_2) and nitrogen oxides (NO_X), which are altered through chemical reaction in the atmosphere, are increasing particulate mass.

Ground-level ozone is formed in the atmosphere by a reaction between volatile organic compounds (VOC) and NO_X in the presence of sunlight. Ozone occurs naturally in the stratosphere and in the troposphere, but in those areas, it is formed by different chemical processes. Ozone in the stratosphere is valuable as it protects the ecosystem from ultraviolet radiation; however, tropospheric ozone near ground level is harmful to ecosystems and human health. Damage caused directly and indirectly by ground-level ozone is one of the most serious regional air pollution problems affecting agriculture in the EnC Contracting Parties.

Acidification of rains and, as a consequence, the contamination of lakes, rivers, forests and other ecosystems is mainly caused by emissions of SO_2, and NO_X. After a significant loss in fauna and flora, it may take several decades for an ecosystem to recover, even when acidifying inputs are reduced to sustainable levels.

Eutrophication is the response of the ecosystem to the addition of artificial or natural substances, such as nitrogen from NO_X. These substances which are also emitted from LCPs can lead to eutrophication further to their contribution of the formation of ground-level ozone that can damage forests, crops and vegetation.

Apart from harmful effects on human life and the environment, air pollution also has an impact on materials, buildings and cultural heritage. The major effects on human health and the environment of thepollutants emitted by power and heat generation are presented in the table below.

Table 1: Multi-pollution/multi-effect review of air pollution from LCPs

Effects	Pollutants		
	Dust (PM)	SO_2	NO_x
Health effects:			
- Particulate matter	√	√	√
- Ground-level ozone			√
Vegetation effects:			
- Ground-level ozone			√
- Acidification		√	√
- Eutrophication			√

The Terms of Reference (ToR) for this study[5] have highlighted that the implementation of the LCP Directive in the Energy Community is a high priority both politically and technically. As Contracting Parties to the Energy Community Treaty, all signatories have undertaken to implement the LCP Directive by 31 December 2017 as set out by Article 16 and Annex II of the Energy Community Treaty. It is important to note that the LCP Directive covers plants with a rated thermal input equal to or greater than 50 MW.

Implementation of the LCP Directive by the Contracting Parties, in compliance with the above-mentioned deadline, has to be supported by the Energy Community Secretariat (ECS) and it's Task Force on Environment as the main body through which efforts are being coordinated. Contracting Parties have already provided information regarding their status of transposition and implementation of the LCP Directive which, however, fails short to demonstrate, on a number of occasions, that the deadline of the Treaty will be met.

At the Second and Third meetings of the Task Force on Environment (20 October 2011 and 23 May 2012, Vienna), a number of Contracting Parties reported that they are facing major challenges regarding the future implementation of the LCP Directive due to the investments needed for modernization and given existing inefficiencies. Furthermore, the Secretariat was invited to seek support for a preliminary compliance assessment regarding the current state of play in the Contracting Parties. The Secretariat reached the conclusion that such a preliminary compliance assessment could be harmonized with a structured analysis on the Contracting Parties' respective LCP sectors and the need for modernization of individual plants.

Having in mind the above, it can be concluded that the preparation of the Study on the Need for Modernization of Large Combustion Plants in the Contracting Parties of the Energy Community in the context of the implementation of the LCP Directive of high importance for all Contracting Parties and would serve as a point of reference for setting priorities.

[5] Energy Community – Tender Documents for the Selection of a Consultant for the Study on the Need for Modernization of Large Combustion Plants in the Contracting Parties of the Energy Community in the context of the implementation of Directive 2001/80/EC, Vienna, 22 October 2012

Objectives and Scope of the Study

The Terms of Reference of this Study have defined the main and specific project objectives as follows.

Main objective

The main objective is to support governments, decision-makers, privately and publicly owned energy companies, private and public investors in their efforts to make Contracting Parties capable to meet their commitments under the Energy Community Treaty within the foreseen deadline. This can be achieved either by the modernization of large combustion plants, by changing fuels or by replacing plants by new capacities. The Consultant has developed a scenario for each of these options.

Specific objectives

The specific objectives of this study are as follows:

- To provide governments, companies and private and public investors with an accurate assessment of the investment needs on a plant-by-plant basis in order to meet the requirements of the LCP Directive in all Contracting Parties.
- To develop different scenarios for the individual plants in order to achieve compliance with the emission limit values of the LCP Directive. In this respect, possible measures (e.g. change of fuels, use of different abatement techniques, etc.); their technical feasibility/limitations and their costs (at a generic level, i.e. by using cost ranges or factors) shall be identified. For each of the plants concerned, these measures and combinations thereof can then be considered and their costs can be assessed in more detail. Measures affecting overall emissions that do not have an impact on meeting the emission limits (e.g. plant efficiency gains) shall also be considered in this respect.
- To develop a realistic investment need scenario at plant and Contracting Party level, taking into account the different modernization options explored as well as the alternative scenario of replacing capacity (by either fossil fuel fired plants or renewable energy sources).
- To examine the potential and the costs involved for achieving compliance with the emission limit values of Annex V of Directive 2010/75/EU on industrial emissions.

The objectives of this assignment had been clearly defined as providing assistance to the Energy Community Secretariat in order to achieve their commitments under the Energy Community Treaty taking into consideration a cost-effective and efficient implementation of the project.

To perform the assignment, in the inception phase the Consultant's experts have developed appropriate questionnaires for data collection which have been approved by the Secretariat. The data lists have contained general technical data on the TPP and CHP units, the data on fuel used in the plants and the current emission values of the required pollutants (SO_2, NO_x and dust). The data lists included the main characteristics of the environmental upgrade systems, as well as the financial data of their implementation.

The approach and methodology was outlined in an Inception Report which was submitted to the Secretariat in January 2013. The choice of the environmental upgrade systems as well as the investment cost estimates has been based on the available national development and investment plans. However, in case there are neither national plans nor feasibility studies, the Consultant had used data on investment costs of the TPP environmental upgrade systems performed within the last decade. These data have been used for the range of thermal capacity, type of fuel, sulphur content, etc.

Scope of the Study

The services carried out within the framework of this project are divided into four main parts, as follows:

Inventory of combustion plants

During the inception phase of the project, the Consultant identified the different categories of combustion plants in each Contracting Party of the Energy Community, taking into consideration currently available data, based on their function and geographical location. Accordingly, the Consultant created a list of LCPs with a rated thermal input equal to or greater than 50 MW for each Contracting Party. These lists were sent to the Contracting Parties' authorities along with the questionnaire in order to have them peer-reviewed.

Data gathering

In order to verify and improve existing data, the Consultant prepared a questionnaire for each Contracting Party, asking for an update on the following information:

- General information on TPPs and CHPs;
- List of TPPs and CHPs with a rated thermal input equal to or greater than 50 MW;
- Technical data on TPP and CHP units.

Also, the Consultant gathered additional information on measures that would be needed to meet the requirements of the LCP Directive and the IED and the associated costs. These have been carried out by collecting information from existing literature and by carrying out interviews with relevant stakeholders (government officials, operators of large combustion plants, suppliers of abatement equipment and consultants in the region).

Estimation of costs and benefits

The Consultant delivered an estimate of the investment costs needed for the measures proposed according to the different scenarios and for each beneficiary for the period 2014-2018. Impacts of electricity and heat production on human health and the environment have been estimated as external costs.

Requirements of the LCPD and the IED

Requirements of Directive 2001/80/EC (LCPD)

Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants (LCP Directive) applies to combustion plants with a rated thermal input equal to or greater than 50 MW, irrespective of the type of fuel used (solid, liquid or gaseous). The Directive entered into force on 27 November 2001 in the EU.

The overall aim of the **LCP Directive** is to reduce emissions of acidifying pollutants, particles, and ozone precursors. Control of emissions from large combustion plants -- those whose rated thermal input is equal to or greater than 50 MW – plays an important role in the European Union's efforts to combat acidification, eutrophication and ground-level ozone as part of the overall strategy to reduce air pollution.

The LCP Directive contains the following provisions (presented in Annex 5):

1. Plants licensed after 26 November 2002 have to comply with the (stricter) emission limit values for SO_2, NO_x and dust fixed in part B of the Annexes III to VII.
2. Plants licensed on or after 1 July 1987 and before 27 November 2002 have to comply with the (less strict) emission limit values fixed in part A of the Annexes III to VII.
3. Significant emission reductions from "existing plants" (licensed before 1 July 1987) are required to be achieved by 1 January 2008:
   a) by individual compliance with the same emission limit values as established for the plants referred to in point 2 above or
   b) through a national emission reduction plan (NERP) that achieves overall reductions calculated on the basis of those emission limit values.

The Commission considers that it is possible to adopt a "combined approach", i.e. combination of points a) and b) for these "existing plants". A NERP must address all three pollutants covered by the Directive for all the plants covered by the plan.[6]

[6] http://ec.europa.eu/environment/air/pollutants/stationary/lcp/legislation.htm

To assist those Member States that choose the national emission reduction plan option as a means of compliance with the requirements for existing plants, the Commission has developed guidance[7] for the preparation of these plans.

According to Annex VIII.B of the LCP Directive, Member States shall establish, starting in 2004 and for each subsequent year, an inventory of SO_2, NO_x and dust emissions from all combustion plants covered by the Directive with a rated thermal input of 50 MW or more. The inventory should include information on a plant-by-plant basis concerning the total annual emissions of SO_2, NO_x and dust (as total suspended particles) and the total annual amount of energy input, related to the net calorific value, broken down in terms of the five categories of fuel: biomass, other solid fuels, liquid fuels, natural gas, other gases. The yearly plant-by-plant data shall be made available to the Commission upon request.[8]

Under Article 4(4) of the LCP Directive, existing combustion plants may be exempted from compliance with the emission limit values and from their inclusion in the national emission reduction plan if they are not operated for more than 20,000 hours starting from 1 January 2008 and ending no later than 31 December 2015. A record of the used and unused time allowed for the plants' remaining operational life has to be submitted each year to the competent authority and Member States have to report this to the Commission.

In January 2006, the European Commission's Directorate-General for Environment informed all Member States about the interpretation of certain important aspects of the LCP Directive[9]:

- **Interpretation of the term "existing combustion plant"**. The Directive is clear that new combustion plants which share a common stack, or in the judgement of the competent authority could share a common stack, are to be regarded as a single plant for the purposes of the Directive. This means that their capacities are aggregated for the purpose of determining whether they fall under the scope of the Directive as well as the applicable emission limit values. Similarly, existing plants whose waste gases are de facto discharged through a common stack should be considered as a single plant. Therefore, when a group of boilers discharge their waste gases through a common stack, the term "existing combustion plant" should be interpreted as that group of boilers. However, this aggregation approach does not apply to existing plants which potentially could share a common stack, but as a matter of fact do not. In other words the requirement to consider the possibility of sharing a common stack where one is not currently used, taking technical and economic factors into account, only applies to new plant.

7 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:016:0059:0067:EN:PDF
8 A summary of inventories can be found at the European Environmental Agency's website: http://www.eea.europa.eu/data-and-maps/data/plant-by-plant-emissions-of-so2-nox-and-dust-and-energy-input-of-large-combustion-plants-covered-by-directive-2001-80-ec-1
9 http://ec.europa.eu/environment/air/pollutants/stationary/lcp_interpretation.htm

- **Interpretation of the term "stack"**. The Directive uses the term "stack" which should not be confused with the term "flue". A "flue" is a compartment or division of a stack (or chimney) for conveying combustion gases to the outer air. A "stack" refers to the structure (providing a conduit for combustion gases) rising above roof level which may embody one or more "flues". As a result, a "common stack" cannot be interpreted as a "common flue".
- **Interpretation of the derogation in Article 4(4) of the Directive**. Article 4(4) allows a plant to be exempted from compliance with the emission limit values of the Directive or inclusion in a national emission reduction plan, provided that the operator undertakes not to operate the plant for more than 20,000 operational hours starting from 1 January 2008 and ending no later than 31 December 2015. After this time the plant must close. A plant is considered to be operating for the purposes of this derogation when any part of it operates, irrespective of the load factor. Therefore, when several boilers discharge their waste gases through a common stack, and any of these boilers operates at any load factor for, say, one hour, it will be considered that the whole plant is operating for one hour for the purposes of the derogation.
- **Conditions for combined approaches**. If a Member State decides to use a "combined approach", in view of the added complexity that this entails the Commission will request two lists of plants from the Member State: those that would be subject to ELVs; and those included in the plan. In addition, in order to ensure compliance with the emission limit values, the Commission will ask to receive every year from 2008 (or the year when the ELVs begin to apply) the inventory of emissions from those existing plants to which they apply. In order to confirm compliance with the targets of the plan, Member States are also strongly recommended to set up the annual national reporting system foreseen in the Commission Recommendation 2003/47/EC.

Requirements of Directive 2010/75/EU (IED)

The IED entered into force on 6 January 2011 and had to be transposed into national legislation by EU Member States by 7 January 2013.

The aim of IED is to achieve significant benefits to the environment and human health by reducing industrial emissions (including those emitted by installations from the energy sector) across the EU, in particular through a better use of the best available techniques (BAT).

The IED is based on several principles, namely: (1) an integrated approach, (2) best available techniques, (3) flexibility, (4) inspections and (5) public participation.

1. The **integrated approach** means that permits must take into account the whole environmental performance of the plant, covering its emissions to air, water and land, generation of waste, use of raw materials, energy efficiency, noise, prevention of and dealing with accidents and incidents as well as restoration of the site upon closure. The purpose of the Directive is to ensure a high level of protection of the environment as a whole.

2. The emission limit values (ELVs), must be based on the **best available techniques (BAT)**. BAT conclusions (documents containing information on the emission levels associated with the best available techniques) shall be the reference for setting permit conditions. To assist the licensing authorities and companies to determine BAT, the Commission organises an exchange of information between experts from the EU Member States, industry and environmental organisations.

3. The IED contains certain **elements of flexibility** by allowing the competent authorities to set less strict emission limit values in specific cases. Such measures are only applicable where an assessment shows that the achievement of emission levels associated with BAT, as described in the BAT conclusions, would lead to disproportionately higher costs compared to the environmental benefits due to (a) geographical location or the local environmental conditions or (b) the technical characteristics of the installation. The competent authority shall always document the reasons for the application of the flexibility measures in the permit including the result of the cost-benefit assessment. Moreover, Chapter III on large combustion plants includes certain flexibility instruments (Transitional National Plan, limited lifetime derogation, etc.)

4. The IED contains mandatory requirements on **environmental inspections**. Member States shall set up a system of environmental inspections and draw up inspection plans accordingly. The IED requires a site visit shall take place at least every 1 to 3 years, using risk-based criteria.

5. The **public has a right to participate** in the decision-making process, and to be informed of its consequences, by having access to:
   (a) Permit applications in order to give opinions,
   (b) Permits,
   (c) Results of the monitoring of releases and
   (d) The European Pollutant Release and Transfer Register (E-PRTR).

In E-PRTR, emission data reported by Member States are made accessible in a public register, which is intended to provide environmental information on major industrial activities. E-PRTR has replaced the previous EU-wide pollutant inventory, the so-called European Pollutant Emission Register (EPER).[10]

[10] http://ec.europa.eu/environment/air/pollutants/stationary/ied/legislation.htm

2. Inventory of LCPs in the EnC Contracting Parties

2.1. Large combustion plants in Albania

There is only one thermal power plant in Albania after the closure and decommissioning of TPP Fier due to the fact that it was already beyond its planned operational lifetime as well as its inefficiency and its incapability to comply with emission standards.

The new TPP in Vlora is a 100 MW combined cycle gas turbine (CCGT) that uses natural gas or distillate fuel oil as a fuel. The plant had been in operation for a short period of time in 2012, after which it was closed down due to some technical failures in the cooling water offshore pipeline. It is planned that the plant will be put back in operation by the end of 2014.

The basic plant characteristics are high net power plant efficiency of 50.5 %, with the net specific heat consumption of 7,135 kJ/kWh. The plant is equipped with continuous emission monitoring system, which, during the short period of time in which the plant has been in operation so far, shows the following emission concentrations:

- Dust (PM) 1.3 mg/m^3
- NO_x 67 mg/m^3
- SO_2 48 mg/m^3.

The plant is designed according to the IED's emission standards and in case of the use of distillate oil as a fuel, it is required that it has a sulphur content of less than 0.1%.

2.2. Large combustion plants in Bosnia and Herzegovina

There are four large thermal power plants in Bosnia and Herzegovina, consisting of a total of 9 units. The total installed capacity is 1,775 MW. All units use lignite as a fuel. TPP Ugljevik, one of the LCPs located in Bosnia and Herzegovina, has the highest sulphur dioxide emission concentration in the EnC Contracting Parties. The basic data on the TPP units are presented in Table 2-1, together with the most important dates for TPP units (start-up, performed or planned rehabilitation, retirement plans), performed service time and load factor. Most units are over 30 years old, with service time in the range of 97,000–312,000 hours.

The pollutant emission concentrations in flue gases, at the present status of combustion chamber characteristics (BAU) are presented in Table 2-2, together with the furnace capacity and the requirements of the LCP and the IE Directives.

Measures to prevent emissions of particulate matter have been undertaken in most of the units of TPPs Tuzla and Kakanj and in some cases they satisfy not only LCPD but also the stronger IED emission standards. Regarding the reduction of NO_x, primary measures have been applied in all units of TPPs Tuzla and Kakanj. To date, no desulphurization measures have been implemented. Furthermore, TPP Tuzla 3 is scheduled for retirement in 2015 as well as TPP Kakanj 5 in 2019 and TPP Tuzla 4 and 5 in 2022 and 2024, respectively. TPP Ugljevik has started the implementation work for the desulfurization process.

Table 2-1: Basic characteristics of LCPs in Bosnia and Herzegovina

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab.	Env. upgrading			Retirement plan		
							Dust	DeNox	FGD			
1	Gacko	L	300	1,934	1983	2017	2000			2030	145	80
2	Ugljevik	L	300	2,176	1985	2015			2017	2025	145	90
3	Tuzla 3	L	110	473	1966	2000				2015	312	54
4	Tuzla 4	L	200	1,196	1971	2002				2018	199	75
5	Tuzla 5	L	200	1,004	1974	2008				2024	196	63
6	Tuzla 6	L	215	1,008	1978	2013				2030	186	59
7	Kakanj 5	L	110	598	1969	2003				2019	235	69
8	Kakanj 6	L	110	312	1977	2012				2027	177	36
9	Kakanj 7	L	230	1,342	1988	2007				2030	97	74
Total			1,775	10,044								

Table 2-2: Emission concentrations of LCPs in Bosnia and Herzegovina

Code	Plant name	Fuel type	Furnace input MW	Emission - BAU			Requirements LCPD			Requirements IED		
				Concentration, mg/m^3			Concentration, mg/m^3			Concentration, mg/m^3		
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Gacko	L	770	250	600	1,500	50	200	400	20	200	200
2	Ugljevik	L	830	210	500	16,200	50	200	400	20	200	200
3	Tuzla 3	L	310	25	312	1,594	100	600	1,160	20	200	200
4	Tuzla 4	L	620	78	344	2,170	50	200	400	20	200	200
5	Tuzla 5	L	620	56	180	1,895	50	200	400	20	200	200
6	Tuzla 6	L	650	30	350	3,946	50	200	400	20	200	200
7	Kakanj 5	L	330	11	1,036	7,831	100	600	1,080	20	200	200
8	Kakanj 6	L	330	20	747	7,733	100	600	1,080	20	200	200
9	Kakanj 7	L	670	173	794	7,833	50	200	400	20	200	200
Total			5,130									

2.3. Large combustion plants in Croatia

There are 9 thermal power plants in Croatia, with 17 TPP units (Table 2-3). The total installed capacity is 1,782 MW. The Plomin TPP, located at the Adriatic coast is a coal-fired plant using imported hard coal. Two plants (TPPs Rijeka and Sisak) are fired by fuel oil while all other TPPs use natural gas as a basic fuel. Environmental upgrading was carried out for several units and some are planned to be implemented before the end of 2017. One unit (TPP Plomin 1) shall be retired in 2017. No information has been provided on the number of hours spent in operation on a plant-by-plant basis.

Table 2-3: Basic characteristics of LCPs in Croatia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab	Env. upgrading			Retirement plan		
							Dust	DeNox	FGD			
1	TPP Plomin 1	HC	125	915	1970		1999			2017		87
2	TPP Plomin 2	HC	210	1,631	1999	2017		2017	1999	2032		97
3	TPP Rijeka	FO	320	1,725	1979	2017		2005		2028		65

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab	Env. upgrading			Retirement plan		
							Dust	DeNox	FGD			
4	TPP Sisak A	FO	210	1,214	1970			2003		2020		70
5	TPP Sisak B	FO	210	1,214	1976	2017		2001		2026		70
6	TPP Jertovac 1	NG	40	47	1975					2021		17
7	TPP Jertovac 2	NG	40	47	1975					2021		17
8	CHP Zagreb C	NG	120	469	1979	2017				2028		46
9	CHP Zagreb K	NG	208	1,591	2001	2017				2030		90
10	CHP Zagreb L	NG	112	866	2011					2040		91
11	CHP Zagreb EL-TOK6	NG	11	21	1971	2017		2015		2020		23
12	CHP Zagreb EL-TOK8	NG	30	82	1980	2017		2008		2035		32
13	CHP Zagreb EL-TOH	NG	25	161	1994	2017				2025		76
14	CHP Zagreb EL-TOJ	NG	25	161	1994	2017				2025		76
15	CHP Osijek A	NG	46	256	1985	2017		2015		2035		65
16	CHP Osijek B	NG	25	42	1976					2020		20
17	CHP Osijek C	NG	25	21	1976					2020		10
	Total		1,782	10,464								

The emission concentrations in the flue gases are presented in Table 2-4, together with the furnace capacity and the requirements of the LCPD and the IED. The emission concentration of certain types of TPP units that use fuel oil as additional fuel shall be presented as fuel oil-fired units.

Table 2-4: Emission concentrations of LCPs in Croatia

Code	Plant name	Fuel type	Furnace input MW	Emission - BAU Concentration, mg/m^3			Requirements LCPD Concentration, mg/m^3			Requirements IED Concentration, mg/m^3			Notes
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2	
1	TPP Plomin 1	HC	338	39	597	1,719	100	600	1,048	20	200	200	
2	TPP Plomin 2	HC	544	22	357	165	50	200	400	20	200	200	
3	TPP Rijeka	FO	800	125	1,011	4,070	50	400	400	20	150	200	
4	TPP Sisak A	FO	548	112	751	3,701	50	400	400	20	150	200	
5	TPP Sisak B	FO	548	112	751	3,701	50	400	400	20	150	200	
6	TPP Jertovac 1	NG	123		257	7	5	300	35	5	100	35	
7	TPP Jertovac 2	NG	123		262	4	5	300	35	5	100	35	
8	CHP Zagreb C	NG	384	113	924	3,689	50	450	1,154	20	150	200	For FO
9	CHP Zagreb K	NG	410	5	31	5	5	300	35	5	100	35	
10	CHP Zagreb L	NG	214	5	22	2	5	300	35	5	100	35	
11	CHP Zagreb EL-TOK6	NG	86	76	704	3,497	50	450	1,700	30	450	350	For FO
12	CHP Zagreb EL-TO K8	NG	86	266	596	3,657	50	450	1,700	30	450	350	For FO
13	CHP Zagreb EL-TO H	NG	91		272	7	5	300	35	5	100	35	
14	CHP Zagreb EL-TO J	NG	91		237	12	5	300	35	5	100	35	
15	CHP Osijek A	NG	139	5	260	18	5	300	35	5	100	35	
16	CHP Osijek B	NG	88	0	234	17	5	300	35	5	100	35	
17	CHP Osijek C	NG	88	0	234	17	5	300	35	5	100	35	
	Total		4,701										

2.4. Large combustion plants in FYR Macedonia

FYR Macedonia has three thermal power plants (two lignite-fired and one fuel oil-fired plant), installed between 1978 and 1988 and two CHP units fired by natural gas that were installed in 2011 (Table 2-5). The total installed capacity is 1,291 MW. While plant and main equipment rehabilitation is in progress, environmental upgrading for TPP Bitola and Oslomej is planned for the period 2012-2016. The plants have been in service for 150,000–190,000 hours, with the exception of TPP Negotino which has only been in operation for 30,000 hours so far, mainly due to high fuel costs that reduce its load factor nearly to zero. The new CHPs have been in operation for a short period of time in the course of 2012.

Table 2-5: Basic characteristics of LCPs in FYR Macedonia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab.	Env. upgrading			Retirement plan		
							Dust	DeNox	FGD			
1	Bitola 1	L	233	1,387	1982	2013		2014		2027	190	74
2	Bitola 2	L	233	1,387	1984	2014		2013		2028	180	74
3	Bitola 3	L	233	1,387	1988	2012		2012		2029	150	74
4	Oslomej	L	125	604	1980	2012		2012		2027	170	60
5	Negotino	FO	210	17	1978					2020	30	1
6	Skopje CHP	NG	227	1,394	2011						3	74
7	Kogel CHP	NG	30	185	2011						3	74
Total			1,291	6,362								

The emission concentrations in the flue gases are presented in Table 2-6. All plants have excessive emissions of pollutants, with the exception of TPP Negotino, which is not in regular service due to a lower power demand and a lack of fuel oil. The emission of dust is between 400 and 640 mg/m^3, the emission of NO_x is over 800 mg/m^3, while the emission of SO_2 is between 4,000 and 5,000 mg/m^3. The new gas-fired CHP units should satisfy both LCP and IE Directives; however, no measurements have been performed with the use of natural gas so far.

Table 2-6: Emission concentrations of LCPs in FYR Macedonia

Code	Plant name	Fuel type	Furnace input MW	Emission - BAU Concentration, mg/m^3			Requirements LCPD Concentration, mg/m^3			Requirements IED Concentration, mg/m^3		
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	DUST	NO_x	SO_2
1	Bitola 1	L	647	370	810	4,800	50	200	400	20	200	200
2	Bitola 2	L	647	640	820	3,900	50	200	400	20	200	200
3	Bitola 3	L	647	640	820	3,900	50	200	400	20	200	200
4	Oslomej	L	334	570	360	4,100	100	600	1,064	20	200	200
5	Negotino	FO	656				50	400	400	20	150	200
6	Skopje CHP[1)]	NG	412	10	160	1	5	300	35	5	100	35
7	Kogel CHP[1)]	NG	65	10	160	1	5	300	35	5	100	35
Total			3,408									

[1)] Emission concentration have been measured in case of HFO use

2.5. Large combustion plants in Moldova

Thermal power plants in Moldova use natural gas as the main fuel. There are two LCPs, containing eight units, with a total installed capacity of 306 MW (Table 2-7). The first plant (CET-1) consists of five TPP units with capacities between 5 and 27 MW that are connected to a common stack. Therefore, their combined rated thermal input will be above 50 MW and would fall under the scope of the LCP and IE Directives. All units are designed for the combined generation of heat and power (CHP). The oldest unit was commissioned in 1951 and the last one was started up in 1977. All units have operated between 180,000 and 250,000 hours.

Apart from these units, there are some TPPs in the Transnistrian region that has an uncertain administrative status. The plants have a total installed capacity of 2,520 MW and produce electricity, which is imported to the main part of Moldova.

The emission concentrations in the flue gases are presented in Table 2-8, together with the EU emission standards. It appears that the current emission levels meet the requirements of the LCPD, while in some units it slightly exceeds the IED requirements. The furnace inputs for CET-1 are estimated, as there were no precise data available. The CHP-1 has one common stack, while the CHP-2 has two stacks, which is taken into account when the ELVs are applied.

Table 2-7: Basic characteristics of LCPs in Moldova

Code	Plant name	Fuel type	Pow. MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/	Notes
					Start up	Rehab.	Env. upgrading			Retirement plan			
							Dust	NO_x	FGD				
1	CET-1, No1	NG	12	59	1951	2008					249	60[1]	[1]Estim.
2	CET-1, No2	NG	12	59	1956	2004					227	60[1]	[1]Estim.
3	CET-1, No3	NG	10	49	1959	2005					239	60[1]	[1]Estim.
4	CET-1, No4	NG	27	132	1961	2006					190	60[1]	[1]Estim
5	CET-1, No5	NG	5	24	1961	2007					191	60[1]	[1]Estim
6	CET-2, No1	NG	80	398	1977	2015					198	61	
7	CET-2, No2	NG	80	371	1977	2014					187	57	
8	CET-2, No3	NG	80	371	1977	2013					179	57	
Total			306	1,463									

Table 2-8: Emission Concentrations of LCPs in Moldova

Code	Plant name	Fuel type	Furnace input*) MW	Emission - BAU Concentration, mg/m3			Requirements LCPD Concentration, mg/m3			Requirements IED Concentration, mg/m3		
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	CET-1, No1	NG	40		96		5	300	35	5	100	35
2	CET-1, No2	NG	40		113		5	300	35	5	100	35
3	CET-1, No3	NG	34		115		5	300	35	5	100	35
4	CET-1, No4	NG	91		97		5	300	35	5	100	35
5	CET-1, No5	NG	18		72		5	300	35	5	100	35
6	CET-2, No1	NG	357		137		5	300	35	5	100	35
7	CET-2, No2	NG	357		155		5	200	35	5	100	35
8	CET-2, No3	NG	357		142		5	200	35	5	100	35
Total			1,294									

*) CET-1 with one common stack, CET–2 No2 and No3 with one common stack

2.6. Large combustion plants in Montenegro

Montenegro has one 219 MW coal-fired TPP unit, commissioned in 1982 and rehabilitated in 2009. Its decommissioning is envisaged for 2025. Despite the fact that its electrostatic precipitators were retrofitted in 2009, it still has emission concentrations of NO_x and SO_2 that exceed the ELVs of the LCPD (Table 2-10).

Table 2-9: Basic characteristics of LCPs in Montenegro

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab.	Env. upgrading			Retirement plan		
							Dust	DeNox	FGD			
1	Pljevlja	L	219	1,489	1982	2009		2001		2025		85
Total			219	1,489								

Table 2-10: Emission concentrations of LCPs in Montenegro

Code	Plant name	Fuel type	Furnace input MW	Emission - BAU Concentration, mg/m³			Requirements LCPD Concentration, mg/m³			Requirements IED Concentration, mg/m³		
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Pljevlja	L	516	30	450	6,000	50	200	400	20	200	200
Total			516									

2.7. Large combustion plants in Serbia

There are 9 thermal power plants in Serbia, consisting of 22 units. Eighteen units are coal-fired and four units are fired by natural gas. The total installed capacity is 4,679 MW and the power production is 26,240 GWh/year (see Table 2-11). Some units are in operation from 1957 and the newest one was put into operation in 1991. The coal-fired units have operated between 113,000 and 378,000 hours, while the natural gas-/oil-fired units have spent considerably less time in operation, primarily due to the shortage of fuel and lower electricity demand.

Table 2-11: Basic characteristics of LCPs in Serbia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab.	Env. upgrading			Retirement plan		
							Dust	NO_x	FGD			
1	Nikola Tesla A1	L	210	1,231	1970		2006			2020	274	73.6
2	Nikola Tesla A2	L	210	1,198	1970		2005			2022	288	71.6
3	Nikola Tesla A3	L	305	1,923	1976		2014		2018		225	78.4
4	Nikola Tesla A4	L	309	1,989	1978		2007	2012	2017		226	81.1
5	Nikola Tesla A5	L	309	1,999	1979		2004				221	81.5
6	Nikola Tesla A6	L	309	1,987	1979		2010				195	81.0
7	Nikola Tesla B1	L	620	4,151	1983		2012		2018		218	81.7
8	Nikola Tesla B2	L	620	4,004	1985		2011		2019		203	78.8
9	Kolubara 1	L	32	175	1956					2017	378	68.9
10	Kolubara 2	L	32	116	1957					2017	330	45.5
11	Kolubara 3	L	64	135	1961					2018	296	26.5
12	Kolubara 4	L	32	0	1961					2009	281	0.0
13	Kolubara 5	L	110	626	1979		2009			2019	150	71.5
14	Morava	L	125	566	1969		2015			2020	214	59.8
15	Kostolac A1	L	100	560	1967		2006			2020	275	71
16	Kostolac A2	L	210	1,196	1980		2006			2024	168	71.5
17	Kostolac B1	L	348	1,937	1987		2014		2014		141	69.1
18	Kostolac B2	L	348	1,895	1991		2012		2014		113	67.6
19	Novi Sad 1	NG	135	189	1981						98	20
20	Novi Sad 2	NG	110	175	1984						63	20
21	Zrenjanin	NG	110	66	1989	2010					30	10
22	Sr. Mitrovica 1	NG	32	123	1979						118	50
Total			4,679	26,240								

Within the above table, the retirement plan is given approximately and in view of larger investments for the rehabilitation of TPP units, the closure date can be significantly postponed. Also, the retirement dates will strongly depend on the investments plan for the constructions of new LCPs.

The emission concentrations in the flue gases are presented in Table 2-12. In certain TPP units, emissions of particulate matter have been reduced by replacing the electrostatic precipitators, in accordance with the LCPD standards. Other TPPs are planned to be retrofitted in the coming years. Regarding the reduction of NO_x and SO_2, certain preparatory works are ongoing for installing new equipment based on the best available techniques.

Table 2-12: Emission concentrations of LCPs in Serbia

Code	Plant name	Fuel type	Furnace input MW	Emission - BAU Concentration, mg/m^3			Requirements LCPD Concentration, mg/m^3			Requirements IED Concentration, mg/m^3		
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Nikola Tesla A1	L	638	143	392	1,997	50	200	400	20	200	200
2	Nikola Tesla A2	L	638	143	392	1,997	50	200	400	20	200	200
3	Nikola Tesla A3	L	907	143	392	1,997	50	200	400	20	200	200
4	Nikola Tesla A4	L	907	38	428	2,031	50	200	400	20	200	200
5	Nikola Tesla A5	L	907	38	428	2,031	50	200	400	20	200	200

Code	Plant name	Fuel type	Furnace input MW	Emission - BAU Concentration, mg/m^3			Requirements LCPD Concentration, mg/m^3			Requirements IED Concentration, mg/m^3		
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2
6	Nikola Tesla A6	L	907	38	428	2,031	50	200	400	20	200	200
7	Nikola Tesla B1	L	1,755	41	450	2,081	50	200	400	20	200	200
8	Nikola Tesla B2	L	1,755	41	450	2,081	50	200	400	20	200	200
9	Kolubara 1	L	126	1,243	399	2,423						
10	Kolubara 2	L	126	1,243	399	2,423						
11	Kolubara 3	L	251	1,243	399	2,423	100	600	2,000	30	450	400
12	Kolubara 4	L	126									
13	Kolubara 5	L	373	58	409	2,376	100	600	907	20	200	200
14	Morava	L	382	1,161	535	3,897	100	600	870	20	200	200
15	Kostolac A1	L	303	418	397	6,211	100	600	1,187	20	200	200
16	Kostolac A2	L	643	112	381	6,183	50	200	400	20	200	200
17	Kostolac B1	L	1,037	600	561	6,329	50	200	400	20	200	200
18	Kostolac B2	L	1,037	265	511	5,758	50	200	400	20	200	200
19	Novi Sad 1	NG	372	6	933	154	5	300	35	5	100	35
20	Novi Sad 2	NG	341	6	933	154	5	300	35	5	100	35
21	Zrenjanin	NG	385	6	933	154	5	300	35	5	100	35
22	Sr. Mitrovica 1	NG	26	0	418	0	5	300	35	5	100	35
Total			13,943									

2.8. Large combustion plants in Ukraine

There are 15 thermal power plants in Ukraine consisting of 101 units and 9 CHP plants with a total of 12 units. The TPP plants have 93 coal-fired units, with a total capacity of 21,853 MW and 8 gas-fired units, with a total capacity of 5,400 MW. The CHP plants have 4 coal-fired units, with a total capacity of 404 MW and 8 gas-fired units, with a total capacity of 1,711 MW. The total installed capacity is 29,368 MW and electricity production is 88,669 GWh/year. The TPP units are generally old, with operational time of more than 200,000 hours (in certain cases, more than 300,000 hours). The oldest TPP unit was commissioned in 1959 while the newest one was commissioned in 1988. In several TPP units, emissions of dust (particulate matter) have been reduced and there are similar plans for other units as well. Furthermore, there are plans for construction of pilot projects for the reduction of NO_x and SO_2 according to the requirements of the LCPD. After gaining experience from the pilot projects, the necessary plans shall be made for the implementation of BAT in other TPP and CHP units.

Table 2-13 Basic characteristics of LCPs in Ukraine

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab.	Env. upgrading			Retirement plan		
							Dust	NOx	FGD			
1	Prydniprovska 7	HC	150	439	1959						320	38
2	Prydniprovska 8	HC	150	682	1960						340	59
3	Prydniprovska 9	HC	150	0	1060	2012					306	
4	Prydniprovska 10	HC	150	590	1961						318	51
5	Prydniprovska 11	HC	310	1,186	1963	2017					255	48
6	Prydniprovska 12	HC	285	0	1964							
7	Prydniprovska 13	HC	285	774	1964	2016					222	34
8	Prydniprovska 14	HC	285	0	1965	2015					290	
9	Kryvorizka 1	HC	282	1,106	1965	2013					296	48
10	Kryvorizka 2	HC	282	1,382	1966	2018					296	60
11	Kryvorizka 3	HC	282	0	1966	2012					254	
12	Kryvorizka 4	HC	282	1,221	1968	2017					233	53
13	Kryvorizka 5	HC	282	1,221	1968	2015					278	53
14	Kryvorizka 6	HC	282	714	1969	2016					240	31
15	Kryvorizka 7	HC	282	0	1970							
16	Kryvorizka 8	HC	282	1,014	1970						190	44

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab.	Env. upgrading			Retirement plan		
							Dust	NOx	FGD			
17	Kryvorizka 9	HC	282	0	1972	2014					249	
18	Kryvorizka 10	HC	282	1,198	1973						179	52
19	Zaporiska 1	HC	325	1,048	1972	2012	2012				256	40
20	Zaporiska 2	HC	300	1,277	1972	2016	2016				251	53
21	Zaporiska 3	HC	300	1,301	1972	2014	2014				258	54
22	Zaporiska 4	HC	300	1,205	1973	2015	2015				238	50
23	Zaporiska 5	NG	800	0	1975						149	
24	Zaporiska 6	NG	800	0	1976						127	
25	Zaporiska 7	NG	800	0	1977						133	
26	Starobeshivska 4	HC	175	715	1961							
27	Starobeshivska 5	HC	175	715	1962							50
28	Starobeshivska 6	HC	175	715	1962							50
29	Starobeshivska 7	HC	175	715	1963							
30	Starobeshivska 8	HC	175	715	1963							50
31	Starobeshivska 9	HC	175	715	1964							50
32	Starobeshivska 10	HC	175	715	1965							50
33	Starobeshivska 11	HC	175	715	1965							50
34	Starobeshivska 12	HC	175	715	1966							50
35	Starobeshivska 13	HC	175	715	1967							50
36	Slovianska 7	HC	800	3,269	1971							50
37	Burshtynska 1	HC	195	915	1965						275	59
38	Burshtynska 2	HC	185	397	1965						252	27
39	Burshtynska 3	HC	185	662	1966						272	45
40	Burshtynska 4	HC	195	884	1966						291	57
41	Burshtynska 5	HC	195	465	1977		2013				286	30
42	Burshtynska 6	HC	185	986	1977						284	67
43	Burshtynska 7	HC	185	508	1988		2012				268	31
44	Burshtynska 8	HC	195	806	1988		2016				287	52
45	Burshtynska 9	HC	195	961	1988		2007				269	62
46	Burshtynska 10	HC	195	930	1969		2006				281	60
47	Burshtynska 11	HC	195	992	1969		2005				245	64
48	Burshtynska 12	HC	195	667	1969		2018				239	43
49	Dobrotvirska 5	HC	100	402	1960						322	51
50	Dobrotvirska 6	HC	100	402	1961						315	51
51	Dobrotvirska 7	HC	150	786	1963	2013					326	65
52	Dobrotvirska 8	HC	150	568	1964	2014					304	47
53	Ladyzhinska 1	HC	300	874	1970						231	36
54	Ladyzhinska 2	HC	300	1,092	1971	2018	2018				223	45
55	Ladyzhinska 3	HC	300	1,262	1971	2019	2019				210	52
56	Ladyzhinska 4	HC	300	752	1971	2015	2015				225	31
57	Ladyzhinska 5	HC	300	582	1971	2016	2016				210	24
58	Ladyzhinska 6	HC	300	558	1971	2017	2017				223	23
59	Trypilska 1	HC	300	1,250	1969		2005				275	51
60	Trypilska 2	HC	300	1,250	1970	2014	2014	2014	2014		276	51
61	Trypilska 3	HC	300	1,250	1970						280	51
62	Trypilska 4	HC	300	1,250	1970						272	51
63	Trypilska 5	NG	300	0	1971							
64	Trypilska 6	NG	300	0	1972							
65	Zmiivska 1	HC	175	548	1960		2015		2015		312	38
66	Zmiivska 2	HC	175	548	1961						311	38
67	Zmiivska 3	HC	175	548	1962						280	38
68	Zmiivska 4	HC	175	548	1963						295	38
69	Zmiivska 5	HC	175	548	1964						293	38
70	Zmiivska 6	HC	175	548	1965						287	38
71	Zmiivska 7	HC	275	793	1966						252	35
72	Zmiivska 8	HC	325	937	1968	2005					265	35
73	Zmiivska 9	HC	275	793	1969						239	35
74	Zmiivska 10	HC	275	793	1969						258	35
75	Vuglegirska 1	HC	300	1,359	1972							55
76	Vuglegirska 2	HC	300	1,359	1973							55
77	Vuglegirska 3	HC	300	1,359	1973							55
78	Vuglegirska 4	HC	300	1,359	1973							55
79	Vuglegirska 5	NG	800	0	1975							

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab.	Env. upgrading			Retirement plan		
							Dust	NOx	FGD			
80	Vuglegirska 6	NG	800	0	1976							
81	Vuglegirska 7	NG	800	0	1977							
82	Zuevvskaya 1	HC	325	1,606	1982	2015					179	60
83	Zuevvskaya 2	HC	320	1,660	1982	2014					175	63
84	Zuevvskaya 3	HC	300	1,606	1986	2013					159	65
85	Zuevvskaya 4	HC	325	1,740	1988	2012					144	65
86	Kurakhovskaya 3	HC	200	1,005	1972	2016					264	61
87	Kurakhovskaya 4	HC	210	1,003	1973	2015					244	58
88	Kurakhovskaya 5	HC	222	969	1973	2015					226	53
89	Kurakhovskaya 6	HC	210	640	1973	2013					219	37
90	Kurakhovskaya 7	HC	225	982	1974	2016					232	53
91	Kurakhovskaya 8	HC	210	674	1974	2012					228	39
92	Kurakhovskaya 9	HC	221	1,019	1975	2014					233	56
93	Luganskaya 9	HC	200	1,070	1962	2017					309	65
94	Luganskaya 10	HC	200	642	1962	2012					298	39
95	Luganskaya 11	HC	200	988	1963	2014					307	60
96	Luganskaya 12	HC	175	0	1967						200	
97	Luganskaya 13	HC	175	951	1968	2013					274	66
98	Luganskaya 14	HC	200	1,070	1968	2016					268	65
99	Luganskaya 15	HC	200	988	1969	2015					277	60
100	Bilotserkivska CHP	NG	120	494								50
101	Darnytska CHP 5,10	NG	50	212								50
102	Darnytska CHP 6-9	HC	110	453								50
103	Kaluska CHP 1, 2	HC	100	412								50
104	Kaluska CHP 3, 4	NG	100	425								50
105	Kyivska CHP-5	NG	540	1,147								25
0	Kyivska CHP-5	FO	540	1,147								25
106	Kyivska CHP-6	NG	500	1,062								25
0	Kyivska CHP-6	FO	500	1,062								25
107	Kramatorska CHP	HC	120	494								50
108	Myronivska 4	HC	60	247	1954						335	50
109	Myronivska 9	HC	115	616		2004					49	65
110	Odeska CHP-2	NG	68	289								50
111	Sevastopolska CHP	NG	55	234								50
112	Simferopilska CHP	NG	278	1,181								50
113	Kharkivska CHP-2	HC	74	314								50
Total			29,368	88,669								

The emission concentrations in the flue gases accompanied with the emission standards of the LCPD and the IED are presented in Table 2-14. One of the main characteristics is the excess of dust (PM) and NO_x emissions, the latter of which is above 1,000 mg/m^3 in most cases which is significantly above the ELVs of the LCPD. SO_2 emissions from the coal fired TPPs are usually in the range between 3,000 and 5,000 mg/m^3, which is also considerably above the LCPD's requirements.

Some of the TPP units with common stacks have higher emission standards as they would have in case of separate stack. That is the case for the TPP units of Prydniprovska (4x150 MW), Dobrotvirska (2x100 MW and 2x150 MW) and for Zmiivska No 1 to No 10 with common stacks for every two units.

Table 2-14: Emission concentrations of LCPs in Ukraine

Code	Plant name	Fuel type	Furnace input MW	Emission - BAU Concentration, mg/m^3			Requirements LCPD Concentration, mg/m^3			Requirements IED Concentration, mg/m^3		
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Prydniprovska 7	HC	393	1,082	1,200	3,129	50	200	400	20	200	200
2	Prydniprovska 8	HC	393	1,112	1,260	3,400	50	200	400	20	200	200
3	Prydniprovska 9	HC	393	100	1,300	3,200	50	200	400	20	200	200
4	Prydniprovska 10	HC	393	955	1,180	3,055	50	200	400	20	200	200
5	Prydniprovska 11	HC	706	1,267	1,286	3,348	50	200	400	20	200	200
6	Prydniprovska 12	HC	649				50	200	400	20	200	200
7	Prydniprovska 13	HC	649	1,410	1,315	3,159	50	200	400	20	200	200
8	Prydniprovska 14	HC	649				50	200	400	20	200	200
9	Kryvorizka 1	HC	695	1,420	1,380	3,640	50	200	400	20	200	200
10	Kryvorizka 2	HC	695	1,300	1,420	3,680	50	200	400	20	200	200
11	Kryvorizka 3	HC	695	40	1,300	4,500	50	200	400	20	200	200
12	Kryvorizka 4	HC	695	293	1,470	3,620	50	200	400	20	200	200
13	Kryvorizka 5	HC	695	1,570	1,510	3,790	50	200	400	20	200	200
14	Kryvorizka 6	HC	695	1,590	1,590	3,840	50	200	400	20	200	200
15	Kryvorizka 7	HC	695				50	200	400	20	200	200
16	Kryvorizka 8	HC	695	1,400	1,603	3,850	50	200	400	20	200	200
17	Kryvorizka 9	HC	695				50	200	400	20	200	200
18	Kryvorizka 10	HC	695	1,500	1,603	3,850	50	200	400	20	200	200
19	Zaporiska 1	HC	786	986	1,550	3,840	50	200	400	20	200	200
20	Zaporiska 2	HC	723	860	1,490	3,939	50	200	400	20	200	200
21	Zaporiska 3	HC	723	848	1,484	4,089	50	200	400	20	200	200
22	Zaporiska 4	HC	723	842	1,600	3,939	50	200	400	20	200	200
23	Zaporiska 5	NG	1,963		598		5	200	35	5	100	35
24	Zaporiska 6	NG	2,058				5	200	35	5	100	35
25	Zaporiska 7	NG	2,133		682		5	200	35	5	100	35
26	Starobeshivska 4	HC	480				100	600	470	20	200	200
27	Starobeshivska 5	HC	480				100	600	470	20	200	200
28	Starobeshivska 6	HC	480				100	600	470	20	200	200
29	Starobeshivska 7	HC	480				100	600	470	20	200	200
30	Starobeshivska 8	HC	480				100	600	470	20	200	200
31	Starobeshivska 9	HC	480				100	600	470	20	200	200
32	Starobeshivska 10	HC	480				100	600	470	20	200	200
33	Starobeshivska 11	HC	480				100	600	470	20	200	200
34	Starobeshivska 12	HC	480				100	600	470	20	200	200
35	Starobeshivska 13	HC	480				100	600	470	20	200	200
36	Slovianska 7	HC	1,993				50	200	400	20	200	200
37	Burshtynska 1	HC	505	1,310	590	4,326	50	200	400	20	200	200
38	Burshtynska 2	HC	505	1,280	585	4,286	50	200	400	20	200	200
39	Burshtynska 3	HC	505	1,440	560	4,318	50	200	400	20	200	200
40	Burshtynska 4	HC	505	1,400	575	4,402	50	200	400	20	200	200
41	Burshtynska 5	HC	505	1,345	560	4,617	50	200	400	20	200	200
42	Burshtynska 6	HC	505	1,270	540	4,405	50	200	400	20	200	200
43	Burshtynska 7	HC	505	1,291	590	4,691	50	200	400	20	200	200
44	Burshtynska 8	HC	505	760	575	4,871	50	200	400	20	200	200
45	Burshtynska 9	HC	505	50	600	4,283	50	200	400	20	200	200
46	Burshtynska 10	HC	505	50	610	4,337	50	200	400	20	200	200
47	Burshtynska 11	HC	505	50	500	4,279	50	200	400	20	200	200
48	Burshtynska 12	HC	505	250	510	4,306	50	200	400	20	200	200
49	Dobrotvirska 5	HC	183	699	775	4,718	100	600	876	25	200	250
50	Dobrotvirska 6	HC	183	699	775	4,718	100	600	876	25	200	250
51	Dobrotvirska 7	HC	383	1,300	785	5,100	50	200	400	20	200	200
52	Dobrotvirska 8	HC	383	1,300	785	5,100	50	200	400	20	200	200
53	Ladyzhinska 1	HC	693	1,191	1,287	3,200	50	200	400	20	200	200
54	Ladyzhinska 2	HC	693	398	1,284	3,300	50	200	400	20	200	200
55	Ladyzhinska 3	HC	693	378	1,290	3,430	50	200	400	20	200	200
56	Ladyzhinska 4	HC	693	1,191	1,276	3,270	50	200	400	20	200	200
57	Ladyzhinska 5	HC	693	1,490	1,279	3,410	50	200	400	20	200	200
58	Ladyzhinska 6	HC	693	1,791	1,286	3,367	50	200	400	20	200	200
59	Trypilska 1	HC	767	1,118	736	2,626	50	200	400	20	200	200
60	Trypilska 2	HC	767	1,532	1,031	2,680	50	200	400	20	200	200
61	Trypilska 3	HC	767	1,449	748	2,610	50	200	400	20	200	200

Code	Plant name	Fuel type	Furnace input MW	Emission - BAU Concentration, mg/m^3			Requirements LCPD Concentration, mg/m^3			Requirements IED Concentration, mg/m^3		
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2
62	Trypilska 4	HC	767	1,410	739	2,640	50	200	400	20	200	200
63	Trypilska 5	NG	767				5	200	35	5	100	35
64	Trypilska 6	NG	767				5	200	35	5	100	35
65	Zmiivska 1	HC	492	3,506	920	2,881	50	200	400	20	200	200
66	Zmiivska 2	HC	490	3,557	923	2,798	50	200	400	20	200	200
67	Zmiivska 3	HC	480	3,483	902	2,845	50	200	400	20	200	200
68	Zmiivska 4	HC	483	3,374	879	2,813	50	200	400	20	200	200
69	Zmiivska 5	HC	478	3,261	839	2,959	50	200	400	20	200	200
70	Zmiivska 6	HC	483	3,118	765	2,612	50	200	400	20	200	200
71	Zmiivska 7	HC	773	2,425	1,661	3,728	50	200	400	20	200	200
72	Zmiivska 8	HC	800	289	2,215	5,307	50	200	400	20	200	200
73	Zmiivska 9	HC	702	2,537	1,470	3,663	50	200	400	20	200	200
74	Zmiivska 10	HC	717	2,494	1,460	3,401	50	200	400	20	200	200
75	Vuglegirska 1	HC	764	391	1,231	4,679	50	200	400	20	200	200
76	Vuglegirska 2	HC	762	391	1,231	4,679	50	200	400	20	200	200
77	Vuglegirska 3	HC	767	391	1,231	4,679	50	200	400	20	200	200
78	Vuglegirska 4	HC	766	391	1,231	4,679	50	200	400	20	200	200
79	Vuglegirska 5	NG	2,249				5	200	35	5	100	35
80	Vuglegirska 6	NG	2,249				5	200	35	5	100	35
81	Vuglegirska 7	NG	2,249				5	200	35	5	100	35
82	Zuevvskaya 1	HC	804	190	1,872	5,092	50	200	400	20	200	200
83	Zuevvskaya 2	HC	788	201	1,830	5,071	50	200	400	20	200	200
84	Zuevvskaya 3	HC	741	351	1,627	4,780	50	200	400	20	200	200
85	Zuevvskaya 4	HC	816	46	1,672	4,810	50	200	400	20	200	200
86	Kurakhovskaya 3	HC	530	2,850	667	4,750	50	200	400	20	200	200
87	Kurakhovskaya 4	HC	561	2,870	673	4,860	50	200	400	20	200	200
88	Kurakhovskaya 5	HC	586	2,690	649	5,040	50	200	400	20	200	200
89	Kurakhovskaya 6	HC	575	3,960	608	4,860	50	200	400	20	200	200
90	Kurakhovskaya 7	HC	593	1,880	651	4,630	50	200	400	20	200	200
91	Kurakhovskaya 8	HC	557	2,440	631	4,900	50	200	400	20	200	200
92	Kurakhovskaya 9	HC	586	2,000	597	4,860	50	200	400	20	200	200
93	Luganskaya 9	HC	555	2,501	1,113	3,650	50	200	400	20	200	200
94	Luganskaya 10	HC	564	764	1,010	3,506	50	200	400	20	200	200
95	Luganskaya 11	HC	547	2,354	1,180	3,595	50	200	400	20	200	200
96	Luganskaya 12	HC	494				100	600	420	20	200	200
97	Luganskaya 13	HC	480	2,312	1,203	3,899	100	600	472	20	200	200
98	Luganskaya 14	HC	555	2,540	1,283	3,856	50	200	400	20	200	200
99	Luganskaya 15	HC	561	2,343	1,208	3,960	50	200	400	20	200	200
100	Bilotserkivska CHP	NG	337		298		5	300	35	5	100	35
101	Darnytska CHP 5,10	NG	147		300		5	300	35	5	100	35
102	Darnytska CHP 6-9	HC	316	1,110	1,230	2,350	100	600	1,054	20	200	200
103	Kaluska CHP 1, 2	HC	287	1,200	176	2,595	100	600	1,157	25	200	250
104	Kaluska CHP 3, 4	NG	283		360		5	300	35	5	100	35
105	Kyivska CHP-5	NG	1,382				5	200	35	5	100	35
106	Kyivska CHP-5	FO	1,382				50	400	400	20	150	200
107	Kyivska CHP-6	NG	1,280		360		5	200	35	5	100	35
108	Kyivska CHP-6	FO	1,280		399	3001	50	400	400	20	200	200
109	Kramatorska CHP	HC	345	468	482	3,430	100	600	952	20	200	200
110	Myronivska 4	HC	175	228	603	3,395	100	600	1,554	25	200	250
111	Myronivska 9	HC	333	183	687	2,776	100	600	993	20	200	200
112	Odeska CHP-2	NG	198		1,020		5	300	35	5	100	35
113	Sevastopolska CHP	NG	160		224		5	300	35	5	100	35
114	Simferopilska CHP	NG	787		125		5	200	35	5	100	35
115	Kharkivska CHP-2	HC	215	2,525	680	5,661	100	600	1,412	25	200	250
Total			75,874									

2.9. Large combustion plants in Kosovo*

At this moment, there are two TPPs in Kosovo*, with the total capacity of 1,288 MW. The first plant is constructed between1970-1975 while the second plant was started up in 1983-1984 (see Table 2-15). Although the units of TPP Kosovo A have a service time between 150,000 and 200,000 hours it is planned that the plant shall be closed down by the end of the year 2017, mainly due to its poor environmental performance, the deterioration of its technical characteristics and its very low net plant efficiency of 22%.

Table 2-15: Basic characteristics of LCPs in Kosovo*

Code	Plant name	Fuel type	Powerer MW	Energy GWh/a	Key dates						Service time /000h/	Load factor /%/
					Start up	Rehab.	Env. upgrading			Retirement plan		
							Dust	DeNox	FGD			
1	Kosovo A3	L	200	590	1970		2012			2017	196	37
2	Kosovo A4	L	200	590	1971		2013			2017	188	37
3	Kosovo A5	L	210	606	1975		2012			2017	151	37
4	Kosovo B1	L	339	1,083	1983	2017	2017	2017	2017	2030	152	40[1)]
5	Kosovo B2	L	339	1,083	1984	2017	2017	2017	2017	2030	147	40[1)]
Total			1,288	3,951								

[1)]The latest statistics have shown that the Load factor is increased to 63%. Therefore the energy output from Kosovo B is 3,435 GWh/year

The other plant, TPP Kosovo B, shall be retrofitted by 2017 in order to meet the requirements of the LCPD as presented in Table 2-16.

Table 2-16: Emission concentrations of LCPs in Kosovo*

Code	Plant name	Fuel type	Furnace input MW	Emission - BAU			Requirements LCPD			Requirements IED		
				Concentration, mg/m3			Concentration, mg/m3			Concentration, mg/m3		
				Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Kosovo A3	L	540	49	650	599	50	200	400	20	200	200
2	Kosovo A4	L	540	728	687	582	50	200	400	20	200	200
3	Kosovo A5	L	570	45	680	592	50	200	400	20	200	200
4	Kosovo B1	L	850	419	789	623	50	200	400	20	200	200
5	Kosovo B2	L	850	444	805	611	50	200	400	20	200	200
Total			3,350									

3. External cost of electricity and heat production in LCPs

“Externalities“ are the hidden costs of an activity that are not included in its price – such as the impacts on human health and the environment of gases emitted into the air during power and heat production.

Combustion of any fossil fuel, whether it is solid (coal and lignite), liquid (oil) or gaseous (natural gas) at a thermal power plant (TPP) or a combined heat and power plant (CHP) results in the emission of a number of substances into the atmosphere. These have various effects around the emission point, including an increase in respiratory diseases, deterioration of buildings and lower agricultural production. Impacts vary widely depending on the type of fuel, on the technical characteristics of the plant (with special regard to the combustion methods), as well as the local environmental conditions.

The different impacts on receptors are presented in the below tables in the case of large combustion plants using solid, liquid and gaseous fuels.

Table 3-1: Main negative health and environmental impacts from LCPs using coal and lignite

Burden	Receptor	Negative impacts
Emissions to atmosphere		
SO_2	General public	Health
	Ecosystems	Impacts on biodiversity and productivity
	Building (etc.) materials	Damage, including to cultural heritage
	Agriculture	Productivity
	Visibility	Reduction
NO_x	General public	Health
	Ecosystems	Impacts on biodiversity and productivity
	Building (etc.) materials	Damage, including to cultural heritage
	Agriculture	Productivity
	Visibility	Reduction
Dust (PMx)	General public	Health
	Building (etc.) materials	Soiling
	Visibility	Amenity
Lead	General public	Health
	Agriculture, fisheries	Contamination of food
Mercury	General public	Health
	Agriculture, fisheries	Contamination of food
Other heavy metals	General public	Health
	Agriculture, fisheries	Contamination of food
CO_2	Climate	Effects on climate change
CH_4	Climate	Effects Climate change
Cooling tower plumes	General public	Spread of *Legionella*?
	General public	Spread of enteric pathogens?
Other air pollutants		

Table 3-2: Main negative health and environmental impacts from LCPs using oil

Burden	Receptor	Impact
Emissions to atmosphere		
SO_2	General public	Health
	Ecosystems	Impacts on biodiversity and productivity
	Building (etc.) materials	Damage, including to cultural heritage
	Agriculture	Productivity
	Visibility	Reduction
NO_x	General public	Health
	Ecosystems	Impacts on biodiversity and productivity
	Building (etc.) materials	Damage, including to cultural heritage
	Agriculture	Productivity
	Visibility	Reduction
CO_2	Climate	Effects on climate change
CH_4	Climate	Effects on climate change
Cooling tower plumes	General public	Spread of *Legionella*
	General public	Spread of enteric pathogens
Other air pollutants		

Table 3-3: Main negative health and environmental impacts from LCPs using natural gas

Burden	Receptor	Impact
Emissions to atmosphere		
SO_2	General public	Health
	Ecosystems	Impacts on biodiversity and productivity
	Building (etc.) materials	Damage, including to cultural heritage
	Agriculture	Productivity
	Visibility	Reduction
NO_x	General public	Health
	Ecosystems	Impacts on biodiversity and productivity
	Building (etc.) materials	Damage, including to cultural heritage
	Agriculture	Productivity
	Visibility	Reduction
CO_2	Climate	Effects on climate change
CH_4	Climate	Effects on climate change
Cooling tower plumes	General public	Spread of *Legionella*
	General public	Spread of enteric pathogens
Other air pollutants		

External costs for electricity and heat production are those that are not reflected in its price, but which society as a whole must bear. For example, damage to human health is caused by emissions of dust – particulate matter (PM). SO_2 and NO_x emissions also lead to adverse impacts on human health through the formation of secondary pollutants. NO_x emissions have adverse health impacts through the formation of ground-level ozone. SO_2 and NO_x emissions form secondary particles in the atmosphere (which have similar effects to primary PM). There are also costs associated with non-health impacts. SO_2 is the main pollutant of concern for building-related damage, though ground-level ozone also affects certain materials. The secondary pollutants formed by SO_2 and NO_x also impact crops and terrestrial and aquatic ecosystems.[11]

Damages from climate change, associated with the high emissions of greenhouse gases from fossil fuel based power production, also have considerable costs; however, this is an issue that goes beyond the subject of this study.

The overall level of these externalities will depend upon a number of factors including:

- the fuel mix for electricity generation (e.g. the use of coal releases far more air pollutants than natural gas);
- the efficiency of electricity production (as the higher this is the less input fuel, and hence output emissions, are required to produce each unit of electricity);
- the use of pollution abatement technology, and;
- the location of the plant itself with respect to population centres, agricultural land, etc.[12]

The damages caused by power and heat production from fossil fuel (hard coal, lignite, oil and natural gas) are, for the most part, not integrated into the current pricing system and so represent external costs. Certain costs are quantifiable in other sectors, such as health care. Others are more of a virtual nature. Nevertheless they can be estimated according to the price and citizens would be prepared to pay in order to avoid them. In the member states of EU, there is a growing urgency to make a precise and rigorous evaluation of all these externalities as they are important decision-making factors when making major political and economic choices in the field of energy policy.

Although the principle may seem obvious, implementation is particularly complex. The ExternE (External Costs of Energy) project was originally launched in 1991 by a consortium of European and American researchers and both the European Commission and the US Department of Energy were involved.[13] The aim was to define energy externalities – and more precisely electricity production externalities – for each of the available sources: wind, solar, nuclear, biomass, coal, oil, natural gas, and hydroelectric. The project required the co-operation of many specialists from different disciplines: economists, physicists, chemists, epidemiologists and ecologists.

The European Union has made a determined choice towards a policy of sustainable development, involving a review of economic calculations to include previously ignored costs. If these externalities were to be taken into account in the energy field, the price per kWh of fuel of conventional sources origin would increase.

11 http://www.eea.europa.eu/data-and-maps/indicators/en35-external-costs-of-electricity-production-1/en35,
12 http://www.eea.europa.eu/data-and-maps/indicators/en35-external-costs-of-electricity-production-1/en35,
13 http://ec.europa.eu/research/news-centre/en/env/02-10-env02.html

The ExternE study was initiated because of the growing concern that the environmental impacts of energy production were not properly integrated into decision-making processes. Advances in scientific knowledge over recent years have demonstrated that the production and the use of energy cause damage to a wide range of receptors, including human health, natural ecosystems and the built environment. These damages are referred to as external costs, or externalities, to the extent that they are not reflected in the market price of the goods in question (in this case electricity and heat).

Over the years, ExternE has been developing and it turned into a series of projects (ExternE, NewExt and ExternePol), from the early 90s until 2005.

Among other things, specific software systems were developed within the ExternE project:

- EcoSense - the integrated environmental impact assessment model;
- EcoSenseLE - a simplified online version of the EcoSense model.

The ExternE, NewExt and ExternePol projects have developed a remarkable methodology which serves as a reference for this kind of cost calculation.

Also, the so called ExternE-Methodology is very important as an approach of calculating environmental external costs as it was developed during the ExternE project-series, called Impact-Pathway-Approach. The tool and data for calculating environmental external costs according to the Impact-Pathway-Approach have been implemented in the EcoSense model.

All the results of the ExternE project-series have been made available on the ExternE project website (Old version from 2006 and last update on 5th October 2010)[14].

After 2005, there have been many other projects applying the tools but also further developing them towards a more and more integrated assessment. For example, during the NEEDS-project (2004-2009), the EcoSense model has been transferred into the web-based tool EcoSenseWeb[15].

The objective of this study is to assess the external costs associated with the production of electricity and heat by power plants and combined heat and power plants according to the requirements of the Terms of Reference and related to the ELVs and other measures of the LCPD and the IED.

In this study, the assessment of external costs is based upon the sum of components associated with electricity and heat production: damage costs (such as impacts on health, environment, crops etc.) associated with NO_x, SO_2 and dust – PM10. Non-environmental (such as social) costs for non-fossil electricity and heat generating technologies are not taken into account in the scope of the present analysis. Moreover, climate change damage

14 http://www.externe.info/externe
15 http://ecosenseweb.ier

costs associated with emissions of CO_2 and other pollutants (such as NH_3, NMVOC, dust – PM2.5, Cd, As, Ni, Pb, Hg, Cr, Cr-VI, formaldehydes, dioxins) are also not taken into account in the assessment, bearing in mind that they are not subject to the relevant requirements of the LCPD and the IED which are part of the Energy Community environmental *acquis*.

Total external costs (sum of human health regional [north hemispheric model], crops, materials, biodiversity [in € per tonne of pollutant]) were taken from NEEDS software tools as an aggregated scheme (External Costs Euro2000 per tonne) for each year in the period of 2014 up to 2030.

According to the Terms of Reference, external costs estimates had been calculated for the years of release from 2014 up to 2030. Summing up the damage costs of each pollutant gives the total damage costs in the each Contracting Party of the Energy Community for each year. A complete data set for the external costs for Serbia, Montenegro and Kosovo* are the same having in mind that all of them by the time of development of the NEEDS tools, they have been incorporated in the Federal Republic of Yugoslavia.

The level of uncertainties in this external costs calculations are high having in mind that coverage of externalities is not complete (without the emissions of CO_2 and all other pollutants into the air, water, soil or waste production). However, the external costs presented here are sufficient to indicate approximate values of the external costs associated with each unit of electricity and heat overall generation for the period of 2014 up to 2030 year in each Contracting Party of the Energy Community. For more precise calculations of external costs, a closer and more detailed analysis should be carried out at plant level.

The Estimated External Costs (euro per tonne) for emissions of SO_2, NO_x and dust from LCPs from 2014 up to 2030 are presented in the Table 3-4 below and in Graph 3-1 for the year 2014.

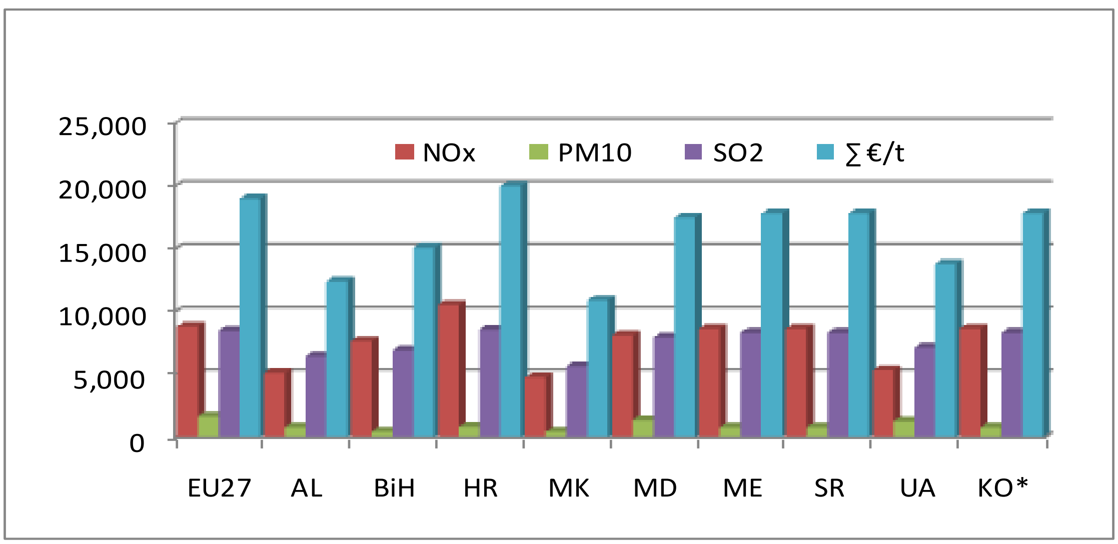
Table 3-4: Total estimated external costs per emission unit in the period 2014-2030[16] /€/t/

Year	Energy Community Contracting Party									
Pollutant	EU27	AL	BiH	HR	MK	MD	ME	SR	UA	KO*
2014										
NO_x	8,836	5,132	7,683	10,562	4,786	8,130	8,660	8,660	5,360	8,660
PM10	1,680	815	485	853	460	1,395	817	817	1,300	817
SO_2	8,491	6,480	6,940	8,593	5,671	7,979	8,339	8,339	7,154	8,339
∑ €/t	19,007	12,427	15,108	20,008	10,916	17,503	17,816	17,816	13,815	17,816
2015										
NO_x	10,365	5,316	8,651	11,804	5,250	9,082	9,736	9,736	6,211	9,736
PM10	1,781	806	491	865	467	1,349	830	830	1,322	830
SO_2	9,415	6,828	7,391	9,366	6,050	8,519	8,879	8,879	7,961	8,879
∑ €/t	21,561	12,950	16,532	22,036	11,767	18,950	19,445	19,445	15,493	19,445
2016										
NO_x	10,533	5,400	8,786	11,991	5,332	9,233	9,893	9,893	6,314	9,893
PM10	1,811	820	499	880	475	1,372	844	844	1,345	844
SO_2	9,571	6,940	7,513	9,522	6,149	8,660	9,026	9,026	8,092	9,026
∑ €/t	21,916	13,160	16,798	22,393	11,957	19,265	19,763	19,763	15,751	19,763
2017										
NO_x	10,703	5,485	8,925	12,182	5,416	9,387	10,053	10,053	6,419	10,053
PM10	1,842	834	507	895	483	1,395	858	858	1,367	858
SO_2	9,730	7,054	7,637	9,681	6,250	8,803	9,176	9,176	8,226	9,176
∑ €/t	22,276	13,373	17,069	22,757	12,149	19,585	20,087	20,087	16,012	20,087
2018										
NO_x	11,087	5,572	9,065	12,375	5,501	9,544	10215	10,215	6,526	10,215
PM10	1,874	848	516	910	492	1,419	873	873	1,391	873
SO_2	9,892	7,170	7,763	9,842	6,352	8,949	9,328	9,328	8,361	9,328
∑ €/t	22,853	13,590	17,344	23,127	12,345	18,494	20416	20,416	16,278	20,416
2019										
NO_x	11,053	5,660	9,208	12,572	5,588	9,703	10,380	10380	6,635	10380
PM10	1,905	862	525	925	500	1,443	888	888	1,414	888
SO_2	10,057	7,288	7,891	10,006	6,456	9,097	9,482	9,482	8,499	9,482
∑ €/t	23,015	13,810	17,624	23,503	12,544	20,243	20,750	20750	16,548	20750
2020										
NO_x	11,232	5,750	9,353	12,772	5,677	9,865	10,548	10,548	6,746	10,548
PM10	1,938	877	534	941	508	1,467	903	903	1,438	903
SO_2	10,225	7,408	8,021	10,173	6,561	9,247	9,640	9,640	8,640	9,640
∑ €/t	23,395	14,035	17,908	23,886	12,746	20,579	21,091	21,091	16,824	21,091
2021										
NO_x	11,415	5,841	9,501	12,975	5,766	10,029	10,719	10,719	6,858	10,719
PM10	1,971	892	543	957	517	1,492	918	918	1,463	918
SO_2	10,395	7,530	8,153	10,343	6,669	41373	9,800	9,800	8,783	9,800
∑ €/t	23,781	14,263	18,197	24,275	12,952	52,894	21,437	21,437	17,104	21,437
2022										
NO_x	11,600	5,934	9,652	13,182	5,858	10,197	10,893	10,893	6,973	10,893
PM10	2,004	907	552	973	526	1,518	934	934	1,488	934
SO_2	10,568	7,654	8,288	10,515	6,778	9,556	9,962	9,962	8,928	9,962
∑ €/t	24,172	14,495	18,492	24,670	13,162	21,271	21,789	21,789	17,389	21,789
2023										
NO_x	11,789	6,028	9,805	13,393	5,951	10,367	11,069	11,069	7,089	11,069
PM10	2,038	922	561	990	535	1,544	950	950	1,513	950
SO_2	10,744	28,672	8,425	10,691	32,660	9,715	10,128	10,128	9,076	10,128
∑ €/t	24,571	35,622	18,791	25,074	39,146	21,626	22,147	22,147	17,678	22,147
2024										
NO_x	11,980	6,124	9,960	13,607	6,045	10,540	11,249	11,249	7,208	11,249
PM10	2,073	938	571	1,007	544	1,570	966	966	1,539	966
SO_2	10,924	7,908	8,564	10,869	7,003	9,876	10,296	10,296	9,226	10,296
∑ €/t	24,977	14,970	19,095	25,483	13,592	21,986	22,511	22,511	17,973	22,511
2025										

16 Estimated external costs are based on aggregation scheme "SIA_E_PPMc" for Human Health (HH) Impacts, based on average meteorology - corresponding to emissions from All SNAP-(Sum of HH regional, crops, materials, biodiversity and HH North Hemispheric model.

Year	Energy Community Contracting Party									
Pollutant	EU27	AL	BiH	HR	MK	MD	ME	SR	UA	KO*
NO_x	12,176	6,222	10,118	13,825	6,141	10,716	6,362	11,431	7,328	11,431
PM10	2,108	954	581	1,024	553	1,597	1,181	982	1,565	982
SO_2	11,106	8,039	8,706	11,051	7,118	10,apr	11,333	10,467	9,379	10,467
∑ €/t	25,390	15,215	19,405	25,900	13,812	53,687	18,876	22,880	18,272	22,880
2026										
NO_x	12,374	6,321	10,279	14,046	6,239	10,895	11,617	11,617	7,450	11,617
PM10	2,144	970	590	1,041	563	1,624	999	999	1,592	999
SO_2	11,291	8,171	8,850	11,236	7,235	10,206	10,641	10,641	9,534	10,641
∑ €/t	25,809	15,462	19,719	26,323	14,037	22,725	23,257	23,257	18,576	23,257
2027										
NO_x	12,576	6,422	10,443	14,271	6,338	11,077	11,806	11,806	7,575	11,806
PM10	2,181	987	601	1,059	572	1,651	1,016	1,016	1,619	1,016
SO_2	11,480	8,306	8,997	11,423	7,353	10,376	10,818	10,818	9,692	10,818
∑ €/t	26,237	15,715	20,041	26,753	14,263	23,104	23,640	23,640	18,886	23,640
2028										
NO_x	12,781	6,525	10,609	6,688	6,439	11,263	11,998	11,998	7,702	11,998
PM10	2,218	1,004	611	1,077	582	1,679	1,033	1,033	1,646	1,033
SO_2	11,671	8,444	9,146	11,614	7,474	10,548	10,998	10,998	9,853	10,998
∑ €/t	26,670	15,973	20,366	19,379	14,495	23,490	24,029	24,029	19,201	24,029
2029										
NO_x	12,990	6,629	10,778	14,733	6,542	11,451	12,193	12,193	7,831	12,193
PM10	2,255	1,021	621	1,095	592	1,708	1,051	1,051	1,674	1,051
SO_2	11,866	8,583	9,297	11,808	7,597	10,723	11,181	11,181	10,016	11,181
∑ €/t	27,111	16,233	20,696	27,636	14,731	23,882	24,425	24,425	19,521	24,425
2030										
NO_x	13,202	6,735	10,950	14,970	6,646	11,643	12,392	12,392	7,962	12,392
PM10	2,294	1,038	632	1,114	602	1,737	1,068	1,068	1,703	1,068
SO_2	12,064	8,725	9,451	12,006	7,723	10,902	11,367	11,367	10,183	11,367
∑ €/t	27,560	16,498	21,033	28,090	14,971	24,282	24,827	24,827	19,848	24,827

EU27 - European Union
AL - Albania
BiH - Bosnia and Herzegovina
HR - Croatia
MK - FYR of Macedonia
MD - Moldova
ME - Montenegro
SR - Serbia
UA – Ukraine
KO* - Kosovo*



Graph 1: Total estimated external pollutants emission unit cost in 2014 (€/t)

Environmental and social externalities are highly site specific and thus results may vary widely even within a given country according to the plant's geographical location. The above results show that the highest estimated external costs (euro per tonne) are found in Croatia (higher than the EU average) and the lowest in FYR

Macedonia. This is mainly due to the variation in exposure of people and crops to the pollutants – emissions in the countryside will affect fewer people than emissions in urban areas, due to the degree of urbanization and population density. In other EnC Contracting Parties, the estimated external costs are lower than the EU average.

To calculate the external costs (eurocents/kWh) for each Contracting Party and for each fuel/technology, the following data were necessary:

- pollutant-specific emissions from each fuel/technology used for electricity production;
- average emissions per unit of electricity generation include emissions from the operation of the power plant and the rest of the energy chain;
- pollutant-specific (SO_2, NO_X and dust – PM10) and EnC-average (based on party-specific values) damage cost factors.

The external costs estimates for a particular pollutant are different depending on the fuel because of different average emissions per kWh. The external costs used to calculate this indicator are based upon the sum of next components: damage costs (such as impacts on health, crops etc.) associated with air pollutants (NO_x, SO_2, and dust – PM10). The results of these calculations are presented in Tables 3-5 to 3-13 for the present pollutants emission concentrations and for the expected power generation in 2014.

Table 3-5: Estimated external costs of emissions in 2014 in Albania

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs – BAU				
					Pollutants emiss, t/year			Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
1	Vlora	NG	100	722	2	98	70	0.0	0.50	0.46	0.96	0.1
Total			100	722	2	98	70	0.0	0.50	0.46	0.96	0.1

Table 3-6: Estimated external costs of emissions in 2014 in Bosnia and Herzegovina

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External Costs – BAU				
					Pollutants emiss, t/year			Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
1	Gacko	L	300	1,934	2,299	5,517	13,793	1.1	42.4	95.7	139	7.2
2	Ugljevik	L	300	2,176	2,074	4,937	159,958	1.0	37.9	1,110	1,149	52.8
3	Tuzla 3	L	110	473	71	881	4,499	0.0	6.8	31.2	38	8.0
4	Tuzla 4	L	200	1,196	460	2,030	12,807	0.2	15.6	88.9	105	8.8
5	Tuzla 5	L	200	1,004	281	903	9,505	0.1	6.9	66.0	73	7.3
6	Tuzla 6	L	215	1,008	129	1,508	17,003	0.1	11.6	118.0	130	12.9
7	Kakanj 5	L	110	598	30	2,785	21,055	0.0	21.4	146.1	168	28.0
8	Kakanj 6	L	110	312	27	1,016	10,523	0.0	7.8	73.0	81	25.9
9	Kakanj 7	L	230	1,342	1,036	4,756	46,917	0.5	36.5	325.6	363	27.0
Total			1,775	10,044	6,407	24,334	296,060	3	187	2,055	2,245	22.3

Table 3-7: Estimated external costs of emissions in 2014 in Croatia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External Costs – BAU				
					Pollutants emiss, t/year			Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
1	TPP Plomin 1	HC	125	915	122	1,861	5,357	0.1	19.7	46.0	66	7.2
2	TPP Plomin 2	HC	210	1,631	116	1,888	873	0.1	19.9	7.5	28	1.7
3	TPP Rijeka	FO	320	1,725	594	4,803	19,335	0.5	50.7	166.2	217	12.6
4	TPP Sisak A	FO	210	1,214	454	3,042	14,994	0.4	32.1	128.8	161	13.3
5	TPP Sisak B	FO	210	1,214	454	3,042	14,994	0.4	32.1	128.8	161	13.3
6	TPP Jertovac 1	NG	40	47	0	32	1	0.0	0.3	0.0	0	0.7
7	TPP Jertovac 2	NG	40	47	0	33	1	0.0	0.3	0.0	0	0.8
8	CHP Zagreb C	NG	120	469	129	1,056	4,218	0.1	11.2	36.2	48	10.1

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU Pollutants emiss, t/year			External Costs – BAU Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
9	CHP Zagreb K	NG	208	1,591	20	123	20	0.0	1.3	0.2	1	0.1
10	CHP Zagreb L	NG	112	866	11	47	4	0.0	0.5	0.0	1	0.1
11	CHP Zagreb EL-TOK6	NG	11	21	8	71	353	0.0	0.8	3.0	4	17.6
12	CHP Zagreb EL-TOK8	NG	30	82	66	148	910	0.1	1.6	7.8	9	11.6
13	CHP Zagreb EL-TOH	NG	25	161	0	174	4	0.0	1.8	0.0	2	1.2
14	CHP Zagreb EL-TOJ	NG	25	161	0	151	8	0.0	1.6	0.1	2	1.0
15	CHP Osijek A	NG	46	256	4	217	15	0.0	2.3	0.1	2	0.9
16	CHP Osijek B	NG	25	42	0	38	3	0.0	0.4	0.0	0	1.0
17	CHP Osijek C	NG	25	21	0	19	1	0.0	0.2	0.0	0	1.0
Sum			1,782	10,464	1,977	16,747	61,090	2	177	525	704	6.7

Table 3-8: Estimated external costs of emissions in 2014 in FYR Macedonia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU Pollutants emiss, t/year			External costs – BAU Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
1	Bitola 1	L	233	1,387	2,571	5,629	33,359	1.2	26.9	189.2	217	15.7
2	Bitola 2	L	233	1,387	4,448	5,699	27,104	2.0	27.3	153.7	183	13.2
3	Bitola 3	L	233	1,387	4,448	5,699	27,104	2.0	27.3	153.7	183	13.2
4	Oslomej	L	125	604	1,722	1,087	12,383	0.8	5.2	70.2	76	12.6
5	Negotino	FO	210	17	0	0	0	0.0	0.0	0.0	0	0.0
6	Skopje CHP	NG	227	1394	28	456	2	0.0	2.2	0.0	2	0.2
7	Kogel CHP	NG	30	185	4	72	0	0.0	0.3	0.0	0	0.2
Total			1,291	6,362	13,222	18,642	99,953	6	89	567	662	10.4

Table 3-9: Estimated external costs of emissions in 2014 in Moldova

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU Pollutants emission, t/year			External costs – BAU Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
1	CET-1, No 1	NG	12	59	0	21	0	0.0	0.2	0.0	0.2	0.3
2	CET-1, No 2	NG	12	59	0	25	0	0.0	0.2	0.0	0.2	0.3
3	CET-1, No 3	NG	10	49	0	21	0	0.0	0.2	0.0	0.2	0.4
4	CET-1, No 4	NG	27	132	0	49	0	0.0	0.4	0.0	0.4	0.3
5	CET-1, No 5	NG	5	24	0	7	0	0.0	0.1	0.0	0.1	0.2
6	CET-2, No 1	NG	80	398	0	175	0	0.0	1.4	0.0	1.4	0.4
7	CET-2, No 2	NG	80	371	0	185	0	0.0	1.5	0.0	1.5	0.4
8	CET-2, No 3	NG	80	371	0	170	0	0.0	1.4	0.0	1.4	0.4
Total			306	1,580	0	734	0	0	6	0	6	0.4

Table 3-10: Estimated external costs of emissions in 2014 in Montenegro

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU Pollutants emission, t/year			External costs - BAU Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kW
1	Pljevlja	Lignite	219	1,489	221	3,322	44,295	0.2	28.8	369.4	398.3	26.7
Total			219	1,489	221	3,322	44,295	0	29	369	398	26.7

Table 3-11: Estimated external costs of emissions in 2014 in Serbia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU Pollutants emissions, t/year			External costs - BAU Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kW
1	Nikola Tesla A1	L	210	1,231	852	2,336	11,901	0.7	20.2	99.2	120	9.8
2	Nikola Tesla A2	L	210	1,198	829	2,273	11,578	0.7	19.7	96.5	117	9.8
3	Nikola Tesla A3	L	305	1,923	1,295	3,551	18,092	1.1	30.8	150.9	183	9.5
4	Nikola Tesla A4	L	309	1,989	353	3,973	18,855	0.3	34.4	157.2	192	9.6
5	Nikola Tesla A5	L	309	1,999	351	3,957	18,776	0.3	34.3	156.6	191	9.6
6	Nikola Tesla A6	L	309	1,987	349	3,932	18,661	0.3	34.1	155.6	190	9.6
7	Nikola Tesla B1	L	620	4,151	763	8,378	38,742	0.6	72.6	323.1	396	9.5
8	Nikola Tesla B2	L	620	4,004	743	8,157	37,723	0.6	70.6	314.6	386	9.6
9	Kolubara 1	L	32	175	1,534	492	2,990	1.3	4.3	24.9	30	17.4
10	Kolubara 2	L	32	116	1,013	325	1,974	0.8	2.8	16.5	20	17.4
11	Kolubara 3	L	64	135	1,180	379	2,300	1.0	3.3	19.2	23	17.4
12	Kolubara 4	L	32	0	0	0	0	0.0	0.0	0.0	0	
13	Kolubara 5	L	110	626	192	1,356	7,876	0.2	11.7	65.7	78	12.4
14	Morava	L	125	566	3,283	1,513	11,018	2.7	13.1	91.9	108	19.0

Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
					Pollutants emissions, t/year			Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kW
15	Kostolac A1	L	100	560	1,282	1,218	19,052	1.0	10.5	158.9	170	30.5
16	Kostolac A2	L	210	1,196	672	2,285	37,078	0.5	19.8	309.2	330	27.5
17	Kostolac B1	L	348	1,937	5,489	5,132	57,898	4.5	44.4	482.8	532	27.5
18	Kostolac B2	L	348	1,895	2,361	4,553	51,300	1.9	39.4	427.8	469	24.8
19	Novi Sad 1	NG	135	189	4	649	107	0.0	5.6	0.9	7	3.4
20	Novi Sad 2	NG	110	175	4	601	99	0.0	5.2	0.8	6	3.4
21	Zrenjanin	NG	110	66	2	248	41	0.0	2.1	0.3	2	3.8
22	Sr. Mitrovica 1	NG	32	123	0	230	0	0.0	2.0	0.0	2	1.6
Total			4,679	26,240	22,551	55,536	366,060	18	481	3,053	3,552	13.5

Table 3-12: Estimated external costs of emissions in 2014 in Ukraine

Code	Plant mame	Fuel type	Power MW	Ener. GWh/a	Emission - BAU			External costs - BAU				
					Pollutants emissions, t/year			Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
1	Prydniprovska 7	HC	150	439	1,794	1,990	5,189	2	11	37	50	11.4
2	Prydniprovska 8	HC	150	682	2,727	3,090	8,338	4	17	60	80	11.7
3	Prydniprovska 9	HC	150	0	0	0	0	0	0	0	0	
4	Prydniprovska 10	HC	150	590	2,042	2,523	6,532	3	14	47	63	10.7
5	Prydniprovska 11	HC	310	1,186	4,955	5,030	13,094	6	27	94	127	10.7
6	Prydniprovska 12	HC	285	0	0	0	0	0	0	0	0	
7	Prydniprovska 13	HC	285	774	3,819	3,561	8,555	5	19	61	85	11.0
8	Prydniprovska 14	HC	285	0	0	0	0	0	0	0	0	
9	Kryvorizka 1	HC	282	1,106	5,226	5,079	13,397	7	27	96	130	11.7
10	Kryvorizka 2	HC	282	1,382	5,800	6,336	16,420	8	34	117	159	11.5
11	Kryvorizka 3	HC	282	0	0	0	0	0	0	0	0	
12	Kryvorizka 4	HC	282	1,221	1,144	5,741	14,139	1	31	101	133	
13	Kryvorizka 5	HC	282	1,221	6,234	5,996	15,050	8	32	108	148	
14	Kryvorizka 6	HC	282	714	3,785	3,785	9,141	5	20	65	91	
15	Kryvorizka 7	HC	282	0	0	0	0	0	0	0	0	
16	Kryvorizka 8	HC	282	1,014	4,684	5,364	12,882	6	29	92	127	
17	Kryvorizka 9	HC	282	0	0	0	0	0	0	0	0	
18	Kryvorizka 10	HC	282	1,198	5,937	6,345	15,239	8	34	109	151	
19	Zaporiska 1	HC	325	1,048	3,572	5,616	13,912	5	30	100	134	
20	Zaporiska 2	HC	300	1,277	3,799	6,583	17,402	5	35	125	165	12.9
21	Zaporiska 3	HC	300	1,301	3,817	6,680	18,406	5	36	132	172	13.3
22	Zaporiska 4	HC	300	1,205	3,509	6,669	16,417	5	36	117	158	13.1
23	Zaporiska 5	NG	800	0	0	0	0	0	0	0	0	10.9
24	Zaporiska 6	NG	800	0	0	0	0	0	0	0	0	12.1
25	Zaporiska 7	NG	800	0	0	0	0	0	0	0	0	12.7
26	Starobeshivska 4	HC	175	715	0	0	0	0	0	0	0	
27	Starobeshivska 5	HC	175	715	0	0	0	0	0	0	0	12.5
28	Starobeshivska 6	HC	175	715	0	0	0	0	0	0	0	
29	Starobeshivska 7	HC	175	715	0	0	0	0	0	0	0	12.6
30	Starobeshivska 8	HC	175	715	0	0	0	0	0	0	0	12.8
31	Starobeshivska 9	HC	175	715	0	0	0	0	0	0	0	0.0
32	Starobeshivska 10	HC	175	715	0	0	0	0	0	0	0	0.0
33	Starobeshivska 11	HC	175	715	0	0	0	0	0	0	0	0.0
34	Starobeshivska 12	HC	175	715	0	0	0	0	0	0	0	0.0
35	Starobeshivska 13	HC	175	715	0	0	0	0	0	0	0	0.0
36	Slovianska 7	HC	800	3,269	0	0	0	0	0	0	0	0.0
37	Burshtynska 1	HC	195	915	3,929	1,769	12,973	5	9	93	107	11.7
38	Burshtynska 2	HC	185	397	1,830	836	6,128	2	4	44	51	12.8
39	Burshtynska 3	HC	185	662	3,463	1,347	10,385	5	7	74	86	13.0
40	Burshtynska 4	HC	195	884	4,462	1,833	14,031	6	10	100	116	13.1
41	Burshtynska 5	HC	195	465	2,262	942	7,763	3	5	56	64	13.7
42	Burshtynska 6	HC	185	986	4,495	1,911	15,591	6	10	112	128	12.9
43	Burshtynska 7	HC	185	508	2,362	1,079	8,582	3	6	61	70	13.8
44	Burshtynska 8	HC	195	806	2,160	1,634	13,846	3	9	99	111	13.7
45	Burshtynska 9	HC	195	961	170	2,038	14,551	0	11	104	115	12.0
46	Burshtynska 10	HC	195	930	165	2,018	14,347	0	11	103	114	12.2
47	Burshtynska 11	HC	195	992	173	1,727	14,777	0	9	106	115	11.6
48	Burshtynska 12	HC	195	667	590	1,205	10,170	1	6	73	80	12.0

Code	Plant mame	Fuel type	Power MW	Ener. GWh/a	Emission - BAU			External costs - BAU				
					Pollutants emissions, t/year			Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
49	Dobrotvirska 5	HC	100	402	1,110	1,231	7,495	1	7	54	62	15.3
50	Dobrotvirska 6	HC	100	402	1,110	1,231	7,495	1	7	54	62	15.3
51	Dobrotvirska 7	HC	150	786	3,683	2,224	14,448	5	12	103	120	15.3
52	Dobrotvirska 8	HC	150	568	2,705	1,633	10,610	4	9	76	88	15.5
53	Ladyzhinska 1	HC	300	874	3,515	3,799	9,445	5	20	68	93	10.6
54	Ladyzhinska 2	HC	300	1,092	1,468	4,737	12,175	2	25	87	114	10.5
55	Ladyzhinska 3	HC	300	1,262	1,612	5,500	14,624	2	29	105	136	10.8
56	Ladyzhinska 4	HC	300	752	3,027	3,243	8,311	4	17	59	81	10.7
57	Ladyzhinska 5	HC	300	582	2,932	2,517	6,710	4	13	48	65	11.2
58	Ladyzhinska 6	HC	300	558	3,377	2,425	6,349	4	13	45	63	11.3
59	Trypilska 1	HC	300	1,250	5,004	3,294	3,294	7	18	24	48	3.8
60	Trypilska 2	HC	300	1,250	6,857	4,615	4,615	9	25	33	67	5.3
61	Trypilska 3	HC	300	1,250	6,486	3,348	3,348	8	18	24	50	4.0
62	Trypilska 4	HC	300	1,250	6,311	3,308	3,308	8	18	24	50	4.0
63	Trypilska 5	NG	300	0	0	0	0	0	0	0	0	
64	Trypilska 6	NG	300	0	0	0	0	0	0	0	0	
65	Zmiivska 1	HC	175	548	7,494	1,966	6,158	10	11	44	64	11.7
66	Zmiivska 2	HC	175	548	7,565	1,963	5,950	10	11	43	63	11.5
67	Zmiivska 3	HC	175	548	7,265	1,881	5,934	9	10	42	62	11.3
68	Zmiivska 4	HC	175	548	7,074	1,843	5,897	9	10	42	61	11.2
69	Zmiivska 5	HC	175	548	6,768	1,741	6,141	9	9	44	62	11.3
70	Zmiivska 6	HC	175	548	6,547	1,606	5,484	9	9	39	56	10.3
71	Zmiivska 7	HC	275	793	7,504	5,140	11,535	10	28	83	120	15.1
72	Zmiivska 8	HC	325	937	925	7,093	16,995	1	38	122	161	17.2
73	Zmiivska 9	HC	275	793	7,128	4,130	10,292	9	22	74	105	13.3
74	Zmiivska 10	HC	275	793	7,153	4,187	9,754	9	22	70	102	12.8
75	Vuglegirska 1	HC	300	1,359	1,882	5,925	22,520	2	32	161	195	14.4
76	Vuglegirska 2	HC	300	1,359	1,878	5,913	22,476	2	32	161	195	14.3
77	Vuglegirska 3	HC	300	1,359	1,889	5,947	22,603	2	32	162	196	14.4
78	Vuglegirska 4	HC	300	1,359	1,887	5,941	22,580	2	32	162	196	14.4
79	Vuglegirska 5	NG	800	0	0	0	0	0	0	0	0	
80	Vuglegirska 6	NG	800	0	0	0	0	0	0	0	0	
81	Vuglegirska 7	NG	800	0	0	0	0	0	0	0	0	
82	Zuevvskaya 1	HC	325	1,606	1,067	10,517	28,607	1	56	205	262	16.3
83	Zuevvskaya 2	HC	320	1,660	1,161	10,567	29,282	2	57	209	268	16.1
84	Zuevvskaya 3	HC	300	1,606	1,967	9,117	26,786	3	49	192	243	15.1
85	Zuevvskaya 4	HC	325	1,740	284	10,326	29,707	0	55	213	268	15.4
86	Kurakhovskaya 3	HC	200	1,005	10,815	2,531	18,025	14	14	129	157	15.6
87	Kurakhovskaya 4	HC	210	1,003	10,962	2,571	18,563	14	14	133	161	16.0
88	Kurakhovskaya 5	HC	222	969	9,818	2,369	18,395	13	13	132	157	16.2
89	Kurakhovskaya 6	HC	210	640	9,898	1,520	12,148	13	8	87	108	16.9
90	Kurakhovskaya 7	HC	225	982	6,937	2,402	17,084	9	13	122	144	14.7
91	Kurakhovskaya 8	HC	210	674	6,228	1,611	12,507	8	9	89	106	15.7
92	Kurakhovskaya 9	HC	221	1,019	7,711	2,302	18,738	10	12	134	156	15.3
93	Luganskaya 9	HC	200	1,070	10,262	4,567	14,977	13	24	107	145	13.5
94	Luganskaya 10	HC	200	642	1,912	2,528	8,775	2	14	63	79	12.3
95	Luganskaya 11	HC	200	988	8,781	4,402	13,410	11	24	96	131	13.3
96	Luganskaya 12	HC	175	0	0	0	0	0	0	0	0	
97	Luganskaya 13	HC	175	951	8,324	4,331	14,037	11	23	100	134	14.1
98	Luganskaya 14	HC	200	1,070	10,424	5,265	15,825	14	28	113	155	14.5
99	Luganskaya 15	HC	200	988	8,975	4,627	15,168	12	25	109	145	14.7
100	Bilotserkivska CHP	NG	120	494	0	470	0	0	3	0	3	0.5
101	DarnytskaCHP5,10	NG	50	212	0	207	0	0	1	0	1	0.5
102	Darnytska CHP6-9	HC	110	453	2,011	2,228	4,258	3	12	30	45	9.9
103	Kaluska CHP 1,2	HC	100	412	1,982	291	4,285	3	2	31	35	8.5
104	Kaluska CHP 3, 4	NG	100	425	0	476	0	0	3	0	3	0.6
105	Kyivska CHP-5	NG	540	1,147	0	0	0	0	0	0	0	0.0
106	Kyivska CHP-5	FO	540	1,147	0	0	0	0	0	0	0	0.0
107	Kyivska CHP-6	NG	500	1,062	682	1,803	10,152	1	10	73	83	7.8
108	Kyivska CHP-6	FO	500	1,062	535	2,007	8,108	1	11	58	69	6.5
109	Kramatorska CHP	HC	120	494	918	945	6,727	1	5	48	54	11.0
110	Myronivska 4	HC	60	247	232	613	3,453	0	3	25	28	11.5

Code	Plant mame	Fuel type	Power MW	Ener. GWh/a	Emission - BAU			External costs - BAU				
					Pollutants emissions, t/year			Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
111	Myronivska 9	HC	115	616	460	1,725	6,972	1	9	50	60	9.7
112	Odeska CHP-2	NG	68	289	0	941	0	0	5	0	5	1.7
113	SevastopolskaCHP	NG	55	234	0	167	0	0	1	0	1	0.4
114	Simferopilska CHP	NG	278	1,181	0	458	0	0	2	0	2	0.2
115	Kharkivska CHP-2	HC	74	314	3,108	837	6,967	4	4	50	58	18.6
Total			29,368	88,669	336,517	291,830	996,765	437	1,564	7,131	9,133	10.3

Table 3-13: Estimated External Costs of Emissions in 2014 on Kosovo*

Code	Plant name	Fuel Type	Power MW	Energy GWh/a	Emission - BAU			External Costs - BAU				
					Pollutants emissions, t/year			Total costs, million €/year				Unit cost
					Dust	NO_x	SO_2	Dust	NO_x	SO_2	Sum	€c/kWh
1	Kosovo A3	L	200	590	200	2,651	2,443	0.2	23.0	20.4	43	7.4
2	Kosovo A4	L	200	590	2,969	2,802	2,374	2.4	24.3	19.8	46	7.9
3	Kosovo A5	L	210	606	189	2,850	2,481	0.2	24.7	20.7	46	7.5
4	Kosovo B1	L	339	1,083	2,537	4,777	3,772	2.1	41.4	31.5	75	6.9
5	Kosovo B2	L	339	1,083	2,688	4,873	3,699	2.2	42.2	30.8	75	6.9
Total			1,288	3,951	8,582	17,952	14,768	7	155	123	286	7.2

4. Estimated investment cost of the environmental upgrade scenarios

One of the main objectives of this study is to develop different scenarios in order to meet the requirements of the LCPD/IED, which can be achieved either by the modernization of large combustion plants, by changing fuels or by the replacement of existing LCP units with new, more energy efficient units the emissions of which are in compliance with therequiremets of the Directives. For each plant at least two scenarios for reaching compliance with the requirements of the LCPD and at least one scenario for reaching compliance with the requirements of the IED should have been developed.

To fulfil the above mentioned objectives, it is necessary to define the best available technologies (BAT), including their technical and economical characteristics, which can be applied for the environmental upgrade of large combustion plants in the Energy Community Contracting Parties.

The description of the assessed technologies for the environmental upgrade of thermal power plants or combined heat and power plants and their technical performances relating to the efficiency of the pollutants removal from flue gas (reliability, energy consumption, etc.) is presented in Annex 1 of this study.

In Annex 2 a description of the methods of environmental upgrading techniques is presented with estimates on the necessary investment and O&M (operation and maintenance) costs.

The elements that have a dominant influence on the costs are:

- Flue gas flow rate or unit size
- Concentration of pollutant in flue gas
- Kind and characteristics of fuel
- Time of emission reduction techniques implementation (index of cost at the market)
- Site conditions.

For each Contracting Party, two scenarios for reaching compliance with the requirements of the LCPD and one for reaching compliance with the requirements of the IED is developed, with the exceptions of Albania and partially for Moldova, as they have very low emission concentrations.

The characteristics of electric power systems represent important elements for the creation of scenarios.

The costs of unit replacement, by use of contemporary technology, are found to be in the ranges of:

- For lignite fired TPPs, depending on the unit size 1.55 – 1.7 mil. €/MW,
- For BC fired TPP, depending on the unit size 1.5 – 1.65 mil. €/MW,

- For HC fired units, depending on the unit size 1.4 – 1.55 mil. €/MW,
- For gas fired units, depending on the unit size 1.3 – 1.4 mil. €/MW,
- For Combined Gas-fired Turbine (CCGT) 1.0 mil. €/MW.

The majority of LCPs include units of different size and some of them include units fired by different fuels. For this reason, each LCP unit had to be analysed individually. The aggregated values of costs for individual LCPs are presented here, in order to concise the study report.

4.1. Scenarios for environmental upgrading of LCPs in Albania

The Albanian power system is almost entirely based on hydro resources. Approximately 98 % of the electricity production is coming from the hydro power plants (with 65 % of hydro potential still unexploited. Nine TPP units have been decommissioned in the past and only TPP Vlora is in operation at present.

TPP Vlora is an oil and gas-fired combined cycle power plant, with one shaft turbine-generator set, consisting of one gas turbine, one steam turbine and a generator in a single shaft arrangement. The plant was commissioned in October 2011 and, due to severe defects, it was stopped and put in reserve operation in January 2012. The current plan is to start its commercial operation by the end of 2014.

The main technical data of TPP Vlora are:

- Installed capacity 100 MW
- Existing emission in air (measuring data)
  - Emission of NO_x 67 mg/Nm^3
  - SO_2 48 mg/Nm^3
  - Dust - PM 1.37 mg/Nm^3.

Taking into account the results of emission measurements and the ELVs of both directives, it is not necessary to apply any emission reduction measures as the plant is already in line with their requirements.

4.2. Scenarios for environmental upgrading of LCPs in Bosnia and Herzegovina

The existing thermal power system in BiH is based on the use of coal (lignite and brown coal) as a fuel. The characteristic of the coal used results in major differences in sulphur dioxide emissions: at TPP Ugljevik, the concentration of sulphur dioxide in the raw flue gas varies from 12,000 to 20,000 mg/Nm^3 (with a representative value of 16,200 mg/Nm^3) while TPP Gacko has sulphur dioxide emissions that are about 20 times lower. The country does not have its own natural gas resources, nor has it developed the gas transport system. The reserves of crude oil are too low to be used for electricity production.

All TPP units are old and a number of them are running beyond their planned operational lifetime. All units have a low energy efficiency rate (their specific heat consumption varies from 11,500 up to 14,500 kJ/kWh) and some are de-rated.

Bearing in mind the above-mentioned facts, it can be concluded that the only logical scenario, besides the two scenarios relating to application of the emission reduction measures, is the replacement of the oldest, low energy efficient LCP units, with new modern coal fired units.

4.2.1. Scenario 1 - Installation of emission reduction measures in compliance with the LCPD

The first emission reduction scenario includes application of the emission reduction measures aimed to bring all TPP units that will be in operation after 31 December 2017, into compliance with the requirements of the LCP Directive. The scenario is presented in Table 4-1.

Retrofitting of electrostatic precipitators of TPP Kakanj 5 and 6 was done before 31/12/2012 to bring the dust - PM emissions into compliance with the LCP Directive. Similarly, the ESP is upgraded in TPP Kakanj 7, but the emission concentrations are still higher than the ELVs of the Directive.

Primary measures for the reduction of NO_x emissions were applied in TPP Tuzla 5 before 31/12/2012 to bring NO_x emissions into compliance with the LCPD. Similar measures have been implemented in other units of TPP Tuzla and Kakanj, but the emissions of NO_x still fail to demonstrate compliance with the ELVs.

The analysis of Scenario 1 has shown that the investments necessary for reaching compliance with the LCPD would be the following:

Table 4-1 Emission reduction cost in compliance with LCPD, Scenario 1, BiH (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Gacko	11.4	9	13	33.4
2	Ugljevik	14	8.4	85.5	107.9
3	Tuzla	6.3	5.6	74	85.8
4	Kakanj	0.5	22.8	87	110.3
Total		31.9	45.8	259.5	337.2

4.2.2. Scenario 2 - Emission reduction measures in compliance with the IED

Scenario 2 includes application of emission reduction measures with a view to bring emissions into compliance with the IED. The retrofitting of the electrostatic precipitators of TPP Kakanj 5 and 6 was done before 31/12/2012 to bring the emissions of dust - PM into compliance with the IED. Primary measures for the reduction of NO_x emissions were applied inTPP Tuzla 5 before 31/12/2012 to bring the emissions of NO_x into compliance with the IED.The results of the analysis are presented in Table 4-2.

Table 4-2 Emission reduction cost, Scenario 2, BiH (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Gacko	14	9	14.3	37.3
2	Ugljevik	15	8.4	95	118.4
3	Tuzla	3	5.6	83	91.6
4	Kakanj	1.5	29.4	96	127.4
Total		33.5	53	288.3	374.7

4.2.3. Scenario 3 - Emission reduction measures and replacement of some TPP units for reaching ELV in compliance with the LCPD

Scenario 3 includes the replacement of TPP Tuzla 4 and TPP Kakanj 5, whose decommissioning are planned for 2018 and 2019, respectively, with modern, high energy efficient (minimum 41 %) units. Furthermore, this scenario includes the application of emission reduction measures in other TPP units. The retrofitting of electrostatic precipitators of units 5 and 6 of TPP Kakanj was done before 31.12.2012 to bring the emissions of dust into compliance with the LCP Directive. Primary measures for the reduction of NO_x emissions were done in TPP Tuzla 5 before 31.12.2012 to bring the emissions of NO_x into compliance with the LCP Directive.

The specific construction costs for new units are assessed to be 1,650,000 €/MW for the lignite-fired TPP Tuzla 4 and 1,600,000 €/MW for the brown coal-fired TPP Tuzla 5.

The results of the analysis of investment costs for Scenario 3 are presented in Table 4-3.

Table 4-3 Emission reduction cost, Scenario 3, BiH (mil. €)

No.	Plant name	Pollutant			Total for reduction measures	Total for other measures	Total for plant
		Dust	NO_x	SO_2			
1	Gacko	11,4	9	13	33.4		33.4
2	Ugljevik	14	8,4	86	107.9		107.9
3	Tuzla	5.2	2.6	39	34.7	330	364.7
4	Kakanj	0.5	22,8	87	110.3	320	430.3
Total		32.2	45,8	260	297.9	650	947.9

4.3. Scenarios for environmental upgrading of TPPs in Croatia

The Croatian thermal power system has only one coal-fired TPP, TPP Plomin, with two of its units fired with imported hard coal. TPP Plomin 1 will be retired when new unit Plomin 3 started operation. In TPP Plomin 2, during the reconstruction works both electrostatic precipitator and WLS FGD system were installed to bring the emission of dust and SO_2 in compliance with the LCPD and IED.

All other TPP and CHP units are fired by oil, natural gas or a combination of the two.

The current emission concentrations of TPP Jertovac and CHPs Zagreb – (units K, L, H and J) and Osijek are in compliance with the LCPD, while the emission concentrations in CHP Zagreb (units K and L) are in compliance with the IED.

4.3.1. Scenario 1 - Emission reduction measures for reaching compliance with the LCPD

Scenario 1 includes application of emission reduction measures in all TPP and CHP units which will not be retired before 31.12.2017 and whose emissions are not in compliance with the ELVs of the LCPD. The results are presented in Table 4-4.

Table 4-4: Emission reduction costs in compliance with LCPD, Scenario 1, Croatia (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Plomin	0	20.0	0	20.0
2	Rijeka	6.0	8.2	47	61.2
3	Sisak	9.6	11.8	92	113.4
4	Zagreb	4.8	3.8	25	33.6
5	0sijek	0	0	0	0
Total		20.4	43.8	164	228.2

4.3.2. Scenario 2 - Emission reduction measures for reaching compliance with IED

This scenario includes the implementation of appropriate emission abatement measures to bring the emissions of dust, NO_x and SO_2 in compliance with ELVs of the IED.

According to the obtained results, the necessary investments for individual TPPs are presented in Table 4-5.

Table 4-5: Emission reduction cost in compliance with IED, Scenario 2, Croatia (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Plomin	0	20.0	0	20.0
2	Rijeka	6.8	30.0	51.7	88.5
3	Sisak	10.6	40	101.2	151.8
4	Jertovac	0	2	0	2.0
5	Zagreb	5.3	15.9	32	53.2
5	0sijek	0	2.7	0	2.7
Total		22.7	109.6	184.9	318.2

4.3.3. Scenario 3 - Emission reduction measures, replacement of some TPP units and change of fuel for reaching compliance with the LCPD, Croatia

This scenario includes the replacement of TPP Rijeka with a new modern unit of the same capacity, the replacement of units K6, K8, H and J in CHP Zagreb with one unit of 100 MW capacity, the use of natural gas instead of fuel oil in TPP Sisak and implementing emission reduction measures for the remaining TPP and CHP units. The results are presented in Table 4-6.

Table 4-6: Emission reduction cost in compliance with LCPD, Scenario 3, Croatia (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Plomin	0	20.0	0	20.0
2	Rijeka				416.0
3	Sisak		6.6		113.4
4	Zagreb	2.7	2.8	19.0	154.5
5	0sijek	0	0	0	0
Total		2.7	29.4	19.0	703.9

4.4. Scenarios for environmental upgrading of LCPs in FYR Macedonia

Thermal power plants in FYR Macedonia include two lignite fired TPPs: TPP Bitola, with a capacity of 3x233 MW and TPP Oslomej, with a capacity of 125 MW. TPP Negotino, with a capacity 210 MW, is designed to be an oil-fired thermal power plant. However, due to high oil price, TPP Negotino has been in reserve operation for most of the time. Furthermore, there are two CHP plants: Skopje (227 MW) and Kogel (30 MW). The CHPs are in operation since 2012 and are fully compliant to the LCPD and IED emission standards.

4.4.1. Scenario 1 - Emission reduction measures in compliance with the LCPD

Scenario 1 includes application of emission reduction measures in all TPP units.The results are presented in Table 4-7. The status of TPP Negotino shall be decided in the future.

Table 4-7: Emission reduction cost, Scenario 1, FYR Macedonia (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Bitola	34.8	30	126.9	191.7
2	Oslomej	7	6	25	38
3	Negotino				0
Total		41.8	36	151.9	229.7

4.4.2. Scenarios 2 - Emission reduction measures for reaching compliance with the IED

The assessed investment costs of this scenario are presented in Table 4-8.

Table 4-8: Emission reduction cost, Scenario 2, FYR Macedonia (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Bitola	39	55.8	139.5	334.3
2	Oslomej	8	1.8	27.5	37.3
3	Negotino				0
Total		47	57.6	167	371.6

4.4.3. Scenario 3 - Replacement of TPP units for reaching compliance with the LCPD

Lignite is the only domestic fuel in FYR Macedonia that can be used for electricity production. At the same time, FYR Macedonia has not developed a gas supply system. These facts indicate that a scenario related to the replacement of existing TPP units with modern lignite-fired units can be considered as a possible option. In this case, the assessed investment costs would amount to a level as presented in Table 4-9.

Table 4-9: Emission reduction cost, Scenario 1, FYR Macedonia (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Bitola	Replaced units (699 MW x 1.65 mil. €/MW)			1,153.0
2	Oslomej	Replaced units (125 MW x 1.7 mil. €/MW)			213.5
3	Negotino				
Total					1,366.5

Decommissioning of TPP units is planned between 2027 and 2029, which suggests that all units are in good technical and operational conditions and that this scenario will probably not be financially viable.

4.5. Scenarios for environmental upgrading of LCPs in Moldova

All CHPs in Moldova use natural gas as a fuel. Table 4-10 presents the main data on the CHP units that are relevant to the determination of the costs for emission reduction. As it can be seen from the table, the current level of emissions is already in compliance with the requirements of the LCPD. The results presented in Table 4-10 indicate that five units should be brought into compliance with the IED and that it is necessary to apply measures for the reduction of NO_x emissions.

Table 4-10: Need for emission reduction and its cost

No	Plant name	Fuel	Capacity		Emission, BAU mg/Nm3			ELV, LCPD mg/Nm3			ELV, IED mg/Nm3			Putting in compliance with IED, mil €
			El. MW	Th. MW	Dust	NO_x	SO_2	Dust	NO_x	SO_2	Dust	NO_x	SO_2	NO_x
1	CET-1, No 1	G	12			96		5	300	35	5	100	35	0,00
2	CET-1, No 2	G	12			113		5	200	35	5	100	35	0,053
3	CET-1, No 3	G	10			115		5	300	35	5	100	35	0,054
4	CET-1, No 4	G	27			97		5	300	35	5	100	35	0,00
5	CET-1, No 5	G	5			72		5	300	35	5	100	35	0,00
6	CET-2, No 1	G	80			137		5	200	35	5	100	35	0,46
7	CET-2, No 2	G	80			155		5	200	35	5	100	35	0,88
8	CET-2, No 3	G	80			142		5	300	35	5	100	35	0,48
Total			306											1.93

Thenecessary investments are estimated at:

- for compliance with the LCPD, for all CHPs 0.0 mil. €
- for compliance with IED:
  - ➢ for CET – 1 0.107 mil. €
  - ➢ for CET-2 1.820 mil. €

4.6. Scenarios for environmental upgrading of TPPs in Montenegro

Montenegro has one TPP unit, TPP Pljevlja, with a capacity of 219 MW and an energy efficiency level of 31 %. According to current plans, it should be decommissioned by 2025 the latest.

4.6.1. Scenario 1 - Emission reduction measures in compliance with the LCPD

The assessed investment cost for achieving compliance with LCPD is 46.9 mil. €. The current dust emission concentation is ≤ 30 mg/Nm^3 which is in line with the ELVs of the LCPD. As regards NO_x emission reduction, primary measures shall be applied (LNB+OFA), which would cost 4.9 mil. €. For the reduction of SO_2 FGD WLS would be the most feasible option, with an estimated investment cost of 42 mil. €.

4.6.2. Scenario 2 - Emission reduction measures for reaching compliance with IED

The necessary investments for reaching compliance with the IED are estimated at 50.9mil. € (4.9 mil. € for deNO_x and 46 mil. € for applying WLS technology). The current level of dust emissions (30 mg/Nm^3) could be further reduced by FGD reaching a level lower than 20 mg/Nm^3.

4.6.3. Scenario 3 - Replacement of TPP for reaching ELV in compliance with the LCPD

The replacement of TPP Pljevlja with a modern unit with high efficiency would require an investment of approximately 370 mil. €.

4.7. Scenarios for environmental upgrading of LCPs in Serbia

Lignite is the only domestic fuel in Serbia that can be used for electricity production and it is the source of the large majority of the TPPs operating in the coutry (Nikola Tesla, Kolubara, Kostolac and Morava). Furthemore, 3 plants (Novi Sad, Zrenjanin and Sremska Mitrovica) are fired by natural gas.

The electric power system of Serbia includes two corporate companies with 6 TPPs. Company Nikola Tesla includes TPP Nikola Tesla A (with a capacity of 2x210 MW+305 MW+ 3x308 MW), TPP Nikola Tesla B (2x620 MW), TPP Kolubara A (3x32 MW+64 MW+110 MW) and TPP Morava (120 MW). Company Kostolac includes TPP Kostolac A (100 MW+210MW) and TPP Kostolac B (2x350 MW).

Scenario 1 includes installation of emission reduction measures in all TPP and CHP units that will not be retired before 31/12/2017 and whose emissions are not in compliance with the ELVs set out in the LCPD. The electrostatic precipitators of units A4, A5, A6 and B2 TPP Nikola Tesla as well as unit A5 of TPP Kolubara are retrofitted thus the existing dust emissions are in compliance with the LCPD.

The results of the analyses for each TPP unit have shown that the necessary investments for bringing emissions into compliance with the LCPD's requirements would amount to those presented in Table 4-11.

Table 4-11: Emission reduction costs in compliance with the LCPD, Scenario 1, Serbia (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Nikola Tesla A	15.2	33.5	188	236.7
2	Nikola Tesla B	9.4	27.2	128	164.6
3	Kolubara A	3.2	0	13.6	16.8
4	Morava	7.2	0	9.8	17
5	Kostolac A	7.9	4.2	45	57.1
6	Kostolac B	15.7	18.9	102	136.6
7	Novi Sad	0	7.3	0	7.3
8	Zrenjanin	0	3.3	0	3.3
9	Sremska Mitrovica	0	1	0	1
Total		58.6	95.4	486.4	640.4

4.7.1. Scenario 2 - Emission reduction costs in accordance with the requirements of the IED

This scenario includes the application of emission reduction measures in all units in operation after 01.01.2018 in order to meet the ELVs set out in the IED.

Table 4-12: Emission reduction cost for reaching compliance with the IED, Scenario 2 (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Nikola Tesla A	17.1	33.5	207	257.6
2	Nikola Tesla B	9.4	27.2	142	178.6
3	Kolubara A	4	3	16.5	23.5
4	Morava	8	3.4	11	22.4
5	Kostolac A	8.7	6.2	50	64.9
6	Kostolac B	17.5	18.9	110	146.4
7	Novi Sad	0	10.7	0	10.7
8	Zrenjanin	0	4.8	0	4.8
9	Sremska Mitrovica	0	1.8	0	1.8
Total		64.7	109.5	536.5	710.7

4.7.2. Scenario 3 - Installation of emission reduction measures in accordance with the ELVs of the LCPD and replacement of existing, low efficiency units

Scenario 3 includes:

a) The replacement of the old lignite-fired TPP units that have low energy efficiency and planned to be retired until 2021 (including Kostolac A2, planned to be retired in 2024) with new, high efficiency TPPs (minimum 41 %, with supercritical steam parameters):
   - Nikola Tesla A1 and A2, efficiency 30 % 420 MW
   - Kolubara A1, A2 and A4, efficiency 25.5 % and A5 efficiency 29.5 % 238 MW
   - Kostolac A1 and A2, efficiencies 33 % and 32.5 % 310 MW
   - Morava, efficiency 30 % 125 MW

b) Replacement of the units in CHP Novi Sad with CCGHT units the emissions of which are in compliance with the requirements of the LCPD.

c) Replacement of CHP Zrenjanin with CCGHT capacity and transferring it in reserve capacity.

d) Switching from natural gas to biomass as a fuel in CHP Sremska Mitrovica with 80 % efficiency.

The results are presented in Table 4-13.

Table 4-13: Emission reduction cost, Scenario 1, Serbia (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Nikola Tesla A1&A2	Replaced by 420 MW unit (420 MWx1.6mil. €/MW)			672
	NikolaTesla A3 to A6	10.5	25.5	156	192
2	Nikola Tesla B	9.4	27.2	128	164.6
3	Kolubara A	Replaced by lignite-fired 174 MW unit (174MWx1.7mil. €/MW)			295.8
4	Morava	7.2	0	9.8	17
5	Kostolac A	Replaced by lignite-fired 310 MW unit (310MWx1.6mil. €/MW)			496
6	Kostolac B	15.7	18.9	102	136.6
7	Novi Sad	Replace by CCGHT (345MWx 1.0 mil. €/MW)			345
8	Zrenjanin	0	3.3	0	3.3
9	Sremska Mitrovica	Change of fuel (135 MW_{th}x.43 mil. €/MW_{th})			58
Total		42.8	74.9	395.8	2776.1

4.8. Scenarios for environmental upgrading of LCPs in Ukraine

Ukrainian thermal power plants mainly use hard coal as a fuel (some of which can be classified as anthracite). Furthermore, there are eight gas-fired units (Trypilska 2x300 MW, Zaporiska 3x800 MW and Vuglegirska 3x800 MW). All gas-fired units are temporary out of operation and mothballed. The reasons are capacity surplus in the electric power industry of Ukraine and the high price of gas compared to the price of coal. According to the decision of the Ukrainian government, these plants would only be re-introduced in operation if the gas price is reduced to a level concurrent to coal. Ukraine is one of the biggest exporters of coal.

Ukraine has a very large LCP sector with a significant amount of data necessary for the elaboration of the scenarios as requested by the ToR of this study. The authors of this study have been in close contact with the Ukrainian authorities throughout the development of this report, however, it seems that not all possibly available data could have been obtained in the data gathering phase. Therefore, the authors had to base their assessment on the data that was made available which does not impede differing calculations on the estimated investment costs carried out in the framework of other studies.

4.8.1. Scenario 1 - Emission reduction measures in compliance with the LCPD

Since data on the planned retirement date of TPP and CHP units was not available, the necessary environmental upgrade measures for reaching the compliance with LCPD standards have been analysed for each TPP and CHP unit. The investment cost estimates for Scenario 1 are presented in Table 4-14, separately for each unit.

Table 4-14: Emission reduction costs in compliance with LCPD, Scenario 1, Ukraine (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
A	**TPPs**				
1	Prydniprovska	57,0	146.6	203.0	406.6
2	Kryvorizka	58.3	244.7	325.6	628.6
3	Zaporiska	24.4	181.8/107.8*	140.9	347.1/239.3*
4	Starobeshivska	126.0	33.3	200.0	359.3
5	Slovianska	23.0	52.0	95.0	170.0
6	Burshtynska	62.3	63.5	296.8	422.6
7	Dobrotvirska	19,7	20.6	56.0	96.3
8	Ladyzhinska	42.6	144.0	198.0	384.6
9	Trypilska	40.5	134.5/89.9*	124.0	299.0/209.1*
10	Zmiivska	68.5	251.3	248.0	567.8
11	Vuglegirska	37.6	291.8/96.8*	140.0	469.4/372.6*
12	Zuevvskaya	28.6	107.5	149.7	285.8
13	Kurakhovskaya	59.2	46.3	175.0	280.5
14	Luganskaya	50.0	105.6	156.9	312.5
15	Myronivska	5.7	0.3	13	19.0
B	**CHPs**				
16	Bilotserkivska	0	0	0	0.0
17	Darnytska	2.3	2.2	9	13.5
18	Kaluska	3.2	0.4	7.8	11.4
19	Kyivska	0	34.9	0	34.9
20	Kramatorska	5.0	0	10.5	15.5
21	Odeska	0	2.2	0	2.2
22	Sevastopolska	0	0	0	0.0
23	Simferopilska	0	0	0	0.0
24	Kharkivska	2.3	1.7	8.6	12.6
Total		709.6	18654/1562.6*	2557.9	5132.9/4819.3*

Remark: *The second value is without deNO_x of gas fired TPPs, which are currently out of operation

Two options are included: application of the emission reduction measures for all coal- and and gas-fired TPP units, with the exception of gas-fired units that are conserved at the time of preparation of this report.

4.8.2. Scenario 2 - Emission reduction in compliance with IED

Results of Scenario 2 include all LCPs presented in Table 4-15 below.

Table 4-15: Emission reduction costs in compliance with IED, Scenario 2, Ukraine (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
A	**TPPs**				
1	Prydniprovska	67.9	154.8	223.0	445.7
2	Kryvorizka	70.5	244.7	356.0	671.2
3	Zaporiska	27.4	181.8/107.8*	155.0	364.2/290.2*
4	Starobeshivska	137.2	281.5	220.0	638.7
5	Slovianska	24.5	52.0	325,1	457,2
6	Burshtynska	68.6	63.5	61.6	129.0
7	Dobrotvirska	22.8	44.6	216	421,5
8	Ladyzhinska	53.1	152.4	136,4	321,4/276,8*
9	Trypilska	50.5	134.5/89.9*	272.7	609.2
10	Zmiivska	85.2	251.3	272.7	609.2
11	Vuglegirska	44.0	291.8/96.8*	154.0	489.8/294.8*
12	Zuevvskaya	44.6	107.5	164.8	316.9
13	Kurakhovskaya	75.0	41.4	192.6	309.0
14	Luganskaya	62.8	117.6	154.0	334.4
B	**CHPs**				
15	Bilotserkivska	0	3,6	0	3.6
16	Darnytska	2,9	19.3	13	35,2
17	Kaluska	4.0	9.5	11.0	24.5
18	Kyivska	0	134.7	114.0	248.7
19	Kramatorska	6.2	0	17.0	23.2
20	Myronivska	6.3	5.2	20.3	31.8
21	Odeska	0	7.8	0	7.8
22	Sevastopolska	0	1.2	0	1.2
23	Simferopilska	0	1.4	0	1.4
24	Kharkivska	2.8	2.4	9.5	14.7
Total		811,7	2,300.9/2,023.3	2,920,6	6,033.2/5,719.6

Remark: * The second value is without $DeNO_x$ of gas fired TPPs, which are currently out of operation

4.8.3. Scenario 3 - Emission reduction in compliance with LCPD

The electric power system of Ukraine has a surplus of installed generation capacity which is one of the main reasons of the very low load factor at which it currently operates (36.8%). The other reason is that the system includes very old units, installed between 1959 and 1963.

This scenario includes:

- Conservation of all gas fired TPP units (Zaporiska 5, 6 and 7, with a capacity of 3x800 MW,Trypilska 5 and 6, with a capacity of 3x300 MW and Vuglegirska 5, 6 and 7, with a capacity of 3x800 MW)
- Conservation of all TPP units which are nowadays in lay-up status (Prydniprovska 12 and 14, with a capacity of 2x285 MW, Kryvorizka 3, 7 and 9, with a capacity of 3x282 MW and Luganskaya 12, capacity 175 MW)

- Conservation of old units constructed before 1963 (Prydniprovska 7, 8, 9 and 10, with a capacity of 4x150 MW, Starobeshivska 4, 5 and 6, with a capacity of 3x175 MW, Dobrotvirska 5 and 6, with a capacity of 2x100 MW, Zmiivska 1, 2 and 3, with a capacity of 3x175 MW and Luganskaya 9, 10 and 11, with a capacity of 3x200 MW)

According to this scenario, the total conserved capacity would amount to:

- Gas-fired units 5400 MW
- In lay-up status 1591 MW
- Units constructed before 1963 2450 MW

Total conserved capacity **9441 MW**.

According to the proposed conservation, the average load factor of the LCP units that would remain in operation would increase to 54.2%.The results and cost estimates of this scenario are presented in Table 4-16.

Table 4-16: Emission reduction costs in compliance with LCPD, Scenario 3, Ukraine (mil. €)

No.	Plant nName	Pollutant			Total for plant
		Dust	NO_x	SO_2	
A	**TPPs**				
1	Prydniprovska	20.9	47.9	68.5	137.3
2	Kryvorizka	44.8	171.4	226.8	443.0
3	Zaporiska	24.4	107.8	140.9	273.1
4	Starobeshivska	90.5	23.9	140.0	254.4
5	Slovianska	23.0	52.0	95.0	170.0
6	Burshtynska	47.0	63.5	296.8	407.3
7	Dobrotvirska	13.3	19.4	34.0	66.7
8	Ladyzhinska	42,6	144.0	198.0	384,6
9	Trypilska	40.5	89.9	124.0	254.4
10	Zmiivska	47.5	152.9	172.0	372.4
11	Vuglegirska	37.6	96.8	140.0	274.4
12	Zuevvskaya	28.6	107.5	149.7	285.8
13	Kurakhovskaya	59.2	46.3	175.0	280.5
14	Luganskaya	25.0	50.4	67.2	142.6
15	Myronivska	5.7	0.3	13	19.0
B	**CHPs**				
16	Bilotserkivska	0	0	0	0.0
17	Darnytska	2.3	2.2	9	13.5
18	Kaluska	3.2	0.4	7.8	11.4
19	Kyivska	0	34.9	0	34.9
20	Kramatorska	5.0	0	10.5	15.5
21	Odeska	0	2.2	0	2.2
22	Sevastopolska	0	0	0	0.0
23	Simferopilska	0	0	0	0.0
24	Kharkivska	2.3	1.7	8.6	12.6
Total		563,4	1215.4	2076.8	3855.6

4.9. Scenarios for environmental upgrading of LCPs in Kosovo*

The electric power system of Kosovo* is completely based on lignite as there is no gas transmission system developed. The lignite reserve in the territory of Kosovo* amounts to approximately 12.4 billion tonnes. Kosovo* plans to decommission three units of TPP Kosovo A due to their very low efficiency and reliability and to replace

Them by two new, supercritical units with a capacity of 2x300 MW (TPP Kosova e Re). Furthermore, it is planned to upgrade the existing two units of TPP Kosovo B.

4.9.1. Scenario 1 - Emission reduction measures in compliance with the LCPD

Scenario 1 consists of the application of emission reduction measures in two units of TPP Kosovo B (Table 4-17).

Table 4-17: Emission reduction costs in compliance with LCPD, Scenario 1, Kosovo* (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Kosovo A3	To be decommissioned before 2018			
2	Kosovo A4	To be decommissioned before 2018			
3	Kosovo A5	To be decommissioned before 2018			
4	Kosovo B1	10.0	13.0	16.0	39
5	Kosovo B2	10.9	13.0	16.0	39
Total		20.0	26.0	32.0	78

4.9.2. Scenario 2 - Emission reduction measures in compliance with the IED

Scenario 2 includes the application of emission reduction measures in two units of TPP Kosovo B (Table 4-18).

Table 4-18: Emission reduction costs in compliance with IED, Scenario 2, Kosovo* (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Kosovo A3	To be decommissioned before 2018			
2	Kosovo A4	To be decommissioned before 2018			
3	Kosovo A5	To be decommissioned before 2018			
4	Kosovo B1	11.5	13.0	17.6	42.1
5	Kosovo B2	11.5	13.0	17.6	42.1
Total		23.0	26.0	35.2	84.2

4.9.3. Scenario 3 - Replacement of TPP units for reaching compliance with the IED

This scenario includes the replacement of two existing TPP units with new ones, constructed in compliance with IED.

Table 4-19: Emission reduction costs in compliance with IED, Scenario 3, Kosovo* (mil. €)

No.	Plant name	Pollutant			Total for plant
		Dust	NO_x	SO_2	
1	Kosovo A3	Will be decommissioned before 2017			
2	Kosovo A4	Will be decommissioned before 2017			
3	Kosovo A5	Will be decommissioned before 2017			
4	Kosovo B1	Replaced by new 339 MW unit			545
5	Kosovo B2	Replaced by new 339 MW unit			545
Total		1090			

5. Cost-benefit analysis of environmental upgrade scenarios for LCPs

5.1. Basic assumptions and input data for analysing costs and benefits

The valuation of different scenarios of the environmental upgrading of thermal power plants and combined heat and power production plants is performed by use of the cost-benefit analysis (CBA) methodology. This methodology represents an economic analysis undertaken from the point of view of the society as a whole, considering also environmental factors.

The CBA used in the present report is an economic quantification of all costs and benefits for thermal power plants and combined heat and power plants in the Energy Community Contracting Parties related to compliance with the requirements of the LCPD and the IED and with regard to emissions of pollutants into the air.

Costs include the following items:

1. Investment costs incurred, which contain all capital expenditures for:
    - The upgrade and/or replacement of electrostatic precipitators and/or fabric filters;
    - The use of necessary primary and secondary measures for NO_x reduction;
    - The construction of a flue gas desulphurization plant for SO_2 reduction.
2. The operation and maintenance (O&M) costs, for the above-mentioned systems and equipment, which include the following: raw material costs, maintenance costs, water and power consumption, labour costs, insurance costs and waste disposal costs. The O&M costs are evaluated on a yearly basis, in proportion to the electricity production.

Benefits consist of the monetization of avoidance of all external costs of emissions, compared to the business as usual (BAU) scenario. Benefits are evaluated by applying the corresponding external cost coefficients per unit of pollutant mass for the emission of all pollutants, presented in Table 3-4 of Chapter 3 for each Contracting Party.

Once the stream of economic costs and benefits is estimated, the standard Discounted Cash Flow (DCF) methodology is applied. Since there is a large variation of costs and benefits during the operational lifetime of a plant, they shall be summarized by the use of an appropriate social discount rate. This rate shall apply after the year of the beginning of the program, which is the start-up year of the post-retrofit plant lifetime. However, as there is a lack of key dates as regards the start-up dates for environmentally upgraded units, the CBA of the present report is carried out with the assumption that environmental udgrades will start at the beginning of 2018 (the final date for implementing the LCPD) and will end by 2030.

The social discount rate has been used according to the new tendency, in relation to social project appraisal in EU countries[17]. Therein, based on social time preference (STPR), a standard benchmark European discount rate of 3% is recommended. This result is similar to the real long-term bond rate for the eurozone countries and squares approximately with the current official discount rates set by the German, French and British governments as well as the usual practice in the European Union. Therefore, the discount rate of **3%** is used throughout this study for the CBA.

The Net Present Value (NPV) for each scenario of the environmental upgrade project had been evaluated. The NPV presents the difference of the sum of all discounted benefits and the sum of all discounted incurred costs. In addition, the B/C Ratio is calculated for each TPP unit, which can be used for the ranking of TPP units, separately for the LCPD and IED scenarios.

The scenarios of environmental upgrading are defined in Chapter 4, together with the application of best available techniques (BAT) for the emission reduction of pollutants, as well as with the estimates of the investment costs and also the estimates of the operation and maintenance costs. Following the analysis made in Chapter 4, the CBA is performed for the following scenarios:

- **Scenario 1,** including the implementation of all necessary measures to upgrade the emission abatement equipment in TPP units according to the LCPD standards:
- **Scenario 2,** similar to Scenario 1, but with the requirements of the IED, which have higher emission standards; and
- **Scenario 3,** an alternative technical solution to Scenario 1, aiming to achieve the LCPD standards with no need of applying BAT to the existing TPP units.

The methodology used in the cases of Scenarios 1 and 2 is the following:

- $B = \sum_{k=1}^{k=n} B_k * (1+r)^{-k}$, and
- $C = I_{eu} + \sum_{k=1}^{k=n} OM_k * (1+r)^{-k}$,

Where:

B_k stands for the benefit in the year “k”,
B stands for the present value of all benefits,
I_{eu} stands for the investment costs of environmental upgrade systems,
OM_k stands for the operation and maintenance costs of environmental upgrade systems,
r stands for the social discount rate,
C stans for the present value of all costs.

[17]Social Discount Rates for the European Union, David J. Evans, J. of Economic Studies, Vol. 321ss:1, pp. 47-59

Scenario 3 has to be in compliance with the LCPD and therefore can be compared with Scenario1. Scenario 3 is usually defined as a replacement of one or more old TPP units, by new TPP units using the same fuel with modern, contemporary technology. The change of fuels in the existing TPPs is a theoretical possibility as TPPs are generally based on particular coal mines, with the exemption on coal-fired stations running on imported coal. Switching plants to natural gas is more costly and in a number of cases, gas is not available.

The existing thermal power plants are over 30 years old (in some cases over 50 years), with the net plant efficiency between 30-33% (corresponding to specific fuel consumption of 10,900 to 12,000 kJ/kg), in certain cases even below 25% (fuel consumption of 14,400 kJ/kWh). Contemporary thermal power plants using state-of –the-art technologies are designed with supercritical steam boilers of larger capacities, with a net plant efficiency of approximately 42% (specific fuel consumption of 8,570 kJ/kWh). New TPPs will fulfil all requirements of the LCPD and therefore will have the same concentrations of emissions as in the case of Scenario 1. However, due to higher net plant efficiency, there will be fuel savings per each unit of electricity produced. As a consequence of fuel savings, a reduction of total emissions is expected resulting in a reduction of external costs which, at the same time, means an increase of benefits by reducing fuel costs as well as the O&M costs of the emission control systems.

The above-mentioned parameters of certain foreseen alternative solutions are presented within this Chapter. They are to be analysed and used for the preparation of feasibility studies for individual TPP units, which would be chosen as candidates for the units' replacements.

5.2. CBA for Albania

Albania has only one thermal power plant, Vlora, with a combined cycle gas turbine and steam generator as well as a steam turbine. The plant uses light distillate oil with low sulphur content and shall use natural gas once it becomes available. TPP Vlora is a new plant, designed according to contemporary technology, with a net plant efficiency exceeding 50%. The plant is designed to meet the emission standards of the IED. Therefore, there is no need to carry out a cost-benefit analysis. All other thermal power plants in Albania have been decommissioned.

5.3. CBA for Bosnia and Herzegovina

The benefits for avoiding external costs for TPPs in Bosnia and Herzegovina are presented in Table 5-1, both for the LCPD and the IED. These benefits are obtained according to the methodology and data presented in Chapter 3 for the present state of emission control, reduced by the proportion of the required emission concentrations presented in Chapter 2. However, in case that the present emissions are lower than the required ELVs for a certain scenario, emissions for that scenario are as sumed at their present levels. The benefits are calculated for the period of 2018 to 2030 and discounted to the year 2017.

The cost calculation is based on the data presented in Chapter 4. The investment cost estimate for the environmental upgrade of each TPP unit is presented in Annex 3 (Table A3-1 for Scenario 1 and Table A3-2 for Scenario 2). The annual O&M costs are presented in the same tables alongside the investment costs. The value of total investment costs amounts to 337 million € for LCPD and 375 million € for IED, while O&M costs amount up to 36 million € and 38 million € respectively for these scenarios.

The results of the CBA are presented in Table 5-2 for Scenario 1 and in Table 5-3 for Scenario 2. The results show that in all cases, benefits significantly exceed the costs of environmental upgrading. The average B/C ratio is about 36 for the LCPD scenario and 35 for the IED scenario.

Table 5-1: Pollution control benefits for Bosnia and Herzegovina

Code	Plant name	Fuel type	Power MW	Energy GWh/a	PV for LCPD External costs reduction, million €				PV for IED External costs reduction, million €			
					Dust	NO_x	SO_2	Sum	Dust	NO_x	SO_2	Sum
1	Gacko	L	300	1,934	11	388	917	1,316	13	388	1,084	1,484
2	Ugljevik	L	300	2,176	10	312	14,141	14,463	11	312	14,320	14,643
3	Tuzla 3	L	110	473	0	0	111	111	0	33	357	390
4	Tuzla 4	L	200	1,196	1	90	947	1,038	2	90	1,054	1,146
5	Tuzla 5	L	200	1,004	0	0	680	680	1	0	771	772
6	Tuzla 6	L	215	1,008	0	68	1,385	1,453	0	68	1,463	1,531
7	Kakanj 5	L	110	598	0	124	1,645	1,769	0	237	1,860	2,097
8	Kakanj 6	L	110	312	0	21	821	842	0	78	929	1,008
9	Kakanj 7	L	230	1,342	4	375	4,035	4,415	6	375	4,144	4,525
Total			1,775	10,044	26	1,378	24,681	26,085	33	1,582	25,980	27,595

Table 5-2: Scenario 1 – Cost-benefit analysis for Bosnia and Herzegovina (LCPD)

Code	Plant name	Fuel type	Power MW	Costs		PV			B/C
				Investments	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Gacko	L	300	33.4	6.7	105	1,316	1,211	12.6
2	Ugljevik	L	300	107.9	12.7	243	14,463	14,220	59.5
3	Tuzla 3	L	110						
4	Tuzla 4	L	200	22.0	3.5	59	1,038	979	17.6
5	Tuzla 5	L	200	17.0	2.2	41	680	639	16.7
6	Tuzla 6	L	215	46.6	2.8	76	1,453	1,377	19.0
7	Kakanj 5	L	110	29.4	2.1	52	1,769	1,717	33.9
8	Kakanj 6	L	110	22.4	1.0	33	842	808	25.4
9	Kakanj 7	L	230	58.5	5.0	111	4,415	4,304	39.6
Total			1,775	337.2	36.0	720	25,974	25,254	36

Table 5-3: Scenario 2 - Cost-benefit analysis for Bosnia and Herzegovina (IED)

Code	Plant name	Fuel type	Power MW	Costs		PV			B/C
				Investments	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Gacko	L	300	37.3	6.7	108	1,484	1,376	13.7
2	Ugljevik	L	300	118.4	12.7	254	14,643	14,390	57.8
3	Tuzla 3	L	110						
4	Tuzla 4	L	200	25.0	3.5	62	1,146	1,084	18.5
5	Tuzla 5	L	200	20.0	2.2	44	772	728	17.6
6	Tuzla 6	L	215	46.6	2.8	76	1,531	1,455	20.0
7	Kakanj 5	L	110	36.2	2.7	65	2,097	2,031	32.1
8	Kakanj 6	L	110	27.7	1.4	42	1,008	965	23.8
9	Kakanj 7	L	230	63.5	6.0	127	4,525	4,398	35.6
Total			1,775	375	38	779	27,205	26,426	35

The basic parameters of the alternative scenarios that can be taken into consideration (see Chapter 4) for Tuzla 2x200 MW units, which are presented in Table 5-4. According to Scenario 1, 39 million € shall be necessary for the environmental upgrade. However, in alternative solutions 650 million € are required, thus achieving the annual external benefits of 15.3 million € and direct costs savings (fuel and O&M cost) of 20.8 million € per year.

Table 5-4: Basic differences of scenarios 3 and 1 for Bosnia and Herzegovina

Code	Plant name	Fuel type	Power MW	LCPD				Alternative Scenario		Difference Alt-LCPD	
				Inv-env	OM-env	Ret. Plan	Fuel C.	Investments	Fuel sav.	Ext. Ben.	Fuel+O&M
				Mill. €	Mill. €		Mill. €	Mill. €	%	Mil€/a	Mil€/a
4	Tuzla 4	L	200	22	3.5	2018	36	330	28	8.2	11.2
5	Tuzla 5	L	200	17	2.2	2024	31	320	29	7.2	9.6
Total			400	39	5.7			650		15.3	20.8

5.4. CBA for Croatia

The benefits for avoiding external costs for TPPs in Croatia are presented in Table 5-5, both for the LCPD and the IED. These benefits are obtained according to the methodology and data presented in Chapter 3 for the present state of emission control, reduced by the proportion of the required emission concentrations presented in Chapter 2. However, in case that the existing emissions are lower than the required ELVs for a certain scenario, emissions for that scenario are assumed at their present levels. The benefits are calculated for the period of 2018 to 2030 and discounted to the year 2017.

The cost calculation is based on the data presented in Chapter 4. The investment cost estimate for the environmental upgrade of each TPP unit is presented in Annex 3 (Table A3-3 for Scenario 1 and Table A3-4 for Scenario 2). The annual O&M costs are presented in the same tables alongside the investment costs. The total value of investment costs is up to 228 million € for LCPD and 318 million € for IED, while O&M costs amount up to 16 million € and 18 million € respectively for these scenarios.

The results of the CBA are presented in Table 5-6 for Scenario 1 and in Table 5-7 for Scenario 2.

The results show that in all cases, benefits significantly exceed the costs of environmental upgrading. The average B/C ratio is about 16 for the LCPD scenario and 15 for the IED scenario.

Table 5-5: Pollution control benefits for Croatia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	PV for LCPD				PV for IED			
					External costs reduction, million €				External costs reduction, million €			
					Dust	NO_x	SO_2	Total	Dust	NO_x	SO_2	Total
1	TPP Plomin 1	HC	125	915	0	0	241	241	0.6	171.2	544.6	716
2	TPP Plomin 2	HC	210	1,631	0	115	0	115	0.1	114.9	0.0	115
3	TPP Rijeka	FO	320	1,725	4	402	2,006	2,411	5.3	566.0	2,114.8	2,686
4	TPP Sisak A	FO	210	1,214	3	197	1,538	1,738	4.0	336.9	1631.5	1972
5	TPP Sisak B	FO	210	1,214	3	197	1,538	1,738	4.0	336.9	1631.5	1972
6	TPP Jertovac 1	NG	40	47	0	0	0	0	0.0	2.7	0.0	3
7	TPP Jertovac 2	NG	40	47	0	0	0	0	0.0	2.8	0.0	3
8	CHP Zagreb C	NG	120	469	1	75	333	409	1.1	122.5	458.8	582
9	CHP Zagreb K	NG	208	1,591	0	0	0	0	0.0	0.0	0.0	0
10	CHP Zagreb L	NG	112	866	0	0	0	0	0.0	0.0	0.0	0

11	CHP Zagreb EL-TO K6	NG	11	21	0	4	21	24	0.0	3.5	36.5	40
12	CHP Zagreb EL-TO K8	NG	30	82	1	5	56	62	0.6	5.0	94.7	100
13	CHP Zagreb EL-TO H	NG	25	161	0	0	0	0	0.0	15.2	0.0	15
14	CHP Zagreb EL-TO J	NG	25	161	0	0	0	0	0.0	12.1	0.0	12
15	CHP Osijek A	NG	46	256	0	0	0	0	0.0	18.5	0.0	18
16	CHP Osijek B	NG	25	42	0	0	0	0	0.0	3.0	0.0	3
17	CHP Osijek C	NG	25	21	0	0	0	0	0.0	1.5	0.0	2
Total			1782	10,464	11	994	5,733	6,737	16	1,713	6,512	8,241

Table 5-6: Scenario 1 - Cost–benefit analysis for Croatia (LCPD)

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	TPP Plomin 1	HC	125						
2	TPP Plomin 2	HC	210	20.0	1.6	37	115	78	3
3	TPP Rijeka	FO	320	61.2	5.9	124	2,411	2,287	19
4	TPP Sisak A	FO	210	56.7	3.3	92	1,738	1,646	19
5	TPP Sisak B	FO	210	56.7	3.3	92	1,738	1,646	19
6	TPP Jertovac 1	NG	40	0.0	0.0	0	0	0	
7	TPP Jertovac 2	NG	40	0.0	0.0	0	0	0	
8	CHP Zagreb C	NG	120	24.5	1.3	38	409	371	11
9	CHP Zagreb K	NG	208	0.0	0.0	0	0	0	
10	CHP Zagreb L	NG	112	0.0	0.0	0	0	0	
11	CHP Zagreb EL-TO K6	NG	11	4.5	0.1	5	24	19	5
12	CHP Zagreb EL-TO K8	NG	30	4.4	0.2	7	62	55	9
13	CHP Zagreb EL-TO H	NG	25	0.0	0.0	0	0	0	
14	CHP Zagreb EL-TO J	NG	25	0.0	0.0	0	0	0	
15	CHP Osijek A	NG	46	0.0	0.0	0	0	0	
16	CHP Osijek B	NG	25	0.0	0.0	0	0	0	
17	CHP Osijek C	NG	25	0.0	0.0	0	0	0	
Total			1,782	228	16	396	6,497	6,101	16

Table 5-7: Scenario 2 – Cost-benefit analysis for Croatia (IED)

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	TPP Plomin 1	HC	125						
2	TPP Plomin 2	HC	210	20	2	41	115.0	74.2	2.8
3	TPP Rijeka	FO	320	89	6	152	2,686.2	2,534.0	17.6
4	TPP Sisak A	FO	210	76	4	116	1,972.4	1,856.0	16.9
5	TPP Sisak B	FO	210	76	4	116	1,972.4	1,856.0	16.9
6	TPP Jertovac 1	NG	40	1	0	1	2.7	1.4	2.1
7	TPP Jertovac 2	NG	40	1	0	1	2.8	1.5	2.2
8	CHP Zagreb C	NG	120	37	2	53	582.4	529.3	11.0
9	CHP Zagreb K	NG	208	0	0	0	0.0	0.0	
10	CHP Zagreb L	NG	112	0	0	0	0.0	0.0	
11	CHP Zagreb EL-TO K6	NG	11	7	0	8	40.1	32.5	5.2
12	CHP Zagreb EL-TO K8	NG	30	8	0	10	100.3	90.0	9.7
13	CHP Zagreb EL-TO H	NG	25	1	0	2	15.2	13.5	8.8
14	CHP Zagreb EL-TO J	NG	25	1	0	2	12.1	10.4	7.0
15	CHP Osijek A	NG	46	1	0	3	18.5	15.5	6.3
16	CHP Osijek B	NG	25	1	0	1	3.0	2.0	3.1
17	CHP Osijek C	NG	25	1	0	1	1.5	0.7	1.8
Total			1,782	318	18	508	7,524.9	7,017.1	15

The basic parameters of the alternative scenarios that can be taken into consideration (see Chapter 4) are presented in Table 5-8 for units fired by fuel oil and natural gas, with a total capacity of 411 MW. According to Scenario 1, 70 million € shall be necessary for the environmental upgrade. However, in alternative solutions 546 million € is required, thus achieving the annual external benefits of 6.13 million € and direct costs savings (fuel and O&M cost) of 15.8 million per year.

Table 5-8: Basic differences of Scenarios 3 and 1 for Croatia

Code	Plant name	Fuel type	Power MW	LCPD				Altern. Scenario		Difference Alt-LCPD	
				Inv-env	OM-env	Ret. Plan	Fuel Costs.	Investments	Fuel sav.	Ext. Ben.	Fuel+O&M
				Mill. €	Mill. €		Mill. €	Mill. €	%	Mil€/a	Mil€/a
3	TPP Rijeka	FO	320	61.2	5.91	2028	11	416	11	3.4	14.8
11	CHP Zagreb EL-TO K6	NG	11	4.5	0.06	2020	4	16	45	0.8	2.4
12	CHP Zagreb EL-TO K8	NG	30	4.4	0.24	2035	6	43	15	0.7	2
13	CHP Zagreb EL-TO H	NG	25	0	0	2025	22	36	33	0.6	7.9
14	CHP Zagreb EL-TO J	NG	25	0	0	2025	22	35	33	0.6	7.9
Total			411	70.1	6.2		65	546		6.1	15.8

5.5. CBA for FYR Macedonia

The benefits for avoiding external costs for TPP in FYR Macedonia are presented in Table 5-9, both for the LCPD and the IED. These benefits are obtained according to the methodology and data presented in Chapter 3 for the present state of emission control, reduced by the proportion of the required emission concentrations presented in Chapter 2. However, in case that the existing emissions are lower than the required ELVs for a certain scenario, emissions for that scenario are assumed at their present levels. The benefits are calculated for the period of 2018 to 2030 and discounted to the year 2017.

Table 5-9: Pollution control benefits for FYR Macedonia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	PV for LCPD				PV for IED			
					External costs reduction, million €				External costs reduction, million €			
					Dust	NO_x	SO_2	Total	Dust	NO_x	SO_2	Total
1	Bitola 1	L	233	1,387	13	271	2,926	3,210	14	271	3,059	3,345
2	Bitola 2	L	233	1,387	24	276	2,328	2,627	25	276	2,461	2,761
3	Bitola 3	L	233	1,387	24	276	2,328	2,627	25	276	2,461	2,761
4	Oslomej	L	125	604	8	0	878	886	10	31	1,127	1,168
5	Negotino	FO	210	17	0	0	0	0	0	0	0	0
6	Skopje CHP	NG	227	1394	0	0	0	0	0	0	0	0
7	Kogel CHP	NG	30	185	0	0	0	0	0	0	0	0
	Total		1,034	4,783	68	0	8,459	9,350	73	854	9,108	10,035

The cost calculation is based on the data presented in Chapter 4. The investment cost estimate for the environmental upgrade of each TPP unit is presented in Annex 3 (Table A3-5 for Scenario 1 and Table A3-6 for Scenario 2). The annual O&M costs are presented in the same tables alongside the investment costs. The total investment costs are calculated to be 230 million € for LCPD and 272 million € for IED, while O&M costs amount up to 12 million € and 17 million € respectively for these scenarios. The results of the CBA are presented in Table 5-10 for Scenario 1 and in Table 5-11 for Scenario 2.

Table 5-10: Scenario 1 – Cost-benefit analysis for FYR Macedonia (LCPD)

Code	Plant name	Fuel type	Pow. MW	Costs		PV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	
1	Bitola 1	L	233	63.9	3.7	103	3,210	3,107	31
2	Bitola 2	L	233	63.9	3.4	100	2,627	2,527	26
3	Bitola 3	L	233	63.9	3.4	100	2,627	2,527	26
4	Oslomej	L	125	38.0	1.5	54	886	832	16
5	Negotino	FO	210	0	0	0	0	0	0
6	Skopje CHP	NG	227	0	0	0	0	0	0
7	Kogel CHP	NG	30	0	0	0	0	0	0
	Total		1,034	230	12	358	9,350	8,992	26

Table 5-11: Scenario 2 - Cost-benefit analysis for FYR Macedonia (IED)

Code	Plant name	Fuel type	Power MW	Costs		PV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Bitola 1	L	233	78	5	135	3,345	3,209	24.7
2	Bitola 2	L	233	78	5	133	2,761	2,629	20.8
3	Bitola 3	L	233	78	5	133	2,761	2,629	20.8
4	Oslomej	L	125	37	2	55	1,168	1,112	21.1
5	Negotino	FO	210	0	0	0	0	0	
Total			1,034	272	17	456	10,035	9,579	22

The results show that in all cases, benefits significantly exceed the costs of environmental upgrading. The average B/C ratio is about 26 for the LCPD scenario and 22 for the IED scenario. The basic parameters of the alternative scenarios that can be taken into consideration (see Chapter 4) for lignite-fired TPP units, with a total capacity of 824 MW, are presented in Table 5-12. According to Scenario 1, 230 million € shall be necessary for the environmental upgrading. However, in alternative solutions 1,369 million € is required, thus achieving the annual external benefits of nearly 33 million € and direct costs savings (fuel and O&M cost) of 69 million € per year.

Table 5-12: Basic differences of Scenarios 3 and 1 for FYR Macedonia

Code	Plant name	Fuel type	Power MW	LCPD				Alternative Scenario		Difference Alt-LCPD	
				Inv-env	OM-env	Ret. Plan	Fuel C.	Investments	Fuel sav.	Ext. Ben.	Fuel+O&M
				Mill. €	Mill. €		Mill. €	Mill. €	%	Mil€/a	Mil€/a
1	Bitola 1	L	233	63.9	3.7	2027	40	385	25	8.5	19.4
2	Bitola 2	L	233	63.9	3.4	2028	40	385	25	8.5	19.4
3	Bitola 3	L	233	63.9	3.4	2029	40	385	25	8.5	19.4
4	Oslomej	L	125	38.0	1.5	2027	17	214	18	7.4	10.7
Total			824	229.7	12.1		137	1.369		32.9	68.9

5.6. CBA for Moldova

The TPPs in Moldova fulfil the requirements of the LCPD. Therefore, the only scenario that needs to be analysed is Scenario 2 (compliance with the IED). The benefits of the IED Scenario, based on the avoidance of the external costs, are presented in Table 5-13. These benefits are obtained according to the methodology and data presented in Chapter 3 for the present state of pollutant emission control, reduced by the proportion of the required emission concentrations as presented in Chapter 2. However, in case that the existing emissions are lower than the required ELVs for a certain scenario, the emissions for that scenario is assumed at their present levels. The benefits are calculated for the period of 2018 to 2030 and discounted to the year 2017.

The cost calculation is based on the data presented in Chapter 4. The investment cost estimate for the environmental upgrade of each TPP unit is presented in Annex 3 (Table A3-7). The annual O&M costs are presented in the same tables alongside the investment costs.The value of total investment costs for the IED Scenario is 1.92 million €, while O&M costs amount up to 0.4 million € per year. The results of the CBA are presented in Table 5-14. The results show that in all cases, benefits are considerably higher than the costs of environmental upgrading. The average B/C ratio is 3.24 for the IED scenario.

Table 5-13: Pollution control benefits for Moldova

Code	Plant name	Fuel type	Power MW	Energy GWh/a	PV for IED External costs reduction, million €			
					Dust	NO_x	SO_2	Total
1	CET-1, No 1	NG	12	59	0.0	0.0	0.0	0.0
2	CET-1, No 2	NG	12	59	0.0	0.3	0.0	0.3
3	CET-1, No 3	NG	10	49	0.0	0.3	0.0	0.3
4	CET-1, No 4	NG	27	132	0.0	0.0	0.0	0.0
5	CET-1, No 5	NG	5	24	0.0	0.0	0.0	0.0
6	CET-2, No 1	NG	80	398	0.0	5.3	0.0	5.3
7	CET-2, No 2	NG	80	371	0.0	7.3	0.0	7.3
8	CET-2, No 3	NG	80	371	0.0	5.6	0.0	5.6
Total			330	1580	0.0	22.7	0.0	22.7

Table 5-14: Scenario 2 - Cost-benefit analysis for Moldova (IED)

Code	Plant name	Fuel type	Power MW	Costs		PV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	CET-1, No 1	NG	12						
2	CET-1, No 2	NG	12	0.1	0.0	0.2	0.3	0.1	1.3
3	CET-1, No 3	NG	10	0.1	0.0	0.2	0.3	0.1	1.5
4	CET-1, No 4	NG							
5	CET-1, No 5	NG	5						
6	CET-2, No 1	NG	80	0.6	0.1	1.9	5.3	3.4	2.8
7	CET-2, No 2	NG	80	0.6	0.1	1.8	7.3	5.5	4.1
8	CET-2, No 3	NG	80	0.6	0.1	1.8	5.6	3.8	3.1
Total			306	2	0	6	19	13	3.2

5.7. CBA for Montenegro

The benefits of avoiding the external costs for the only TPP in Montenegro are presented in Table 5-15, both for the LCPD and the IED. These benefits are obtained according to the methodology and data presented in Chapter 3 for the present state of emission control, reduced by the proportion of the required emission concentrations as presented in Chapter 2. The benefits are calculated for the period of 2018 to 2030 and discounted to the year 2017.

The cost calculation is based on the data presented in Chapter 4. The investment cost estimate for the environmental upgrade of each TPP unit is presented in Annex 3 (Table A3-8 for Scenario 1 and Table A3-9 for Scenario 2). The annual O&M costs are presented in the same tables alongside the investment costs. The value of total investment costs is 47 million € for the LCPD and 51 million € for the IED, while O&M costs amount up to 4 million € for each scenario.

The results of the CBA are presented in Table 5-16 for Scenario 1 and in Table 5-17 for Scenario 2. The results show that in all cases, benefits are considerably higher than the costs of environmental upgrading. The average B/C ratio is approximately 51 for the LCPD scenario and 50 for the IED scenario.

Table 5-15: Pollution control benefits for Montenegro

Code	Plant name	Fuel type	Power MW	Energy GWh/a	PV for LCPD External costs reduction, million €				PV for IED External costs reduction, million €			
					Dust	NO_x	SO_2	Total	Dust	NO_x	SO_2	Total
1	Pljevlja	L	219	1,489	0	220	4,505	4,725	1	220	4,666	4,886
Total			219	1,489	0	220	4,505	4,725	1	220	4,666	4,886

Table 5-16: Scenario 1 – Cost-benefit analysis for Montenegro (LCPD)

Code	Plant name	Fuel type	Pow. MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Pljevlja	L	219	46.9	4.3	93	4,725	4,632	51
Total			219	47	4	93	4,725	4,632	51

Table 5-17: Scenario 2 – Cost-benefit analysis for Montenegro (IED)

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Pljevlja	Lignite	219	51	4.3	96.8	4,886	4,789	50
Total			219	51	4.3	96.8	4,886	4,789	50

The basic parameters of the alternative scenarios that can be taken into consideration (see Chapter 4) for lignite-fired TPP units, with the capacity of 219 MW, are presented in Table 5-18. According to Scenario 1, approximately 47 million € shall be necessary for the environmental upgrade. By the use of alternative solutions, 370 million € is required, thus achieving the annual external benefits of nearly 8.9 million € and direct savings (fuel and O&M cost) of 13 million € per year.

Table 5-18: Basic differences of Scenarios 3 and 1 for Montenegro

Code	Plant Name	Fuel Type	Power MW	LCPD				Alternative Scenario		Difference Alt-LCPD	
				Inv-env	OM-env	Ret. Plan	Fuel C.	Investments	Fuel sav.	Ext. Ben.	Fuel+O&M
				Mill. €	Mill. €		Mill. €	Mill. €	%	Mil€/a	Mil€/a
1	Pljevlja	L	219	46.9	4.3	2,025	48	370	24	8.9	12.9
Total			219	46.9	4.3	2,025	48	370	24	8.9	12.9

5.8. CBA for Serbia

The benefits of avoiding of external costs for the TPPs in Serbia are presented in Table5-19, both for the LCPD and the IED. These benefits are obtained according to the methodology and data presented in Chapter 3 for the present state of emission control, reduced by the proportion of the required emission concentrations as presented in Chapter 2. However, in case that the existing emissions are lower than the required ELVs for a certain scenario, the emission for that scenario is assumed as it is at present. The benefits are calculated for the period of 2018 to 2030 and discounted to the year 2017.

The cost calculation is based on the data presented in Chapter 4. The investment cost estimate for the environmental upgrade of each TPP unit is presented in Annex 3 (Table A3-10 for Scenario 1 and Table A3-11 for Scenario 2). The annual O&M costs are presented in the same tables alongside the investment costs. The value of total investment costs is 640 million € for LCPD and 711 million for IED €, while annual O&M costs amount up to 68 million € and 66 million € respectively for these scenarios.

The results of the CBA are presented in Table 5-20 for Scenario 1 and in Table 5-21 for Scenario 2.The results show that in all cases, benefits significantly exceed the costs of environmental upgrading. The average B/C ratio is approximately 27 for the LCPD Scenario and 28 for the IED Scenario.

Table 5-19: Pollution control benefits for Serbia

Code	Plant Name	Fuel Type	Power MW	Energy GWh/a	PV for LCPD External Costs Reduction, Million €				PV for IED External Costs Reduction, Million €			
					Dust	NO_x	SO_2	Total	Dust	NO_x	SO_2	Total
1	Nikola Tesla A1	L	210	1,231	5.7	136.2	1,037.1	1,179	7.5	136.2	1,167	1,311
2	Nikola Tesla A2	L	210	1,198	5.5	132.5	1,008.9	1,147	7.3	132.5	1,135	1,275
3	Nikola Tesla A3	L	305	1,923	8.6	207.1	1,576.5	1,792	11.4	207.1	1,774	1,992
4	Nikola Tesla A4	L	309	1,989	0.0	252.0	1,649.9	1,902	1.7	252.0	1,852	2,106
5	Nikola Tesla A5	L	309	1,999	0.0	251.0	1,643.0	1,894	1.7	251.0	1,844	2,097
6	Nikola Tesla A6	L	309	1,987	0.0	249.4	1,632.9	1,882	1.7	249.4	1,833	2,084
7	Nikola Tesla B1	L	620	4,151	0.0	554.1	3,410.1	3,964	4.0	554.1	3,816	4,374
8	Nikola Tesla B2	L	620	4,004	0.0	539.6	3,320.4	3,860	3.9	539.6	3,715	4,259
9	Kolubara 1	L	32	175	14.4	0.0	70.6	85	15.4	29.2	292	337
10	Kolubara 2	L	32	116	9.5	0.0	37.6	47	10.1	0.0	180	190
11	Kolubara 3	L	64	135	11.1	0.0	43.7	55	11.8	0.0	209	221
12	Kolubara 4	L	32	0	0.0	0.0	0.0	0	0.0	0.0	0	0
13	Kolubara 5	L	110	626	0.0	0.0	530.5	530	1.3	82.5	786	870
14	Morava	L	125	566	30.7	0.0	932.4	963	33.0	112.8	1,139	1,285
15	Kostolac A1	L	100	560	10.0	0.0	1,679.2	1,689	12.5	71.9	2,009	2,094
16	Kostolac A2	L	210	1,196	3.8	129.2	3,778.8	3,912	5.6	129.2	3,909	4,044
17	Kostolac B1	L	348	1,937	51.4	393.2	5,910.1	6,355	54.2	393.2	6,110	6,557
18	Kostolac B2	L	348	1,895	19.6	329.9	5,201.6	5,551	22.3	329.9	5396	5,748
19	Novi Sad 1	NG	135	189	0.0	52.4	9.0	61	0.0	68.9	9	78
20	Novi Sad 2	NG	110	175	0.0	48.5	8.3	57	0.0	63.8	8	72
21	Zrenjanin	NG	110	66	0.0	20.0	3.4	23	0.0	26.4	3	30
22	Sr. Mitrovica 1	NG	32	123	0.0	7.7	0.0	8	0.0	20.8	0	21
Total			4,679	26,240	170	3,303	33,484	36,957	205	3,651	37,188	41,044

Table 5-20: Scenario 1 - Cost-benefit analysis for Serbia (LCPD)

Code	Plant name	Fuel type	Pow. MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Nikola Tesla A1	L	210	21.7	3.0	53	1179	1,126	22.2
2	Nikola Tesla A2	L	210	23.0	2.9	54	1147	1,093	21.4
3	Nikola Tesla A3	L	305	55.2	4.6	104	1792	1,688	17.2
4	Nikola Tesla A4	L	309	45.6	4.8	97	1902	1,805	19.7
5	Nikola Tesla A5	L	309	45.6	4.8	97	1894	1,797	19.6
6	Nikola Tesla A6	L	309	45.6	4.8	96	1882	1,786	19.5
7	Nikola Tesla B1	L	620	87.0	10.0	194	3964	3,771	20.5
8	Nikola Tesla B2	L	620	77.6	9.7	180	3860	3,679	21.4
9	Kolubara 1	L	32						
10	Kolubara 2	L	32						
11	Kolubara 3	L	64	8.2	0.3	12	55	43	4.7
12	Kolubara 4	L	32						
13	Kolubara 5	L	110	8.6	1.5	24	530	506	21.9
14	Morava	L	125	17.0	1.5	33	963	930	28.8
15	Kostolac A1	L	100	47.5	1.5	63	1689	1,626	26.7
16	Kostolac A2	L	210	9.6	3.9	51	3912	3,861	77.0
17	Kostolac B1	L	348	70.8	7.7	152	6355	6,203	41.7
18	Kostolac B2	L	348	65.8	7.1	142	5551	5,409	39.2
19	Novi Sad 1	NG	135	4.0	0.1	5	61	56	11.4
20	Novi Sad 2	NG	110	3.3	0.1	5	57	52	12.4
21	Zrenjanin	NG	110	3.3	0.0	4	23	20	6.2
22	Sr. Mitrovica 1	NG	32	1.0	0.1	2	8	6	4.3
Total			4,679	640	68	1,368	3,6825	35,458	27

Table 5-21: Scenario 2 –Cost-benefit analysis for Serbia (IED)

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Nikola Tesla A1	L	210	24.9	3	56	1,311	1,254	23.3
2	Nikola Tesla A2	L	210	24.7	3	55	1,275	1,220	23.1
3	Nikola Tesla A3	L	305	59.2	5	108	1,992	1,884	18.4
4	Nikola Tesla A4	L	309	49.6	5	101	2,106	2,005	21.0
5	Nikola Tesla A5	L	309	49.6	5	101	2,097	1,996	20.8
6	Nikola Tesla A6	L	309	49.6	5	100	2,084	1,984	20.8

7	Nikola Tesla B1	L	620	94.0	10	201	4,374	4,173	21.8
8	Nikola Tesla B2	L	620	84.6	10	187	4,259	4,071	22.7
9	Kolubara 1	L	32						
10	Kolubara 2	L	32						
11	Kolubara 3	L	64	11.4	0	15	259	245	17.8
12	Kolubara 4	L	32						
13	Kolubara 5	L	110	12.1	2	29	870	841	30.4
14	Morava	L	125	22.4	1	36	1,285	1,249	36.2
15	Kostolac A1	L	100	54.8	2	74	2,094	2,019	28.3
16	Kostolac A2	L	210	10.1	4	51	4,044	3,993	78.9
17	Kostolac B1	L	348	75.8	5	131	6,557	6,426	50.2
18	Kostolac B2	L	348	70.6	7	147	5,748	5,601	39.2
19	Novi Sad 1	NG	135	5.9	0	9	78	69	8.8
20	Novi Sad 2	NG	110	4.8	0	8	72	65	9.6
21	Zrenjanin	NG	110	4.8	0	6	30	24	5.1
22	Sr. Mitrovica 1	NG	32	1.8	0	3	21	18	8.1
Total			4,679	711	69	1,448	40,706	39,258	28

The basic parameters of the alternative scenarios that can be taken into consideration (see Chapter 4) for lignite-fired TPP units (with a total capacity of 594 MW) and gas-fired units (with a total capacity of 245 MW) are presented in Table 5-22. According to Scenario 1, approximately 69 million € shall be necessary for the environmental upgrade. However, in alternative solutions 1,273 million € is required, thus achieving the annual external benefits of about 36 million € and direct costs savings (fuel and O&M cost) of 77 million € per year.

Table 5-22: Basic differences of Scenarios 3 and 1 for Serbia

Code	Plant Name	Fuel Type	Power MW	LCPD				Alternative Scenario		Difference Alt-LCPD	
				Inv-env	OM-env	Ret. Plan	Fuel C.	Investment	Fuel sav.	Ext. Ben.	Fuel+O&M
				Mill. €	Mill. €		Mill. €	Mill. €	%	Mil€/a	Mil€/a
1	Nikola Tesla A1	L	210	21.7	3.0	2020	21	366	24	7.1	5.8
2	Nikola Tesla A2	L	210	23	2.9	2022	20	366	24	6.9	5.6
11	Kolubara 3	L	64	8.2	0.3	2018	3	109	43	8.5	10
13	Kolubara 5	L	110	8.6	1.5	2019	12	187	24	10.1	13.3
19	Novi Sad 1	NG	135	4	0.3	2027	47	135	43	1.8	22.1
20	Novi Sad 2	NG	110	3.3	0.2	2027	44	110	43	1.6	20.5
Total			839	68.8	8.1		147	1273		36.0	77.3

5.9. CBA for Ukraine

The benefits for the avoidance of external costs for the TPPs in Ukraine are presented in Table 5-23, both for the LCPD and the IED. These benefits are obtained according to the methodology and data presented in Chapter 3 for the present state of emission control, reduced by the proportion of the required emission concentrations as presented in Chapter 2. However, in case that the existing emissions are lower than the required ELVs for a certain scenario, the pollutant emission for that scenario is assumed as it is at present. The benefits are calculated for the period of 2018 to 2030 and discounted to the year 2017.

The cost calculation is based on the data presented in Chapter 4. The investment cost estimate for the environmental upgrade of each TPP unit is presented in Annex 3 (Table A3-12 for Scenario 1 and Table A3-13 for Scenario 2). The annual O&M costs are presented in the same tables alongside the investment costs. The value of total investment costs is 5,115 million € for LCPD and 6,033 million € for IED, while annual O&M

costs amount to 302 million € and 323 million € respectively for these scenarios. The results of benefit-cost calculation are presented in Table 5-24 for Scenario 1 and in Table 5-25 for Scenario 2. The results show that in all cases, benefits significantly exceed the costs of environmental upgrading. The average B/C ratio is approximately 13 for the LCPD Scenario and 12 for the IED Scenario.

Table 5-23: Pollution control benefits for Ukraine

Code	Plant name	Fuel type	Power MW	Energy GWh/a	PV for LCPD				PV for IED			
					External costs reduction, million €				External costs reduction, million €			
					Dust	NO_x	SO_2	Total	Dust	NO_x	SO_2	Total
1	Prydniprovska 7	HC	150	439	27	76	380	483	29	127	474	629
2	Prydniprovska 8	HC	150	682	40	123	627	791	44	198	766	1008
3	Prydniprovska 9	HC	150	0	0	0	0	0	0	0	0	0
4	Prydniprovska 10	HC	150	590	30	95	475	599	33	160	596	788
5	Prydniprovska 11	HC	310	1,186	78	324	1,126	1,527	79	324	1,202	1,606
6	Prydniprovska 12	HC	285	0	0	0	0	0	0	0	0	0
7	Prydniprovska 13	HC	285	774	60	230	730	1,020	61	230	782	1,074
8	Prydniprovska 14	HC	285	0	0	0	0	0	0	0	0	0
9	Kryvorizka 1	HC	282	1,106	82	331	1,164	1,578	84	331	1,236	1,651
10	Kryvorizka 2	HC	282	1,382	91	415	1,429	1,935	93	415	1,516	2,024
11	Kryvorizka 3	HC	282	0	0	0	0	0	0	0	0	0
12	Kryvorizka 4	HC	282	1,221	15	378	1,228	1,622	17	378	1,304	1,700
13	Kryvorizka 5	HC	282	1,221	98	397	1,314	1,810	100	397	1,392	1,889
14	Kryvorizka 6	HC	282	714	60	252	800	1,112	61	252	846	1,159
15	Kryvorizka 7	HC	282	0	0	0	0	0	0	0	0	0
16	Kryvorizka 8	HC	282	1,014	74	358	1,127	1,559	75	358	1,192	1,626
17	Kryvorizka 9	HC	282	0	0	0	0	0	0	0	0	0
18	Kryvorizka 10	HC	282	1,198	93	424	1,333	1,850	95	424	1,411	1,930
19	Zaporiska 1	HC	325	1,048	55	373	1,217	1,645	57	373	1,288	1,718
20	Zaporiska 2	HC	300	1,277	58	435	1,527	2,020	60	435	1,613	2,108
21	Zaporiska 3	HC	300	1,301	58	441	1,621	2,121	61	441	1,709	2,211
22	Zaporiska 4	HC	300	1,205	54	445	1,440	1,939	56	445	1,522	2,023
23	Zaporiska 5	NG	800	0	0	0	0	0	0	0	0	0
24	Zaporiska 6	NG	800	0	0	0	0	0	0	0	0	0
25	Zaporiska 7	NG	800	0	0	0	0	0	0	0	0	0
26	Starobeshivska 4	HC	175	715	0	0	0	0	0	0	0	0
27	Starobeshivska 5	HC	175	715	0	0	0	0	0	0	0	0
28	Starobeshivska 6	HC	175	715	0	0	0	0	0	0	0	0
29	Starobeshivska 7	HC	175	715	0	0	0	0	0	0	0	0
30	Starobeshivska 8	HC	175	715	0	0	0	0	0	0	0	0
31	Starobeshivska 9	HC	175	715	0	0	0	0	0	0	0	0
32	Starobeshivska 10	HC	175	715	0	0	0	0	0	0	0	0
33	Starobeshivska 11	HC	175	715	0	0	0	0	0	0	0	0
34	Starobeshivska 12	HC	175	715	0	0	0	0	0	0	0	0
35	Starobeshivska 13	HC	175	715	0	0	0	0	0	0	0	0
36	Slovianska 7	HC	800	3,269	0	0	0	0	0	0	0	0
37	Burshtynska 1	HC	195	915	62	89	1,150	1,300	63	89	1,208	1,360
38	Burshtynska 2	HC	185	397	29	42	542	613	29	42	570	642
39	Burshtynska 3	HC	185	662	54	66	920	1,041	56	66	967	1,089
40	Burshtynska 4	HC	195	884	70	91	1,246	1,407	72	91	1,308	1,471
41	Burshtynska 5	HC	195	465	35	46	692	774	36	46	725	808
42	Burshtynska 6	HC	185	986	70	92	1,384	1,546	72	92	1,453	1,617
43	Burshtynska 7	HC	185	508	37	54	767	858	38	54	802	895
44	Burshtynska 8	HC	195	806	33	81	1,241	1,355	34	81	1,296	1,412
45	Burshtynska 9	HC	195	961	0	104	1,288	1,392	2	104	1,354	1,460
46	Burshtynska 10	HC	195	930	0	103	1,272	1,375	2	103	1,336	1,441
47	Burshtynska 11	HC	195	992	0	79	1,308	1,387	2	79	1,375	1,456
48	Burshtynska 12	HC	195	667	8	56	901	964	9	56	947	1,012
49	Dobrotvirska 5	HC	100	402	15	21	495	532	17	70	693	780
50	Dobrotvirska 6	HC	100	402	15	21	495	532	17	70	693	780
51	Dobrotvirska 7	HC	150	786	55	40	1,185	1,280	59	126	1,355	1,541
52	Dobrotvirska 8	HC	150	568	41	29	870	940	43	93	995	1,132
53	Ladyzhinska 1	HC	300	874	55	245	807	1,107	56	245	865	1,166

Code	Plant name	Fuel type	Power MW	Energy GWh/a	PV for LCPD External costs reduction, million €				PV for IED External costs reduction, million €			
					Dust	NO_x	SO_2	Total	Dust	NO_x	SO_2	Total
54	Ladyzhinska 2	HC	300	1,092	21	305	1,045	1,371	23	305	1,117	1,445
55	Ladyzhinska 3	HC	300	1,262	23	354	1,261	1,639	25	354	1,345	1,724
56	Ladyzhinska 4	HC	300	752	47	209	712	968	48	209	762	1,019
57	Ladyzhinska 5	HC	300	582	46	162	578	786	47	162	617	826
58	Ladyzhinska 6	HC	300	558	53	156	546	756	54	156	583	794
59	Trypilska 1	HC	300	1,250	78	183	147	408	80	183	234	497
60	Trypilska 2	HC	300	1,250	108	284	276	668	110	284	363	757
61	Trypilska 3	HC	300	1,250	102	187	152	441	104	187	239	531
62	Trypilska 4	HC	300	1,250	99	184	148	431	101	184	236	521
63	Trypilska 5	NG	300	0	0	0	0	0	0	0	0	0
64	Trypilska 6	NG	300	0	0	0	0	0	0	0	0	0
65	Zmiivska 1	HC	175	548	119	52	512	683	121	117	560	798
66	Zmiivska 2	HC	175	548	120	52	490	662	122	117	539	779
67	Zmiivska 3	HC	175	548	115	48	484	647	118	112	539	768
68	Zmiivska 4	HC	175	548	112	45	481	638	115	109	535	758
69	Zmiivska 5	HC	175	548	107	38	502	647	110	101	559	770
70	Zmiivska 6	HC	175	548	103	26	441	571	106	90	495	691
71	Zmiivska 7	HC	275	793	120	345	1,005	1,470	121	345	1,066	1,532
72	Zmiivska 8	HC	325	937	12	492	1,534	2,039	14	492	1,597	2,103
73	Zmiivska 9	HC	275	793	114	272	895	1,281	115	272	950	1,337
74	Zmiivska 10	HC	275	793	114	276	840	1,230	116	276	896	1,288
75	Vuglegirska 1	HC	300	1,359	27	379	2,011	2,416	29	379	2,105	2,512
76	Vuglegirska 2	HC	300	1,359	27	378	2,007	2,411	29	378	2,101	2,508
77	Vuglegirska 3	HC	300	1,359	27	380	2,018	2,425	29	380	2,113	2,522
78	Vuglegirska 4	HC	300	1,359	27	380	2,016	2,423	29	380	2,111	2,519
79	Vuglegirska 5	NG	800	0	0	0	0	0	0	0	0	0
80	Vuglegirska 6	NG	800	0	0	0	0	0	0	0	0	0
81	Vuglegirska 7	NG	800	0	0	0	0	0	0	0	0	0
82	Zuevvskaya 1	HC	325	1,606	13	717	2,574	3,303	16	717	2,684	3,416
83	Zuevvskaya 2	HC	320	1,660	14	718	2,634	3,366	17	718	2,746	3,481
84	Zuevvskaya 3	HC	300	1,606	27	610	2,397	3,034	30	610	2,506	3,146
85	Zuevvskaya 4	HC	325	1,740	0	693	2,659	3,353	3	693	2,780	3,476
86	Kurakhovskaya 3	HC	200	1,005	173	135	1,612	1,920	175	135	1,686	1,996
87	Kurakhovskaya 4	HC	210	1,003	175	138	1,663	1,977	177	138	1,738	2,053
88	Kurakhovskaya 5	HC	222	969	157	125	1,654	1,935	159	125	1,725	2,009
89	Kurakhovskaya 6	HC	210	640	159	78	1,089	1,325	160	78	1,137	1,376
90	Kurakhovskaya 7	HC	225	982	110	127	1,524	1,761	112	127	1,596	1,835
91	Kurakhovskaya 8	HC	210	674	99	84	1,122	1,305	101	84	1,171	1,356
92	Kurakhovskaya 9	HC	221	1,019	122	117	1,679	1,918	124	117	1,754	1,995
93	Luganskaya 9	HC	200	1,070	164	286	1,302	1,752	166	286	1,382	1,834
94	Luganskaya 10	HC	200	642	29	155	759	943	30	155	808	993
95	Luganskaya 11	HC	200	988	140	279	1,164	1,583	142	279	1,237	1,657
96	Luganskaya 12	HC	175	0	0	0	0	0	0	0	0	0
97	Luganskaya 13	HC	175	951	130	166	1,205	1,500	134	275	1,300	1,710
98	Luganskaya 14	HC	200	1,070	166	339	1,385	1,890	168	339	1,465	1,972
99	Luganskaya 15	HC	200	988	143	295	1,331	1,769	145	295	1,406	1,846
100	Bilotserkivska CHP	NG	120	494	0	0	0	0	0	24	0	24
101	Darnytska CHP 5,10	NG	50	212	0	0	0	0	0	11	0	11
102	Darnytska CHP 6-9	HC	110	453	30	87	229	346	32	142	380	555
103	Kaluska CHP 1, 2	HC	100	412	30	0	232	262	32	0	378	410
104	Kaluska CHP 3, 4	NG	100	425	0	6	0	6	0	26	0	26
105	Kyivska CHP-5	NG	540	1,147	0	0	0	0	0	0	0	0
106	Kyivska CHP-5	FO	540	1,147	0	0	0	0	0	0	0	0
107	Kyivska CHP-6	NG	500	1,062	11	92	981	1,084	11	115	981	1,107
108	Kyivska CHP-6	FO	500	1,062	6	64	678	748	8	109	735	851
109	Kramatorska CHP	HC	120	494	12	0	474	486	14	42	619	675
110	Myronivska 4	HC	60	247	2	0	183	185	3	31	312	347
111	Myronivska 9	HC	115	616	3	17	437	457	7	93	632	732
112	Odeska CHP-2	NG	68	289	0	51	0	51	0	65	0	65
113	Sevastopolska CHP	NG	55	234	0	0	0	0	0	7	0	7
114	Simferopilska CHP	NG	278	1,181	0	0	0	0	0	7	0	7
115	Kharkivska CHP-2	HC	74	314	49	8	511	567	50	45	650	745
Total			29,368	88,669	5,238	16,928	85,682	107,849	5,395	18,254	92,265	115,914

Table 5-24 Scenario 1 – Cost-benefit analysis for Ukraine (LCPD)

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Prydniprovska 7	HC	150	34.6	1.6	51.1	596	545.2	11.7
2	Prydniprovska 8	HC	150	34.6	2.5	60.7	959	898.4	15.8
3	Prydniprovska 9	HC	150	32.4	0.0	32.4			
4	Prydniprovska 10	HC	150	34.3	2.1	56.3	746	689.4	13.2
5	Prydniprovska 11	HC	310	69.0	4.3	114.2	1527	1413.0	13.4
6	Prydniprovska 12	HC	285	65.4	0.0	65.4			
7	Prydniprovska 13	HC	285	68.3	2.7	97.5	1020	922.5	10.5
8	Prydniprovska 14	HC	285	68.3	0.0	68.3			
9	Kryvorizka 1	HC	282	62.2	4.0	105.2	1578	1472.5	15.0
10	Kryvorizka 2	HC	282	64.7	5.1	118.7	1935	1816.4	16.3
11	Kryvorizka 3	HC	282	57.9	0.0	57.9			
12	Kryvorizka 4	HC	282	59.1	4.5	106.6	1622	1515.3	15.2
13	Kryvorizka 5	HC	282	63.1	4.5	111.1	1810	1698.4	16.3
14	Kryvorizka 6	HC	282	65.1	2.6	93.3	1112	1018.4	11.9
15	Kryvorizka 7	HC	282	64.4	0.0	64.4			
16	Kryvorizka 8	HC	282	64.4	3.8	104.4	1559	1454.4	14.9
17	Kryvorizka 9	HC	282	63.3	0.0	63.3			
18	Kryvorizka 10	HC	282	64.4	4.4	111.7	1850	1738.7	16.6
19	Zaporiska 1	HC	325	65.9	3.9	107.2	1645	1538.0	15.3
20	Zaporiska 2	HC	300	70.0	4.8	120.7	2020	1898.9	16.7
21	Zaporiska 3	HC	300	66.2	4.9	118.4	2121	2002.4	17.9
22	Zaporiska 4	HC	300	70.4	4.5	118.2	1939	1820.8	16.4
23	Zaporiska 5	NG	800	24.0	0.0	24.0			
24	Zaporiska 6	NG	800	25.0	0.0	25.0			
25	Zaporiska 7	NG	800	25.6	0.0	25.6			
26	Starobeshivska 4	HC	175	25.0	1.7	42.9			
27	Starobeshivska 5	HC	175	40.0	2.2	63.2			
28	Starobeshivska 6	HC	175	37.9	2.2	61.1			
29	Starobeshivska 7	HC	175	37.2	2.2	60.4			
30	Starobeshivska 8	HC	175	37.2	2.2	60.4			
31	Starobeshivska 9	HC	175	38.2	2.2	61.4			
32	Starobeshivska 10	HC	175	39.2	2.2	62.4			
33	Starobeshivska 11	HC	175	39.2	2.2	62.4			
34	Starobeshivska 12	HC	175	33.8	2.2	57.0			
35	Starobeshivska 13	HC	175	31.6	2.2	54.8			
36	Slovianska 7	HC	800	169.3	10.0	275.3			
37	Burshtynska 1	HC	195	35.6	3.8	76.0	1300	1224.3	17.1
38	Burshtynska 2	HC	185	33.7	1.6	51.2	613	561.9	12.0
39	Burshtynska 3	HC	185	33.6	2.7	62.6	1041	978.0	16.6
40	Burshtynska 4	HC	195	35.5	3.7	74.6	1407	1332.2	18.9
41	Burshtynska 5	HC	195	38.6	1.9	59.3	774	714.7	13.0
42	Burshtynska 6	HC	185	33.6	4.1	76.7	1546	1469.5	20.2
43	Burshtynska 7	HC	185	33.7	2.2	56.6	858	801.3	15.2
44	Burshtynska 8	HC	195	39.0	3.4	75.6	1355	1279.5	17.9
45	Burshtynska 9	HC	195	35.9	4.0	78.4	1392	1313.4	17.8
46	Burshtynska 10	HC	195	35.9	3.9	77.2	1375	1297.9	17.8
47	Burshtynska 11	HC	195	35.1	4.0	77.5	1387	1309.5	17.9
48	Burshtynska 12	HC	195	32.4	2.7	61.1	964	903.3	15.8
49	Dobrotvirska 5	HC	100	14.8	1.4	29.9	633	602.7	21.2
50	Dobrotvirska 6	HC	100	14.8	1.4	29.9	633	602.7	21.2
51	Dobrotvirska 7	HC	150	35.4	2.8	65.7	1484	1418.5	22.6
52	Dobrotvirska 8	HC	150	37.3	2.1	59.2	1090	1030.7	18.4
53	Ladyzhinska 1	HC	300	65.1	3.1	98.1	1107	1008.5	11.3
54	Ladyzhinska 2	HC	300	63.9	3.9	105.4	1371	1265.3	13.0
55	Ladyzhinska 3	HC	300	63.9	4.6	112.3	1639	1526.3	14.6
56	Ladyzhinska 4	HC	300	63.9	2.7	92.4	968	875.7	10.5
57	Ladyzhinska 5	HC	300	63.9	2.1	86.2	786	700.2	9.1
58	Ladyzhinska 6	HC	300	63.9	2.0	85.2	756	670.8	8.9
59	Trypilska 1	HC	300	63.8	4.3	109.1	408	298.6	3.7
60	Trypilska 2	HC	300	63.0	4.3	108.5	668	559.1	6.2
61	Trypilska 3	HC	300	63.8	4.3	109.0	441	332.1	4.0

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
62	Trypilska 4	HC	300	63.8	4.3	109.1	431	322.2	4.0
63	Trypilska 5	NG	300	22.3	0.0	22.3			
64	Trypilska 6	NG	300	22.3	0.0	22.3			
65	Zmiivska 1	HC	175	53.1	1.9	73.3	755	682.2	10.3
66	Zmiivska 2	HC	175	43.6	1.9	63.7	737	673.0	11.6
67	Zmiivska 3	HC	175	55.1	1.9	75.3	726	651.0	9.7
68	Zmiivska 4	HC	175	43.6	1.9	63.7	716	652.3	11.2
69	Zmiivska 5	HC	175	55.1	1.9	75.4	728	652.9	9.7
70	Zmiivska 6	HC	175	43.6	1.9	63.4	649	585.5	10.2
71	Zmiivska 7	HC	275	67.0	2.9	98.0	1470	1372.0	15.0
72	Zmiivska 8	HC	325	75.2	3.8	115.8	2039	1923.2	17.6
73	Zmiivska 9	HC	275	65.0	2.9	95.9	1281	1185.3	13.4
74	Zmiivska 10	HC	275	66.5	2.9	96.8	1230	1133.4	12.7
75	Vuglegirska 1	HC	300	68.6	5.3	125.2	2416	2290.9	19.3
76	Vuglegirska 2	HC	300	68.6	5.3	125.2	2411	2286.2	19.3
77	Vuglegirska 3	HC	300	68.6	5.3	125.2	2425	2299.8	19.4
78	Vuglegirska 4	HC	300	68.6	5.3	125.2	2423	2297.4	19.3
79	Vuglegirska 5	NG	800	65.0	0.0	65.0			
80	Vuglegirska 6	NG	800	65.0	0.0	65.0			
81	Vuglegirska 7	NG	800	65.0	0.0	65.0			
82	Zuevvskaya 1	HC	325	75.3	6.5	144.0	3303	3159.2	22.9
83	Zuevvskaya 2	HC	320	75.0	6.7	145.9	3366	3219.9	23.1
84	Zuevvskaya 3	HC	300	72.0	6.3	139.4	3034	2894.7	21.8
85	Zuevvskaya 4	HC	325	63.5	6.9	136.6	3353	3216.3	24.5
86	Kurakhovskaya 3	HC	200	40.2	4.4	86.5	1920	1833.5	22.2
87	Kurakhovskaya 4	HC	210	39.1	4.4	85.7	1977	1890.9	23.1
88	Kurakhovskaya 5	HC	222	42.8	4.3	88.1	1935	1847.4	22.0
89	Kurakhovskaya 6	HC	210	36.2	2.8	65.5	1325	1260.0	20.2
90	Kurakhovskaya 7	HC	225	43.1	4.2	87.9	1761	1673.0	20.0
91	Kurakhovskaya 8	HC	210	30.9	2.9	62.0	1305	1242.8	21.0
92	Kurakhovskaya 9	HC	221	42.2	4.4	88.7	1918	1829.5	21.6
93	Luganskaya 9	HC	200	48.5	3.9	90.2	1752	1661.4	19.4
94	Luganskaya 10	HC	200	40.3	2.3	65.1	943	877.8	14.5
95	Luganskaya 11	HC	200	51.6	3.6	89.9	1583	1492.6	17.6
96	Luganskaya 12	HC	175	29.3	0.0	29.3			
97	Luganskaya 13	HC	175	43.3	3.2	76.9	1500	1422.9	19.5
98	Luganskaya 14	HC	200	48.6	4.0	90.9	1890	1799.5	20.8
99	Luganskaya 15	HC	200	50.9	3.7	90.2	1769	1678.8	19.6
100	Bilotserkivska CHP	NG	120						
101	Darnytska CHP 5,10	NG	50						
102	Darnytska CHP 6-9	HC	110	4.5	1.3	18.6	346	327.4	18.6
103	Kaluska CHP 1, 2	HC	100	11.0	1.0	21.5	262	240.0	12.2
104	Kaluska CHP 3, 4	NG	100	0.4	0.1	1.8	6	4.3	3.4
105	Kyivska CHP-5	NG	540	8.5	0.7	15.8			
106	Kyivska CHP-5	FO	540	8.5	0.7	15.8			
107	Kyivska CHP-6	NG	500	8.1	0.6	14.9	36	21.6	2.5
108	Kyivska CHP-6	FO	500	18.8	0.6	25.6	742	716.2	29.0
109	Kramatorska CHP	HC	120	15.5	1.3	29.2	486	457.0	16.7
110	Myronivska 4	HC	60	6.3	0.6	13.1	185	172.1	14.1
111	Myronivska 9	HC	115	12.7	1.7	30.7	457	426.7	14.9
112	Odeska CHP-2	NG	68	2.2	0.2	4.0	51	46.6	12.5
113	Sevastopolska CHP	NG	55						
114	Simferopilska CHP	NG	278						
115	Kharkivska CHP-2	HC	74	12.6	1.2	25.2	567	541.5	22.5
	Total		29,368	5,138.5	302.1	8,351	108,243	101,448	13

Table 5-25: Scenario 2 – Cost-benefit analysis for Ukraine (IED)

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Prydniprovska 7	HC	150	38.4	2	56	629	574	11.3
2	Prydniprovska 8	HC	150	38.4	3	66	1008	942	15.3
3	Prydniprovska 9	HC	150	35.6	0	36			

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
4	Prydniprovska 10	HC	150	38.4	2	61	788	727	12.8
5	Prydniprovska 11	HC	310	76.8	5	125	1,606	1,481	12.9
6	Prydniprovska 12	HC	285	70.4	0	70			
7	Prydniprovska 13	HC	285	74.0	3	105	1,074	969	10.2
8	Prydniprovska 14	HC	285	74.0	0	74			
9	Kryvorizka 1	HC	282	66.6	4	113	1,651	1,539	14.6
10	Kryvorizka 2	HC	282	69.5	5	128	2,024	1,897	15.8
11	Kryvorizka 3	HC	282	60.5	0	61			
12	Kryvorizka 4	HC	282	62.8	5	114	1,700	1,586	14.9
13	Kryvorizka 5	HC	282	67.5	5	120	1,889	1,769	15.8
14	Kryvorizka 6	HC	282	69.9	3	101	1,159	1,058	11.5
15	Kryvorizka 7	HC	282	69.1	0	69			
16	Kryvorizka 8	HC	282	69.1	4	113	1,626	1,513	14.4
17	Kryvorizka 9	HC	282	67.1	0	67			
18	Kryvorizka 10	HC	282	69.1	5	121	1,930	1,808	15.9
19	Zaporiska 1	HC	325	70.1	4	115	1,718	1,602	14.9
20	Zaporiska 2	HC	300	74.4	5	130	2,108	1,979	16.3
21	Zaporiska 3	HC	300	70.3	5	127	2,211	2,084	17.4
22	Zaporiska 4	HC	300	74.8	5	127	2,023	1,895	15.9
23	Zaporiska 5	NG	800	24.0	0	24			
24	Zaporiska 6	NG	800	25.0	0	25			
25	Zaporiska 7	NG	800	25.6	0	26			
26	Starobeshivska 4	HC	175	56.5	2	80			
27	Starobeshivska 5	HC	175	68.0	2	91			
28	Starobeshivska 6	HC	175	65.6	2	89			
29	Starobeshivska 7	HC	175	64.9	2	88			
30	Starobeshivska 8	HC	175	64.9	2	88			
31	Starobeshivska 9	HC	175	66.0	2	89			
32	Starobeshivska 10	HC	175	66.5	2	90			
33	Starobeshivska 11	HC	175	66.5	2	90			
34	Starobeshivska 12	HC	175	61.1	2	84			
35	Starobeshivska 13	HC	175	58.7	2	82			
36	Slovianska 7	HC	800	180.8	10	287			
37	Burshtynska 1	HC	195	38.6	4	79	1,360	1,281	17.2
38	Burshtynska 2	HC	185	36.5	2	54	642	588	11.9
39	Burshtynska 3	HC	185	36.4	3	65	1,089	1,023	16.7
40	Burshtynska 4	HC	195	38.5	4	78	1,471	1,393	19.0
41	Burshtynska 5	HC	195	40.9	2	62	808	746	13.1
42	Burshtynska 6	HC	185	36.4	4	80	1,617	1,538	20.3
43	Burshtynska 7	HC	185	36.5	2	59	895	835	15.1
44	Burshtynska 8	HC	195	42.4	3	79	1,412	1,333	17.9
45	Burshtynska 9	HC	195	38.9	4	81	1,460	1,378	17.9
46	Burshtynska 10	HC	195	38.9	4	80	1,441	1,361	18.0
47	Burshtynska 11	HC	195	38.1	4	81	1,456	1,376	18.1
48	Burshtynska 12	HC	195	35.1	3	64	1,012	948	15.9
49	Dobrotvirska 5	HC	100	37.9	1	53	780	727	14.6
50	Dobrotvirska 6	HC	100	13.7	1	29	780	751	26.7
51	Dobrotvirska 7	HC	150	56.4	3	88	1,541	1,453	17.6
52	Dobrotvirska 8	HC	150	21.0	2	44	1,132	1,088	25.9
53	Ladyzhinska 1	HC	300	71.5	3	107	1,166	1,059	10.9
54	Ladyzhinska 2	HC	300	70.0	4	114	1,445	1,330	12.7
55	Ladyzhinska 3	HC	300	70.0	5	121	1,724	1,603	14.2
56	Ladyzhinska 4	HC	300	70.0	3	100	1,019	919	10.2
57	Ladyzhinska 5	HC	300	70.0	2	94	826	732	8.8
58	Ladyzhinska 6	HC	300	70.0	2	93	794	701	8.6
59	Trypilska 1	HC	300	69.5	4	110	497	387	4.5
60	Trypilska 2	HC	300	68.3	4	114	757	643	6.6
61	Trypilska 3	HC	300	69.5	4	110	531	420	4.8
62	Trypilska 4	HC	300	69.5	4	110	521	411	4.7
63	Trypilska 5	NG	300	22.3	0	22			
64	Trypilska 6	NG	300	22.3	0	22			
65	Zmiivska 1	HC	175	57.3	2	77	798	721	10.4
66	Zmiivska 2	HC	175	45.5	2	65	779	714	12.0

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
67	Zmiivska 3	HC	175	59.8	2	79	768	689	9.7
68	Zmiivska 4	HC	175	45.5	2	65	758	693	11.7
69	Zmiivska 5	HC	175	59.8	2	79	770	691	9.7
70	Zmiivska 6	HC	175	45.5	2	64	691	627	10.9
71	Zmiivska 7	HC	275	72.3	3	107	1,532	1,425	14.4
72	Zmiivska 8	HC	325	81.2	4	127	2,103	1,976	16.5
73	Zmiivska 9	HC	275	70.3	3	104	1,337	1,234	12.9
74	Zmiivska 10	HC	275	72.0	3	105	1,288	1,183	12.3
75	Vuglegirska 1	HC	300	73.7	6	133	2,512	2,379	18.9
76	Vuglegirska 2	HC	300	73.7	6	133	2,508	2,375	18.8
77	Vuglegirska 3	HC	300	73.7	6	133	2,522	2,389	19.0
78	Vuglegirska 4	HC	300	73.7	6	133	2,519	2,386	18.9
79	Vuglegirska 5	NG	800	65.0	0	65			
80	Vuglegirska 6	NG	800	65.0	0	65			
81	Vuglegirska 7	NG	800	65.0	0	65			
82	Zuevvskaya 1	HC	325	69.6	7	146	3,416	3,269	23.4
83	Zuevvskaya 2	HC	320	69.3	7	148	3,481	3,333	23.5
84	Zuevvskaya 3	HC	300	66.1	7	140	3,146	3,006	22.5
85	Zuevvskaya 4	HC	325	67.3	8	148	3,476	3,328	23.5
86	Kurakhovskaya 3	HC	200	47.0	4	93	1,996	1,903	21.4
87	Kurakhovskaya 4	HC	210	43.6	4	90	2,053	1,963	22.8
88	Kurakhovskaya 5	HC	222	46.8	4	92	2,009	1,916	21.8
89	Kurakhovskaya 6	HC	210	40.1	3	69	1,376	1,306	19.8
90	Kurakhovskaya 7	HC	225	48.1	4	93	1,835	1,742	19.7
91	Kurakhovskaya 8	HC	210	36.0	3	67	1,356	1,289	20.2
92	Kurakhovskaya 9	HC	221	47.4	4	94	1,995	1,901	21.2
93	Luganskaya 9	HC	200	50.0	4	93	1,834	1,741	19.7
94	Luganskaya 10	HC	200	40.3	2	65	993	928	15.2
95	Luganskaya 11	HC	200	53.9	4	94	1,657	1,563	17.7
96	Luganskaya 12	HC	175	42.3	0	42			
97	Luganskaya 13	HC	175	44.8	4	84	1,710	1,626	20.3
98	Luganskaya 14	HC	200	50.1	4	95	1,972	1,878	20.8
99	Luganskaya 15	HC	200	53.0	4	94	1,846	1,752	19.6
100	Bilotserkivska CHP	NG	120	3.6	0	7	24	17	3.5
101	Darnytska CHP 5,10	NG	50	4.5	0	7	11	4	1.6
102	Darnytska CHP 6-9	HC	110	27.1	2	43	555	512	12.9
103	Kaluska CHP 1, 2	HC	100	15.0	1	26	410	384	16.1
104	Kaluska CHP 3, 4	NG	100	9.5	0	14	26	12	1.9
105	Kyivska CHP-5	NG	540	35.0	1	47			
106	Kyivska CHP-5	FO	540	94.0	3	128			
107	Kyivska CHP-6	NG	500	32.6	1	44	59	15	1.4
108	Kyivska CHP-6	FO	500	87.1	4	127	843	717	6.7
109	Kramatorska CHP	HC	120	23.2	1	37	675	638	18.3
110	Myronivska 4	HC	60	11.0	1	21	347	326	16.3
111	Myronivska 9	HC	115	20.8	2	46	732	686	15.9
112	Odeska CHP-2	NG	68	7.8	0	11	65	54	6.0
113	Sevastopolska CHP	NG	55	1.2	0	3	7	4	2.6
114	Simferopilska CHP	NG	278	1.4	0	5	7	2	1.4
115	Kharkivska CHP-2	HC	74	14.7	1	30	745	715	24.8
Total			29,368	6,033	323	9,467	114,860	107,283	12

In the case of Scenario 3 for Ukraine, it is proposed that a selection of old and less economic TPP units should be temporarily shut down. However, in case of a possible future increase in power demand, they could be retrofitted and re-introduced in operation (see Chapter 4). The remaining TPPs shall increase their power production and could operate more economically. However, the total amount of emissions will remain as in the LCPD Scenario, and therefore, there will be no change in external costs of power production and there will be no additional benefits to society.

On the other hand, by the temporary shut-down of several TPP units (with a total rated thermal input of ca. 9,400 MW), the investment costs of environmental upgrading shall be spread out over a longer time period, thus achieving cost reduction of financing for the whole power generation system.

5.10. CBA for Kosovo*

The benefits for the avoidance of the external costs for the one TPP in Kosovo* are presented in Table 5-26, both for the LCPD and the IED directives. These benefits are obtained according to the methodology and data presented in Chapter 3 for the present state of pollutant emission control, reduced by the proportion of the required emission concentrations as presented in Chapter 2. However, in case that the existing emissions are lower than the required ELVs for a certain scenario (dust emission), the pollutant emission for that scenario is assumed as it is at present. The benefits are calculated for the period of 2018 to 2030 and discounted to the year 2017.

Table 5-26: Pollution control benefits for Kosovo*

Code	Plant name	Fuel type	Power MW	Energy GWh/a	PV for LCPD				PV for IED			
					External costs reduction, million €				External costs reduction, million €			
					Dust	NO_x	SO_2	Total	Dust	NO_x	SO_2	Total
1	Kosovo A3	L	200	590	0.0	218.5	88.4	307	1.2	218.5	177.3	397
2	Kosovo A4	L	200	590	28.3	236.5	80.9	346	29.5	236.5	169.8	436
3	Kosovo A5	L	210	606	0.0	239.5	87.7	327	1.1	239.5	179.0	420
4	Kosovo B1	L	339	1,083	22.8	424.5	147.1	594	24.7	424.5	279.0	728
5	Kosovo B2	L	339	1,083	24.4	436.1	139.2	600	26.2	436.1	271.1	733
	Total		1,288	3,951	75	1,555	543	2,174	83	1,555	1,076	2,714

The cost calculation is based on the data presented in Chapter 4. The investment cost estimate for the environmental upgrade of each TPP unit is presented in Annex 3 (Table A3-14 for Scenario 1 and Table A3-15 for Scenario 2). The annual O&M costs are presented in the same tables alongside the investment costs. According to retirement plans, TPP Kosovo A shall be decommissioned by the end of 2017. Therefore, the total investment costs of the environmental upgrade are calculated for TPP Kosovo B units. The estimated value of total investment costs is 78 million € for LCPD and 84 million € for IED, while the annual O&M costs amount up to 7 million € for each scenario. The results of the CBA are presented in Table 5-27 for Scenario 1 and in Table 5-28 for Scenario 2. The results show that in all cases, benefits significantly exceed the costs of environmental upgrading. The average B/C ratio is approximately 8 for the LCPD and 9 for the IED scenario.

Table 5-27: Scenario 1 – Cost-benefit analysis for Kosovo* (LCPD)

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	
1	Kosovo A3	L	200				0		
2	Kosovo A4	L	200				0		
3	Kosovo A5	L	210				0		
4	Kosovo B1	L	339	39.0	3.7	78	594	516	7.6
5	Kosovo B2	L	339	39.0	3.7	78	600	521	7.7
	Total		1,288	78	7.4	156	1,194	1,038	8

Table 5-28: Scenario 2 – Cost-benefit analysis for Kosovo* (IED)

Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
				Invest.	O&M	C	B	B-C	
				Mil. €	Mil. €/y	Mil. €	Mil. €	Mil. €	-
1	Kosovo A3	L	200		0				
2	Kosovo A4	L	200		0				
3	Kosovo A5	L	210		0				
4	Kosovo B1	L	339	42.1	4	81	728	647	9.0
5	Kosovo B2	L	339	42.1	4	81	733	652	9.0
Total			1,288	84	8	163	1,462	1299	9.0

The basic parameters of the alternative scenarios that can be taken into consideration (see Chapter 4) for lignite-fired TPP units, with a total capacity of 678 MW, are presented in Table 5-12. According to Scenario 1, 78 million € shall be necessary for the environmental upgrade. However, in alternative solutions 1,090 million € is required, thus achieving the annual external benefits of nearly 20 million € and direct costs savings (fuel and O&M cost) of 16 million € per year.

Table 5-29: Basic differences of Scenarios 3 and 1 for Kosovo*

Code	Plant name	Fuel type	Power MW	LCPD				Alternative Scenario		Difference Alt-LCPD	
				Inv-env	OM-env	Ret. Plan	Fuel C.	Investments	Fuel saving	Ext. Ben.	Fuel+O&M
				Mill. €	Mill. €		Mill. €	Mill. €	%	Mil€/a	Mil€/a
4	Kosovo B1	L	339	39	3.67998	2030	21	545	33	9.9	8.2
5	Kosovo B2	L	339	39	3.68764	2030	21	545	33	9.9	8.2
	Total		678	78	7.4		42	1,090		19.8	16.4

6. Conclusions

The Energy Community Contracting Parties, with the exception of Croatia, which has joined the European Union in 2013, do not apply adequate measures to reduce emissions of NO_x, SO_2 and dust from large combustion plants. Taking only TPP in Albania is already capable of meeting the more stringent requirements of the IED and therefore no further environmental upgrade measures are considered to be necessary. The TPPs of Moldova already comply with the LCPD's requirements and with a limited amount of adjustments, it would be possible to implement the requirements of the IED. Other Contracting Parties, namely Bosnia and Herzegovina, FYR Macedonia, Montenegro, Serbia, Ukraine and Kosovo* are facing serious challenges to implement the requirements of the LCPD and the IED.

The estimated external costs of the emissions of SO_2, NO_x and dust arising from electricity and heat production are significant in all Energy Community Contracting Parties. The highest amount of external costs are related to electricity and heat production from coal and lignite, followed by oil, while the lowest external costs are related to power plants fired by natural gas.

In 2014, the average estimated external costs of electricity and heat production related to SO_2, NO_x and dust emissions would be between 0.1-26.7 €cent/kWh. These external costs are not adequately reflected in the energy prices of any of the Contracting Parties. Consequently, decision makers, energy companies as well as consumers do not get the accurate price signals that are necessary to reach decisions about the best ways of using energy resources.

The external costs of electricity and heat production related to SO_2, NO_x and dust emissions were estimated in the Contracting Parties at the following amounts:

1.	Montenegro	26.7	€cent/kWh
2.	Bosnia and Herzegovina	22.3	€cent/kWh
3.	Serbia	13.5	€cent/kWh
4.	FYR Macedonia	10.4	€cent/kWh
5.	Ukraine	10.3	€cent/kWh
6.	Kosovo*	7.2	€cent/kWh
7.	Croatia	6.7	€cent/kWh
8.	Moldova	0.4	€cent/kWh
9.	Albania	0.1	€cent/kWh

With the exception of Albania and Moldova, all Contracting Parties of the Energy Community have a high level of estimated external costs.

The implementation of the requirements of the LCPD and the IED in the Contracting Parties has been analysed according to the best available techniques and based on the experience of the utilities. The analysis was carried out separately for every TPP and CHP unit, as they have different technical parameters, fuel characteristics, emission concentrations as well as load factors. In the case of certain plants, abatement techniques for the reduction of particulate matters and nitrogen oxides were already installed and in a few cases, desulphurisation systems are in operation.

On the basis of the above facts, the following techniques were considered as best available for the environmental upgrade:

a) BAT for the reduction of dust emissions are: electrostatic precipitator (ESP) and bag filter (BF). The multi cyclones can be used as auxiliary devices to the ESP or BF.

b) BAT for the reduction of NO_x emission are: primary measures (mainly LNB – Low-NO_x burners designed to control fuel and air mixing at burner in order to create larger and more branched flames, OFA – Over-fire Air and flue gas recirculation) and secondary measures (SNCR – selective non-catalytic reduction and SCR – selective catalytic reduction). Primary measures can be usually applied when the required efficiencies for reduction of NO_x emission are less than 60 % for coal- and oil-fired plants and less than 70 % for gas fired plants.

c) BAT for the reduction of SO_2 emission are: wet processes (WLS – wet limestone scrubber, WL – wet lime), dry techniques (SD – spray drying, including NID – novel innovation de acidification). For TPP units with very low levels of SO_2 emissions, a dry injection system can be used.

The investment cost requirements have been estimated on the basis of the selected technology for the environmental upgrade systems for each TPP and CHP unit. This has been prepared in accordance with the experience of the Contracting Parties, as well as in accordance to data obtained from international studies on various TPPs in the region. Investment costs have been corrected according to current price levels by use of consumer price index. After the price range has been determined, the local conditions of individual TPPs and CHPs have been taken into account, in order to specify the investment costs for the units which will be in operation after 2017.

Apart from the LCPD and IED scenarios, some alternative scenarios were envisaged. These are:

- The decommissioning of certain old TPP units, for which the remaining operation lifetime is not more than 3 to 5years. These units would be replaced by modern, more efficient units compliant to the newest environmental standards.

- Temporary closure of certain old units in order to increase the load factor of the remaining TPP units. This will postpone their environmental upgrade investment costs until when a higher output in production should become necessary once again, with higher load factors. In the meantime the other TPPs shall have more economic operation, due to their larger power production per year.

The valuation of different scenarios of the environmental upgrade systems is performed by the use of the cost-benefit methodology described in Chapter 5.1. Benefits consist of the monetization of avoidance of all external costs, caused by the emission of pollutants with respect to the existing, business as usual (BAU) scenario. Costs mean the investment costs as well as the operation and maintenance (O&M) costs of the environmental upgrade systems. In order to calculate present values over the operation period all benefits and costs are summarized by the use of an appropriate social discount rate of 3%. The reference year for the present values calculation is 2017. The main result of the CBA economic model is the Net Present Value which is defined as a difference of present values of benefits and costs (B-C). In addition the B/C Ratio is evaluated. The CBA is performed for each LCP unit and further ranking is allowed according to the B/C ratio (detailed information can be found in Annex 4). The main criterion for the social viability of the project is that the B/C ratio is greater than 1.

The exceptions of these analyses are the alternative scenarios. For these scenarios, individual feasibility studies are needed, taking into account the remaining fixed assets of the old power plant units, operating conditions of the equipment and technical parameters of new TPP units as well as fuel cost and O&M savings. The alternative scenarios have to be compared with the LCPD scenarios by the use of a financial CBA methodology, which has to be prepared according to the interest of the utilities.

Albania has only one thermal power plant, designed and constructed in accordance with the requirements of the IED and therefore no CBA was necessary.

In order to comply with the requirements of the EU directives, all nine TPP units in Bosnia and Herzegovina need an environmental upgrade. In that respect the largest emitter in the Energy Community is TPP Ugljevik, with average SO_2 emission concentrations of over 16,000 mg/m^3. The required investment costs for the LCPD scenario are estimated at a level of 337 million €, while for the IED Scenario 375 million € is estimated. The B/C Ratio for the LCPD Scenario vary from 12-60, with an average of 36, while the IED scenario has the B/C Ratio is in the range of 14-58 and the average is 35.

Croatia has 17 TPP units, out of which seven units need environmental upgrading. The B/C Ratio is within the range of 3-19, with an average of 16 for the LCPD scenario for which 228 million € is estimated. The highest investments are needed for TPP Rijeka and TPP Sisak. As far as IED compliance is concerned, the investment costs for the necessary environmental upgrades are estimated at 318 million € with an average B/C ratio of 15.

FYR Macedonia has four coal-fired TPP units. All of them are in need of environmental upgrading in order to reach compliance with EU standards. An investment need of 230 million € is estimated for the LCPD scenario with an average B/C Ratio of 26 and 272 million € for the IED scenario with an average B/C ratio of 22.

Moldova has eight gas-fired units that are in compliance with the requirements of the LCPD. For the implementation of the IED, an estimated amount of 1.92 million € of investments would be needed, thus achieving a B/C ratio of 3.

Montenegro has one coal-fired TPP, for which an investment of 47 million € for the implementation of the LCPD is estimated. The investment needs for the compliance with IED emission standards are estimated at a level of 51 million €. In both cases, the B/C Ratio is over 50.

Serbia has 22 TPP units, out of which 18 are coal-fired. The largest polluters are TPP Kostolac A2, B1 and B2. The estimated investment costs for the LCPD scenario are about 640 million €, while for the IED Scenario 711 million € is estimated. The average B/C ratio is 27 for the LCPD scenario (ranging from 4 to 77) and 28 for the IED scenario (ranging from 5 to 79).

Ukraine has 101 TPP units and 12 CHP units. For 27 units, there was no sufficient data to perform a proper CBA. The highest polluters are the TPPs fired by hard coal. The costs of implementing the LCPD in the 83 units where a CBA could have been carried out are estimated at 5.139 billion of €, with the B/C ratio ranging from 2.5 to 29, with an average of 13. For implementing the IED, an estimated 6.033 billion € is required and 87 units are included in the environmental upgrade list. The B/C ratio ranges from 1.4 to 27, with an average value of 27.

Kosovo* has five coal-fired TPP units, out of which three should be shut down before the end of 2017. It is estimated that the remaining two units need ca. 78 million € for the implementation of the LCPD scenario (with an expected B/C ratio of 8) and 84 million € for the IED scenario (with an expected B/C ratio of 9).

For reaching compliance with the requirements of the LCPD in the Contacting Parties, investment costs for the environmental upgrade of LCPs with the aim of reducing emissions of SO_2, NO_x and dust are estimated as follows:

Albania	0	million €
Bosnia and Herzegovina	337.2	million €
Croatia	228.0	million €
FYR Macedonia	229.7	million €
Moldova	0	million €

Montenegro	46.9	million €
Serbia	640.4	million €
Ukraine	5,138.5	million €
Kosovo*	78.0	million €
TOTAL	**6,698.7**	**million €**

For reaching compliance with the IED in the Contracting Parties, investment costs for the environmental upgrade of LCPs with the aim of reducing emissions of SO_2, NO_x and dust are estimated as follows:

Albania	0	million €
Bosnia and Herzegovina	374.7	million €
Croatia	318.2	million €
FYR Macedonia	271.6	million €
Moldova	1.9	million €
Montenegro	50.9	million €
Serbia	710.7	million €
Ukraine	6,033.2	million €
Kosovo*	84.2	million €
TOTAL	**7,845.4**	**million €**

It is therefore visible that, with the exceptions of Albania and Moldova, major investments would be necessary throughout the Contracting Parties in order to carry out the necessary environmental upgrades that could safeguard the proper implementation of the LCPD and the IED. According to the above calculations, however, benefits significantly outweigh the costs the case of each and every Contracting Party.

The investments required to comply with the requirements of the LCPD in the Contracting Parties are estimated at 6,701.6 million €; more specifically:

- 882 million € for the installation and upgrade of electrostatic precipitators;
- 2,123 million € for NO_x control; and
- 3,694 million € for SO_2 control (flue gas desulphurization systems).

The most significant investments are required for the reduction of SO_2 emissions (55.3 %), followed by the costs of NO_x (31.5 %) and dust (13.2 %) emission reduction.

The investments required to comply with IED requirements in the Contracting Parties are estimated at 7,843.8 million €; more specifically:

- 1,003 million € for the installation and upgrade of electrostatic precipitators;
- 2,664 million € for NO_x control; and
- 4,179 million € for SO_2 control (flue gas desulphurization systems).

The most significant investments are required for the reduction of SO_2 emissions (53.3 %), followed by the costs of NO_x (34.0 %) and dust (12.7 %) emission reduction.

7. Recommendations

For all Energy CommunityContracting Parties, the best solution to deal with the requirements on the limitation of emissions of SO_2, NO_x and dust form large combustion plants is to prepare and adopt a combined approach for the implementation of the emission limit values of the LCPD and the IED for the majority of LCPs.

The total capacity of LCPs in the Contracting Parties is over 40,500 MW. They use different kind of fuel with a variety of sulphur content, which has direct implications on the SO_2 emission levels. Furthermore, they have different combustion chamber characteristics, which imply different characteristics in the emissions of nitrogen oxides.

The external costs of the current emissions of LCPs in the Contracting Parties (BAU status) vary between 0.1 – 53 €cent/kWh. Therefore, it is important and economically sensible that Contracting Parties make significant efforts to reduce the emissions of LCPs in order to be able to meet the requirements of EU standards, which could bring major benefits to society. As it is shown by the cost-benefit analyses, compliance with the environmental standards of the LCPD and the IED will bring a number of benefits through avoiding external costs of thermal power production and combined heat and power production. According to the calculations presented in this study, these benefits would significantly outweigh the costs in the case of every Contracting Party.

In this chapter, country-specific recommendations are made for each Contracting Party. The necessary retrofitting measures in order to meet the requirements of the LCPD and the IED have been recommended for each plant for those LCP units remaining in service after 2018.

- **Recommendations for Albania:**

  The TPP in Albania fulfils the requirements of both the LCPD and the IED and therefore no. The TPP presently uses light distillate oil as a fuel and it is therefore important to make sure that the sulphur content of the fuel is not higher than 0.1%.

- **Recommendations for Bosnia and Herzegovina:**
  - To urgently install emission abatement techniques for TPP Ugljevik, as it currently has the highest level of emissions in the Energy Community in terms of SO_2 emissions;
  - To prepare plans for the rest of the TPPs, except for Tuzla 3 that will be decommissioned by the end of 2015. For the units exceeding the ELVs of the LCPD and/or the IED, the recommendations for specific techniques of environmental upgrade are presented in Table 7-1.

Table 7-1: Recommended environmental upgrade measures for Bosnia and Herzegovina

No	Plant name	Capacity /MW/	LCPD retrofit measures			IED retrofit measures		
			Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Gacko	300	ESP	LNB+OFA+SNCR	SD	ESP	LNB+OFA+SNCR	SD
2	Ugljevik	300	ESP	LNB+OFA+SNCR	WLS	ESP	LNB+OFA+SNCR	WLS
3	Tuzla 4, 5	2x200	ESP	LNB+OFA	SD	ESP	LNB+OFA	SD
4	Tuzla 6	215	ESP	LNB+OFA	WLS	ESP	LNB+OFA	WLS
5	Kakanj 5	110		LNB+OFA	WLS		SCR+SNCR	WLS
6	Kakanj 6	110		LNB	WLS		SCR+SNCR	WLS
7	Kakanj 7	230	ESP	SCR+LNB	WLS	ESP	LNB+SCR	WLS

Recommendations for Croatia:

- To install the recommended environmental upgrade system firstly for the oil-fired TPP units (Rijeka and Sisak A and B) as highest priority, followed by the installation of the abatement techniques in other TPP units.The recommendations for specific techniques of environmental upgrade are presented in Table 7-2.

Table 7-2: Recommended environmental upgrade measures for Croatia

No	Plant name	Capacity /MW/	LCPD retrofit measures			IED retrofit measures		
			Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Plomin	210		LNB+SCR			LNB+SCR	
2	Rijeka	320		LNB+OFA+SNCR			SCR	
3	Sisak	2x210		LNB+OFA			SCR	
4	Jertovac	2x40					LNB+OFA	
5	Zagreb C	120	BF	LNB+OFA	WLS	BF	SCR	WLS
6	Zagreb K, L	208+112						
7	Zagreb K6, K8	11+30	BF	LNB	SD	BF	LNB	WLS
8	Zagreb	2x25					LNB+OFA	
9	Osijek	46+2x25					LNB+OFA	

Recommendations for FYR Macedonia:

- To urgently install the environmental abatement techniques in the coal-fired TPPs Bitola and Oslomej;
- To prepare a feasibility study for the oil-fired TPP Negotino, which is presently in reserve operation.The recommendations for specific techniques of environment upgrade are presented in Table 7-3.

Table 7-3: Recommended environmental upgrade measures for FYR Macedonia

No	Plant Name	Capacity /MW/	LCPD retrofit measures			IED retrofit measures			Note
			Dust	NO_x	SO_2	Dust	NO_x	SO_2	
1	Bitola	3x233	ESP	LNB+OFA+SNCR	WLS	ESP	LNB+SCR	WLS	
2	Oslomej	125	ESP		WLS	ESP	LNB+OFA	WLS	
3	Negotino	210							In reserve

Recommendations for Moldova:

- The TPPs in Moldova are in compliance with the requirements of the LCPD and therefore no additional recommendation is needed in that respect. The recommendations for specific techniques of environmental upgrade in order to achieve compliance with the IED are presented in Table 7-4.

Table 7-4: Recommended environmental upgrade measures for Moldova

No	Plant name	Capacity /MW/	LCPD retrofit measures			IED retrofit measures		
			Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	CET-1, Un 2, 3	12+10					LNB	
2	CET-2	3x80					LNB	

Recommendations for Montenegro:

- The one coal-fired TPP in Montenegro is a large polluter and need to be retrofitted as a high priority; the recommendations for specific techniques of environmental upgrade are presented in Table 7-5.

Table 7-5: Recommendedenvironmental upgrade measures for Montenegro

No	Plant name	Capacity /MW/	LCPD retrofit measures			IED retrofit measures		
			Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Pljevlja	219		LNB	WLS		LNB	WLS

Recommendations for Serbia:

- To install the recommended environmental abatement techniques in TPP Kostolac A and B as highest priority;
- To prepare the necessary plans in order to install the necessary abatement techniques in TPP Nikola Tesla A and B;
- To prepare a program for the replacement of gas-fired CHPs with CCGT units with higher efficiency; the recommendations for specific techniques of environmental upgrade are presented in Table 7-6.

Table 7-6: Recommended environmental upgrade measures for Serbia

No	Plant name	Capacity /MW/	LCPD retrofit measures			IED retrofit measures		
			Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	N.Tesla A1+ A2	2x210	ESP	LNB+OFA	SD	ESP	LNB+OFA	WLS
2	N.Tesla A3-6	4x309	ESP	LNB+OFA	WLS	ESP	LNB+OFA	WLS
3	N.Tesla B	2x620	ESP	LNB+OFA	WLS	ESP	LNB+OFA	WLS
4	Kolubara 3	64	ESP		SD	ESP	LNB	WLS
5	Kolubara 5	110	ESP		SD	ESP	LNB+OFA	WLS
6	Morava	125	ESP		SD	ESP	LNB+OFA+SNCR	WLS
7	Kostolac A1	100	ESP		WLS	ESP	LNB+OFA	WLS
7	Kostolac A2	210	ESP	LNB+OFA	WLS	ESP	LNB+OFA	WLS
8	Kostolac B	2x348	ESP	LNB+OFA+SNCR	WLS	ESP	LNB+OFA+SNCR	WLS
9	N. Sad	135+110		LNB+SCR			LNB+SCR	
10	Zrenjanin	110		LNB+SCR			LNB+SCR	
11	S. Mitrovica	32		LNB+OFA			LNB+OFA	

- **Recommendations for Ukraine:**
  - To implement the emission abatement measures for the pilot plants that have been selected already in order to obtain necessary experience on the use of the following technologies: SD in Trypilska 2 and Zmiivska 1 and SNCR for Zaporiska 1 and 2;
  - To prepare the implementation of environmental upgrade systems in coal-fired TPPs which have the highest emission levels, such as: Dobrotvirska, Zuevskaya, Kurakhovskaya, Luganskaya, Burshtynska, Vuglegirska, Zaporishka, Kyivska CHP;
  - Optionally, to prepare the plans for the temporary conservation of certain TPP units which are close to the end of their operational lifetime as well as for TPPs with natural gas as their main fuel. This would increase the efficiency of electricity production in the rest of the TPPs; furthermore, with the use of this option investments costs of the environmental upgrade of TPPs in reserve operation could be postponed until and increase of power consumption will require the reopening of these plants.The recommendations for specific techniques of environmental upgrade are presented in Table 7-7.

Table 7-7: Recommended environmental upgrade measures for Ukraine

No	Plant name	Capacity /MW/	LCPD retrofit measures			IED retrofit measures		
			Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Prydniprovska	4x150+310+3x285	ESP	SCR+LNB	NID	ESP	SCR+LNB	NID
2	Kryvorizka	10x282	ESP	SCR+LNB	NID	ESP	SCR+LNB	NID
3	Zaporiska 1-4	325+3x300	ESP	SCR+LNB	NID	ESP	SCR+LNB	NID
4	Zaporiska 5-7	3x800		LNB+OFA			LNB+OFA	
5	Starobeshivska	10x175	ESP,BF	LNB+OFA	NID	ESP,BF	SCR+LNB	NID
6	Slovianska 7	800	ESP	SCR+LNB	NID	ESP	SCR+LNB	WLS
7	Burshtynska	4x185 + 8x195	ESP	LNB+OFA+SNCR	NID	ESP	LNB+OFA+SNCR	NID
8	Dobrotvirska 5&6	2x100	ESP	LNB+OFA	NID	ESP	LNB+OFA	NID
9	Dobrotvirska 7&8	2x150	ESP	LNB +SCR	NID	ESP	LNB+SCR	NID
10	Ladyzhinska	4x300	ESP	LNB+SCR	NID	ESP	LNB+SCR	NID
11	Trypilska	4x300	ESP,BF	LNB+SCR	NID	ESP	LNB+SCR	NID
12	Trypilska NG	2x300		LNB+SCR			LNB+SCR	
13	Zmiivska	6x175+3x275+325	ESP,BF	LNB+SCR	NID	ESP	LNB+SCR	NID
14	Vuglegirska 1-4	4x300	ESP,BF	LNB+SCR	NID	ESP	LNB+SCR	NID
15	Vuglegirska 5-7	3x800		LNB+SCR			LNB+SCR	
16	Zuevvskaya	2x325+320+300	ESP	LNB+SCR	NID	ESP	LNB+SCR	NID
17	Kurakhovskaya	210+3x210+3x222	ESP	LNB+OFA+SNCR	NID	ESP	LNB+OFA+SNCR	NID
18	Luganskaya 9, 11	2x200	Scr	LNB+SCR	NID	ESP	LNB+SCR	NID
19	Luganskaya 10, 13-15	175+3x200	ESP	LNB+SCR	NID	ESP	LNB+SCR	NID
20	Luganskaya 12	175		LNB+OFA	NID	ESP	LNB+OFA	NID
21	Bilotserkivska	120					LNB+OFA	
22	Darnytska 5,10	50					LNB+SCR	
23	Darnytska 6-9	110	ESP	LNB+OFA	SD	ESP	LNB+SCR	NID
24	Kaluska CHP 1, 2	100	ESP		SD	ESP	LNB+SCR	NID
25	Kaluska CHP 3, 4	100		LNB			LNB+SCR	
26	Kyivska CHP-5	540		LNB+OFA			LNB+SCR	
27	Kyivska CHP-6	500		LNB+OFA			LNB+SCR	
28	Kramatorska CHP	120	Scr		SD	Scr		NID
29	Myronivska 4	60	ESP		SD	ESP	LNB+OFA+SNCR	NID
30	Myronivska 9	115	ESP	LNB	SD	ESP	LNB+OFA+SNCR	NID
31	Odeska CHP-2	68		LNB+OFA			LNB+SCR	
32	Sevastopolska CHP	55					LNB+OFA	
33	Simferopilska CHP	278					LNB	
34	Kharkivska CHP-2	74	ESP	LNB+OFA	NID	ESP	LNB+OFA+SNCR	NID
35	Luganskaya	2x175+5x201	ESP	LNB+SCR	NID	ESP	LNB+SCR	NID

- **Recommendations for Kosovo*:**
  - To install the emission abatement techniques in the two TPP units of Kosovo B before the closure of TPP Kosovo A.The recommendations for specific techniques of environment upgrade are presented in Table 7-8.

Table 7-8: Environmental Upgrade Measures for Kosovo*

No	Plant name	Capacity /MW/	LCPD retrofit measures			IED retrofit measures		
			Dust	NO_x	SO_2	Dust	NO_x	SO_2
1	Kosovo B	2x339	ESP	LNB+OFA+SNCR	SD	ESP	LNB+OFA+SNCR	SD

ANNEXES

Annex 1 Description of BAT for the environmental upgrade of LCPs

Thermal power plants and combined heat and power production plants are the largest emitters of particulate matters, nitrogen oxides and sulphur dioxide.

To comply with the regulatory requirements, LCPs have to be equipped with air pollution control devices. However, such control devices can contribute significantly to the cost of electricity. An understanding of cost structures of various control technologies can assist industry in determining the most cost effective means by which to comply with regulatory requirements[18].

A.1.1. Control of PM (dust) emissions

In modern TPPs and CHPs, PM emissions are controlled by electrostatic precipitators (ESP) or fabric filters (FF). Both technologies are highly efficient and capable of removing particulates to a level well beyond the ELVs of the LCPD and the IED. FFs are generally more efficient in removing fine particles. The choice between ESPs and FFs depends on fuel type, plant size, boiler type and configuration as well as the required PM removal efficiency. ESPs are mainly used in modern TPPs and CHPs. FFs are used only in special cases, for example if the electrical resistivity of ash is extremely high or the emission reduction requirement for PM is extremely strict.

Apart from the above considered modern techniques, wet scrubbers are used in several coal-fired plants to capture fly ash in addition to sulphur dioxide (SO_2). In the most widely used venture scrubber, water is injected into the flue gas stream at the venture throat to form droplets.

a) Electrostatic precipitators (ESP)

From the first development of commercial electrostatic precipitator designed by Fredrick Garner Cottrell in 1907, ESPs remain the dominant device for particulate emission control until nowadays. ESP design has been seriously improved based on the experience collected during the exploitation of ESPs in various industries. Stringent emission standards have also had an important influence on development of ESPs by forcing manufacturers to further improve ESP efficiency. According to the newest trends on the ESP market, intelligent precipitator control including integration into global plant control system, pulse energization, wide plate spacing, Hi-R™ (high reliability) system are used.

The main advantages of ESPs are:

[18] The Consultants used the *Guidance document on control techniques for emissions of sulphur, NOx, VOCs, dust (including PM10, PM2.5 and black carbon) from stationary sources* as a reference (Working Group on Strategies and Review, Fiftieth session, 24 September 2012), which includes the criteria and requirements of the revised LCP BREF

- Possibility of treatment of the large volumes of gas without significantly increasing process pressure drop (0.15-0.3 kPa)
- Possibility of operation over a wide range of temperatures (80-220 ^{0}C, cold ESP and 300-450 ^{0}C,hot ESP)
- Robustness and endurance at the high concentration of erosive ash in flue gases and Low electric energy consumption (0.1-1.8%) and low operating costs.

The efficiencies of modern ESPs are above 99.5% and can reach values up to 99.9 %. In practical terms, ESPs collect larger particles better than smaller ones.

The most important factor which determines the electrical migration velocity is the ash resistivity. If the resistivity is too low, particles lose their charge either before being collected or they may be released back into the flue gas stream after impacting the collection electrodes and secondly, dust re-entrainment can occur. However, when particles have too high resistivity, an insulating layer is formed on the electrode which hinders normal corona discharge and causes an electrical breakdown resulting in back corona or sparking at the surface.

The ash resistivity depends on the flue gas composition, ash composition, sulphur content, flue gas temperature and moisture content.

Other limitations of precipitator performance are flow non-uniformity and re-entrainment. More uniform flow ensures that there is no “sneakage” or gas flow bypassing the electric fields. Re-entrainment of collected particles may occur during rapping. Proper rapping design and timing will minimize rapper re-entrainment.

In order to improve the efficiency of existing ESPs the following action can be performed: replacement of the electrodes, rappers and other internal elements, modernization of the precipitator power supply and control system, enlargement of precipitator size and specific collection area.

b) Bag Filters (Fabric filters)

Bag filters (BF) are used where a very high efficiency (over 99.9%) is required. The performances of BFs are independent of the sulphur content, fluctuation in gas flow conditions and changes in inlet ash load.

BFs are often used for collecting high resistivity fly ash from low-sulphur coals which is relatively difficult to be collected by ESP.

BFs are characterized by:

- very high pressure drop (0.5-2 kPa);
- high electricity consumption (0.2-3 % of TPP capacity);
- low operating temperature, ≤150 ^{0}C (with polyester bags) ≤ 260 ^{0}C (with fiberglass bags);
- high maintenance and operational costs.

Bag life decreases with the increase of the sulphur content of coal and the filtering velocity. The individual bags fail at an average annual rate of about 1 % of installed bags.

For oil-, coal- and lignite-fired TPPs, the selected best available techniques for ash emission control at are ESP or FF in combination with FGD (for units with a rated thermal input of ≥ 100 MW) and ESP or FF (for units with a raterd thermal input from 50 to 100 MW).

c) Wet scrubbers

In the most widely used venture scrubber, water is injected into the flue gas stream at the venture throat to form droplets. Fly ash particulates impact with the droplets forming a wet by-product which then generally requires disposal. The system efficiency is reduced as the particle size decreases. The process can also have high energy consumption due to the use of sorbent slutty pumps and fans. Many of the wet particulate scrubbers are designed to control both SO_2 and particulates by using alkaline fly ash as a sorbent. Lime is frequently used to boost SO_2 removal efficiencies. The method has not been used in power plants with a rated thermal input over 300 MW. The removal efficiency is from 70 % up to 90 %.

A.1.2. DeNO$_x$ techniques

DeNO$_x$ techniques can be grouped into primary (combustion modifications) and secondary (post-combustion techniques) measures.

a) Primary measures

Primary measures include relatively simple and low-cost techniques, such as:

- Low excess air (LEA);
- Over-fire air (OFA);
- Air staging (AS);
- Flue gas recirculation (FGR);
- Fuel staging (FS);
- Low NO_x burners (LNB).

Low excess air (LEA) technique is based on the reduction of air in the reaction zone by the use of which a considerable reduction of NO_x emissions can be achieved. The main idea is to reduce the available oxygen in the combustion zone to the amount necessary for the complete burnout of the fuel. It reduces the conversion of fuel-bound nitrogen as well. Usual excess air in flue gases is in the range of 5-9% O_2. By the use of this technique, **20-40%** of NO_x emission reduction can be achieved.

Air staging is a zoned method in which a primary rich combustion zone is formed with primary air up to 90% and a secondary lean combustion zone with surplus of 10-30 % of the combustion air. The sub stoichiometric combustion in the primary zone suppresses both the thermal NO_x and conversion of fuel-bound nitrogen to NO_x.

Over-fire air (OFA) technique is a method in which a part of the combustion air is injected through separate ports which are located above the top row of burners. Typically, 15-30 % of the total combustion air is introduced through these ports. This is the most frequently used DeNO_x technique. Different combinations of OFA exist. NO_x reduction can reach 40-50% (~40 % for solid fuel; 45 % for oil; ≤ 65 % for gaseous fuel). There are two possible drawbacks of the air staging retrofit techniques: an increase of CO emissions and unburnt carbon in the ash.

Flue gas recirculation (FGR) technique is based on the decrease of combustion peak temperature, a reduction of available oxygen in the combustion zone and a change of the concentration of reacting species by introducing diluents such as nitrogen, water vapour and carbon dioxide. Both fuel-bound nitrogen and thermal NO_x are reduced. The FGR is mainly used in gas- and oil-fuelled boilers. Achievable NO_x reduction is in the range of 15-20%.

Fuel staging or re-burning method is based on the spatially divided zones in a furnace with controlled injection of fuel and air in order to recover nitrogen from already formed nitrogen oxides. In the primary zone, up to 90 % of fuel is burnt in a close stoichiometric atmosphere. In the second zone (the re-burning zone), secondary fuel is injected into a reducing atmosphere. The produced hydrocarbon radicals react with the formed NO_x to form nitrogen. The combustion is completed in the third zone when air is added to burn out the remaining combustible compounds. Although all types of fuel can be used, natural gas is considered the most effective. The re-burned fuel is 15-20% of the total heat input. The corresponding NO_x reduction can reach 40-50% of NO_x level achieved with low NO_x burners.

Low NO_x burners (LNB) are purposely designed burners that utilize combinations of combustion modification techniques such as air staging, fuel staging and FGR. Low NO_x burners are effective in reducing NO_x emissions by 30-50% and can be combined with other primary measures such as over-fire air, re-burning or flue gas recirculation. A drawback is the possible increase of unburnt carbon in the ash. To overcome this problem, an improvement of the fineness of the pulverized coal might be necessary. The most frequently used LNBs are air-staged or fuel-staged type burners with respective NO_x emission reduction levels **of 25-35% and 50-60%.** The LNB technique is the most often applied technique in both new and existing coal-fired boilers. When optimized with other air and fuel control equipment, including secondary and tertiary air, the NO_x reduction efficiency can reach **up to 70%.**

b) Secondary measures or post-combustion NO_x removal

Secondary measures are based on the injection of small quantities of additives into flue gas which react with NO_x and under favourable temperature and residence time conditions produce N_2 and H_2O. Standard additives are ammonia (NH_3) and urea ($[NH_2]_2CO$). If the reaction takes place in the gaseous phase, it is called selective noncatalytic reduction (SNCR) while if a catalyst is present, the technique is selective catalytic reduction (SCR).

Selective non-catalytic reduction (SNCR)

The chemical reaction is very sensitive to temperature and the working temperature range is between 1150 – 1400 ^oK.The efficiency of NO_x reduction is 20 (30) – 50%.

Selective catalytic reduction (SCR) is a process based on the selective reduction of nitrogen oxides with ammonia or urea in the presence of a catalyst, at 300 and 450 °C. There are many possible catalysts, from heavy metal oxides, to zeolites and activated carbon. SCR is widely applied and proven $DeNO_x$ technique. The life of catalyst depending on the applied material can be up to ten years. The reduction potential of the SCR technique is 50 – 80% (95%) and therefore this is the most efficient $DeNO_x$ technique.

Secondary measures have largely been applied to coal-fired plants. At lignite-fired TPPs, the application of primary measures is usually sufficient to reduce NO_x emissions below the ELVs of the EU directives.

Table A1-1: Average reduction efficiency of selected primary and secondary measures for reducing NO_x emissions in large combustion plants

Technique Average	NO_x reduction rate*	Technical limitations
Low excess air (LEA)	10-44 %	incomplete burn-out
Over fire air (OFA)	15 – 30 %	incomplete burn-out
Flue gas recirculation (FGR)	< 20 % (coal) 30-50 % (gas, combined with OFA)	flame instability
Fuel staging (FG)	50-60 %	
Air-staged LNB	25-35 %	incomplete burn-out flame instability
Flue-gas recirculation LNB	<20 %	flame instability
Fuel-staged LNB	50-60 %	incomplete burn-out flame instability
Selective catalytic reduction (SCR)	80-95 %	ammonia slip; contamination of fly ash by ammonia; air heater fouling
Selective non-catalytic reduction (SNCR)	30-50 %	ammonia slip which is usually higher than with SCR

* If several measures are applied reduction rates are different

A.1.3. Sulphur dioxide emissions control

There are a number of techniques for reducing SO_2 emission from coal combustion: wet scrubbers (absorbers), spray dry scrubbers, and sorbent injection. The choice of SO_2 control technology depends on a number of factors: emission requirements, plant size and operating conditions, sulphur content in the coal and the cost of various technology options, all of which are unique to each site.

a) Wet absorbers (scrubbers)

The limestone wet absorbers is the most common type of flue gas desulfurization (FGD). Lime can also be used as a reagent but it is usually more expensive.

There are generally two types of wet limestone scrubber: forced oxidation and natural oxidation. In the limestone with forced oxidation (LSFO) system, air is introduced into the bottom of the absorber to force oxidation of calcium sulphite to calcium sulphate while gypsum is obtained as a by-product.

When implementing wet limestone FGD systems on an existing installation, the flue gas path from the inlet of the absorber to the stack may need to be modified to protect against corrosion and acid attack. In most retrofit units, new stacks are required. As an FGD system requires considerable space, retrofitting may be more expensive in cases where there is a lack of available space.

Wet processes have undergone considerable developments in the last few decades. The state-of-the art wet absorbers are capable of routinely achieving SO_2 removal efficiencies **over 95% and up to 99.6%.**

b) Spray dry scrubbers

In spray dry scrubbers highly atomized aqueous alkaline slurry is sprayed into an absorption tower. As the slurry droplets are evaporating, SO_2 absorbs into the droplet and reacts with the dissolved and suspended alkaline material. These dry droplets are entrained in the flue gas and then collected in ESPs or FFs. Lime is the most commonly used alkaline chemical.

The absorption chemistry is strongly affected by factors such as flue gas temperature, gas humidity, SO_2 concentration in the flue gas and atomized slurry droplet size. The by-product is a dry mixture of calcium sulphite, sulphate, fly ash and un-reacted lime. They are mostly used for small to medium capacity boilers (<300MW) burning low to moderate sulphur fuel.

This technology has relatively low energy consumption, compared to the use of wet scrubbers

The main disadvantage of this technology relates to the disposal of the solid residue as the waste products are mixtures of fly ash, calcium sulphite and calcium sulphate which are less attractive commercially.

On the other hand, an important feature of the spray dry scrubber is that waste water treatment is not required, because the water is completely evaporated in the spray dry scrubber. As they are normally more compact than wet systems, they are suitable for retrofit applications or in sites where there is no space for waste water handling. In addition, this is a highly efficient process for acid gas (SO_3 and HCl) removal.

Application of spray dry scrubbers is limited to the flue gas volume of about 200 MW (electric capacity) plants on average. Larger plants require the use of several modules to deal with the total flue gas flow.

SO2 control efficiencies for spray dry scrubbers are lower than those for wet scrubbers and **vary from 80% to 92%.**

c) Semi-dry NID technology

Semi-dry Novel Innovation De-acidification (NID) Technology for flue gas desulfurization comprises a mixer, J-duct reactor and typically bag filter, but electrostatic precipitators can be used as well. The lime is used as absorbent. SO_2 reacts with hydrated lime under humid conditions. Once bound to the particulate matter, SO_2 is removed from the flue gas in a downstream BF or ESP. The collected particles are recycled to the mixer where fresh lime and water are added to the process. The removal efficiency can reach **up to 98 %.** The by-product is dust and there is no need for waste water treatment.

d) Dry sorbent injection

Dry sorbent injection systems are those where the sorbent is injected into the furnace and/or duct.

Sulphur dioxide adsorbs to the surface of the sorbent particles and reacts to form sulphite and sulphate compounds that are subsequently captured in particulate control devices along with fly ash. In order to increase removal efficiency and sorbent utilization, the reaction product collected by the particulate control device is re-injected into the furnace or duct and circulated several times. Commercially available limestone ($CaCO_3$) or hydrated lime (calcium hydroxide) is commonly used as sorbent; although sodium based alkaline reagents can also be used.

There are three types of sorbent injection processes: furnace, duct sorbent injection and hybrid sorbent injection. Furnace sorbent injection is the most commonly used system, and involves direct injection of dry sorbent into the upper part of the boiler furnace.

Dry sorbent injection is viewed as an emerging SO_2 control technology for medium to small boilers. Due to their low capital cost, but relatively high operating costs, these are suitable for retrofit applications, especially for old boilers with limited remaining lifetime and for peak load boilers with short annual operating time. According to basic characteristics of the system, dry sorbent injection cannot be used for waste gas having SO_2 concentrations greater than 2000 ppm (7500 mg/m^3). The dry process eliminates the slurry production and handling equipment required for wet scrubbers and spray dryers, although the technology also produces large quantity of wastes containing calcium sulphite, calcium sulphate, un-reacted sorbent and ash which may require special handling and disposal. The performance of a sorbent injection process depends on factors such as sorbent reactivity, the relative humidity of the flue gas and the gas and solids residence time, the quantity of injected sorbent, and quantity of recycled, unreacted sorbent from the particulate control device**.**

Sorbent injection systems normally have a moderate **(30-50%)** SO_2 removal efficiency, which is much lower than the wet systems described previously. An even distribution of fine sorbent particles (<5 μm) across the reactor and adequate residence time at the proper temperature (750-1,250°C) are critical for high SO_2 removal rates. More recent applications of dry sorbent injection on small coal-fired industrial boilers have achieved **greater than 90%** SO_2 control efficiencies and in systems where the reaction product is recycled, removal efficiencies of **70-80%** can be achieved.

Annex 2 Methodology for the investment cost estimate for environmental upgrade techniques

A.2.1. General

In general, the cost of measures for emission reduction for all three pollutants (Dust - PM, SO_2 and NO_x) depends on many factors. The main factors are:

- Flue gas flow rate
- Concentration of pollutant in flue gas
- Type and characteristics of fuel
- Site conditions.

a) Cost dependence on the flue gas flow rate

The flue gas flow rate has the dominant influence on the cost of the measure for emission reduction. The cost is decreasing when the flow rate increases. In the range of small flow rates the cost increases quickly with decreasing flow and in the rage of high flow rates it decreases very slowly. In references usually the costs (specific or total) are depending on the TPP unit electric capacity and sometimes are depending on the thermal capacity. If the cost is depending on the electric capacity also the type of fuel should be taken into account.

b) Cost dependence on the pollutant concentration in flue gas

The higher concentration of the pollutant in flue gas requires the application of more effective measure for emission reduction, which is more expensive. In the range of small and medium concentration the cost increase is almost linear and slower than in the range of high concentration of pollutant.

c) Cost dependence on the type and characteristics of fuel

The ash resistivity is one of the dominant elements determining the cost of the ESP and the efficiency of primary measures is higher for gas fuel than for the other ones.

d) Site conditions

Geological, hydro-geological, seismological conditions and available space at the site, and available space in surrounding of the TPP site for disposal of by-products (gypsum, ash), distance from the disposal site, characteristics of soil and environment etc. have an impact on the construction cost of structures.

e) Application of emission reduction measures at the existing TPP

The design solutions for the existing TPP were optimized and executed without taking into account the implementation of less strict measures for emission reduction. The application of more strict measures usually includes the dismantling of some existing constructions and the implementation of complicated solutions as the consequence of the lack of space. Sometimes the increase of cost can reach 30 % of the cost of emission reduction measure applied at the new constructed TPP plant.

A.2.2. Basis of the applied costs in this Study

The basis for determining the emission reduction costs of all three pollutants (SO_2, NO_x and dust - PM) is the available literature, information obtained from the beneficiary countries, information obtained through direct contacts with the manufacturers of the emission reduction measures and European Power Capital Cost Index (EPCCI) issued in 2012.

a) Data from the available references

The data values from the literature vary in a very wide range principally because of the specific conditions at the project site, the retrofit project complexity, and the timing differences between projects. Besides the above-mentioned facts that determine the cost of the emission reduction measures, the time period to which the data is related, completeness of the emission reduction system and many temporal, local and other facts can have the influence on the cost.

b) Data obtained from the beneficiary countries

Unfortunately, a sufficient amount of data on the investment cost estimates of the environmental upgrade equipment could have not been obtained from the beneficiary countries due to the brevity of the current exercise. The findings of the present study are without prejudice to calculations, cost estimates and/or cost-benefit analyses of the ones other entities or institutions may have arrived to.

c) European Power Capital Cost Index (EPCCI)

Investment costs can vary in time very quickly. The power plant capital cost increases during the last decade, provided by Simon Larsen are presented in Figure A2-1[19)]. The cost increases can be partly explained by rising costs on steel, copper and oil, which have an influence on the equipment and material costs. This analysis was prepared both for nuclear power plants and thermal power plants. The capital cost index for thermal power plants is indicated from 2005. The same cost index is applicable not only for new thermal power plants, but also for the environmental upgrade systems.

[19] Simon Larsen: Reviewing Electricity Generation Costs Assessments, Upsala University, Jun 2012

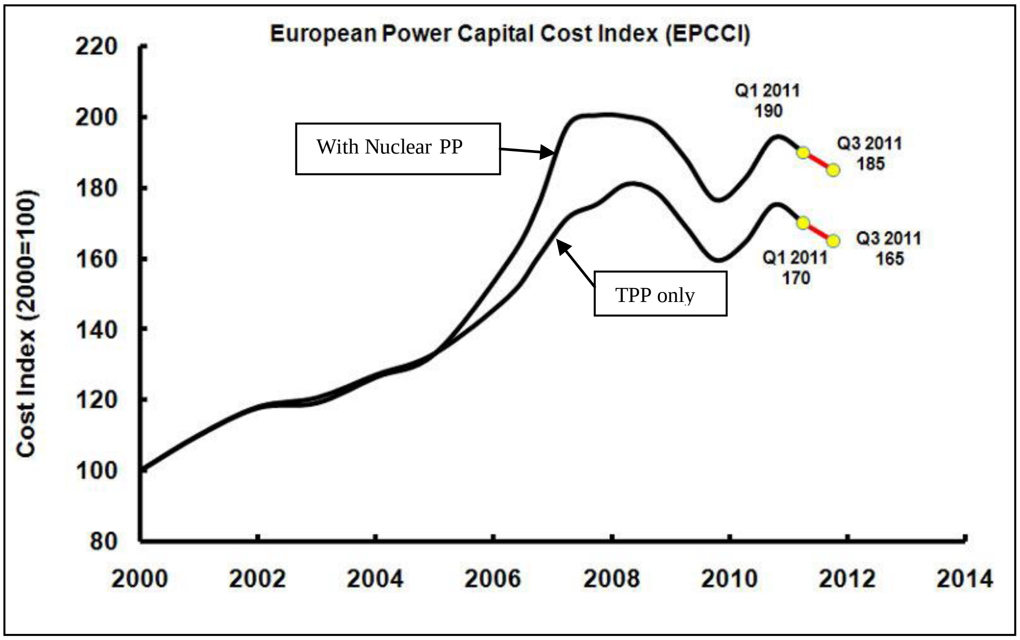


Figure A2-1: EPCCI index (IHS, 2012)

The base cost can be related to the year 2000. The highest index value was at the beginning of 2009 (cca 180 %) and at the end of 2010 and beginning of 2011 (about 170 %).

A.2.3. Particulate matter emission reduction

Efficiency of the electrostatic precipitators depends on the exit ash particulate concentration and resistivity. H. Naguyen et all have shown In Fig. A2-2 is presented the dependence of ESP cost on the range of the exit concentration between 100 mg/Nm^3 and 20 mg/Nm^3[20)].

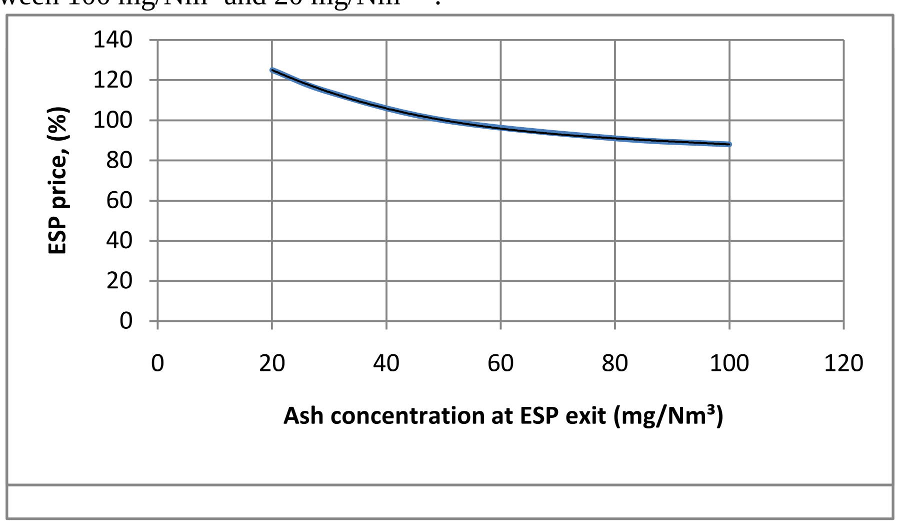


Figure A 2-2: ESP cost changes depending on the exit ash content and ash resistivity

[20] Hao Naguyen at all: Analyzes of Pollutant Control costs in Coal based Electricity Generation, Technology Assessment Report 68, January 2008

The costs of the dust (PM) reduction measures used in this Study

The cost of ESP retrofitting is extremely dependent on the site conditions and can only be estimated on the basis of a detailed knowledge and analyses of the site conditions. That was the reason why the authors of this Study decided to accept the dust (PM) reduction emission costs obtained from beneficiaries as the most correct solution. In the case of missing data from beneficiaries, the above curve is used. The reference specific cost for discharge concentration of 50 mg/Nm^3 is assumed according to the flue gas flow rate as 8 €/Nm^3/h. This value represents a best average cost of the recently retrofitted ESPs or ESPs with documentation prepared for retrofitting, as shown in Table A2-1, which includes a comparison between values provided by the beneficiaries and the calculated values.

Table A2-1: List of the ESP costs obtained from the beneficiary countries and calculated, discharge dust - PM concentration 50 mg/Nm^3

EnC Contracting Party /TPP/TPP's unit	Fuel	Unit(s) capacity, MW	Flue gas flow rate, mil.Nm^3/h	Cost of ESP, mil. €	Calculated cost value mil. €	Year of retrofitting	Remarks
Albania							
TPP Vlora	NG						N/A
Bosnia and Herzegovina							
TPP Ugljevik	BC	300	1.36	20.0	10.9	<2017	<20 mg Nm^3
TPP Tuzla 6	BC	215	0.92	4.95	7.3	2013	<30 mg/Nm^3
TPP Kakanj 5	BC	110	0.49	3.99	3.94	2003	<11 mg/Nm^3
TPP Kakanj 6	BC	110	0.48	3.98	3.82	2012	<20 mg/Nm^3
Croatia							
TPP Plomin 1	HC	125	0.426	4.5	3.41	1999	<25 mg/Nm^3
FYR Macedonia							
TPP Bitola	L	3x225	3x1.13	3x11.6	3x9.1	<2017	<50 mg/Nm^3
Oslomej	L	125	0.625	7.0	5.0	<2017	<100 mg/Nm^3
Moldova							
							N/A
Montenegro							
TPP Pljevlja	L	220		9.7	8.26	2009	<30 mg/Nm^3
Serbia							
TPP Nikola Tesla A3	L	305	1.4	10.5	11.2	2014	<50 mg/Nm^3
Kostolac B1&B2	L	2x350	2x1.62	2x10	2x13.0	2014	<50 mg/Nm^3
Morava	L	120	0.616	8.0	5.0	2015	<100 mg/Nm^3
Ukraine							
Prydniprovska 9	HC	150	0.326	3.7	2.6	2012	
Prydniprovska 13, 14	HC	2x285	2x0.996	11.5	7.96	2012/2015	
Krivovirska 3,5,6,9	HC	4x 282	4x0.911	5.8-8	7.3	2012-2018	
Zaporiska 1,	HC	325	0.928	4.7	7.42	2012	<50 mg/Nm^3
Zaporiska 2,3,4	HC	3x300	3x0.856	9.4/5.6/94	3x6.85	2012-2015	<50 mg/Nm^3
Burshtynska5,7,8	HC	~5x195	~5x0.70	3.2-7.6	5.6	2012-2016	<50 mg/Nm^3
Burshtynska9,10	HC	~5x195	~5x0.70	3.2-7.6	2x5.6	2006/2006	<50 mg/Nm^3
Dobrotvirska 7,8	HC	2x150	2x550	5.5/7.6	2x4.4	2012-2015	<50 mg/Nm^3
Ladyzhinska	HC	6x300	6x0.862	6x6.9	6x6.9	2015-2018	<50 mg/Nm^3
Zuyevskaya 1,2,3	HC	3x315	3x0.993	3x9.5	3x7.95	2013-2015	<50 mg/Nm^3
Zuyevskaya 4	HC	325	1.085	5.8	8.6	2012	<50 mg/Nm^3
Kosovo*							
TPP Kosovo A	L	3x200	3x0.97	3x8.5	3x9.1	2012-2013	
TPP Kosovo B	L	2x339	2x1,57	2x10.0	2x12.5	2017	Calculated for de rated capacity (280MW)

A.2.4. SO_2 Reduction costs

a) Data from references

There is a large difference between costs of FGD presented in the available references and those presented in the answers obtained from the beneficiary countries. The Indicative costs of SO_2 emissions abatement techniques for boiler plants had been recently issued by EPA, with reference to Euros 2001[21], Table A2-2 illustrate these differences.

Table A2-2: Indicative costs of SO_2 emission abatement techniques for boiler plants (2001 Euros)

Control option	Processcapacity MWth	Capital costs €/kW	O&M costs €/kW	Annual costs €/kW	Pollutant removed costs €/ton SO_2
Wet scrubber	>400	104 - 262	2 - 8	21 - 52	210 - 523
Wet scrubber	<400	262 - 1,572	8 - 21	52 - 210	523 - 5,230
Dry Scrubber	>200	41- 157	4 - 11	21 - 52	157 - 314
Dry Scrubber	<200	157 - 1,572	11 - 314	52 - 523	523 - 4190

Robert Peltier has analysed the average total installed costs of FGD systems[22], which are surveyed in the period 2007 and 2008, when quick changes in cost appeared. The prices rose about 15% (in average) from 2007 to 2008. The survey included 78 TPP units. The authors of this study underline a large variation of the costs of considered units of FGD systems. These differences come out as a consequence of the specific site conditions that exist at each project site, the retrofit project complexity, and the timing differences between projects.

Therefore, defining an average project cost is difficult without some understanding of the project-specific details of each of the units surveyed. A look at the summary or "fully loaded" installed costs clearly shows that costs continue to rise and continue to stay consistently above $300/kW (250 €/MW).

The results of analyses of the emission reduction techniques in coal fired plants, done by Orfanoudakis et al.[23] have shown the following:

- For wet FGD systems, efficiency is from 70 % to 98 %, sulphur content in coal 0.3 % to 4.5 %
  - Cost 80 to 120 €/MW_{th} (cca 240 to 360 €/MW)
  - Electricity consumption 2-3 %
  - Operational costs 175-600 €/t
- For spray dry scrubber, efficiency is from 50 % to 70 %, S content in coal 0.5 % to 1.9 %
  - Cost 40-80 €/MW_{th} (cca 120-240 €/MW)
  - Electricity consumption 0.5 %
  - Operational cost 700-1,000 €/t.

[21] EPA: Guidance document on control techniques for emission of sulphur, NO_x, VOC, dust from stationary sources, 2012; http://www.unece.org/fileadmin/DAM/env/documents/2012/EB/Informal_document_7_EGTEI_guidance-document_on_stationary_sources_tracked_changes_compared_with_WGSR_version.pdf

[22] Robert Peltier: Air Quality Compliance, Latest Costs for SO_2 and NO_x Removal, June 13, 2009

[23] N. Orfanoudakis et al.: Emission Reduction Techniques and Economics in Coal fired Power plants, Greece, 2005

Company ALSTOM has shown the results of the economic analyses of FGD system costs[24] in a seminar held in December 2008, for TPP units fired by coal with high sulphur content and units fired by coal with low sulphur content, both with a capacity of 600 MW. The concentration of SO_2 in raw flue gas of TPP unit fired by high sulphur content coal was 3.7 times higher from the units with low sulphur content. The estimated costs of FGD plants were ca. 225 €/MW for high sulphur content coal fired unit and ca. 180 €/MW for low sulphur content coal fired unit.

The operational and maintenance costs were:

- For unit fired by high sulphur content coal cca 2.5 €/MWh
- For unit fired by low sulphur content coal cca 1.5 €/MWh

The specific cost (per 1 t) of SO_2 removal was three times lower for units fired by high S content coal.

The Study on the Economic Partnership Projects in Developing Countries in 2011 and the Study on the Environmental Improvement, FYRM, City Bitola, February, 2012, prepared by the company Yokogawa Electric Corporation includes an analysis of technical, environmental and economic issues of the flue gas desulphurization of lignite fired TPP Bitola (3x233 MW). The obtained results have shown that for all three lignite fired units, with a total capacity of 699 MW, existing SO_2 emission of 3,900 mg/Nm^3 and exit SO_2 emission of 200 mg/Nm^3, the total installed cost will be 19.4 billion yen (ca. 155 million € or 230,000 €/MW). The cost also included 5% contingency and a 5% fee. After the deduction of these expenses, the cost will be 140 million € or 207,000€/MW. The value of exit emission of 400 mg/ Nm^3, without contingency, will be ca. 180,000 €/MW.

The author of the Study refers to the cost of the FGD plant equipment for the on-going project in Romania of 23.3 million yen/MW (cca 186,000 €/MW), which explains the reality of the obtained investment cost for TPP Bitola.

KEMA elaborated the study "Reducing Sulphur Dioxide and Nitrogen Oxide Emission" for TPP Kakanj, B&H, from November 2009 to June 2010[25]. The results of SO_2 emission reduction are presented in Table A2-3. On the basis of the excerpt from the Study it can be concluded that the costs of the considered options for FGD systems include all elements of the project expenses.

b) Data obtained from direct contacts with a company with experience in FGD plant construction

The information obtained from a European experienced consultancy company was that the investment costs for a wet limestone gypsum FGD plant might be approximately 25 – 35 €/Nm^3/h. Sulphur load and concentration will

24 Ray Gansley: Wet FGD system Overview and Operation, Alstom, December 2008
25 KEMA: Reducing Sulfur Dioxide and Nitrogen Oxides Emissions on TPP Kakanj, 2010

have an influence if it is on the lower or on the upper end of the range. Boiler size also has an influence: smaller FGDs are particularly more expensive than large systems. The full range of costs which the company has listed over the last 20 years is approx. 10 – 50 €/Nm³/h (cca from 55,000 to 270,000).

The complete FGD systems (including limestone handling and milling, gypsum handling etc.) will increase costs for about 20 %. This means that in the case of lignite fired TPP units the specific cost of the complete FGD system will vary from 135,000 €/MW to 190,000 €/MW (full range listed for the last 20 years varies from 55,000 €/MW to 270,000 €/MW). These values should be corrected for high and low SO_2 concentration in raw flue gas.

c) Data obtained from the beneficiary countries

A very small amount of data could have been obtained, which is presented in Table A2-3 below.

The obtained data includes the range from 42,000 €/MW for three units of TPP Prydniprovska, with a capacity of 315 MW and SO_2 content in raw gas starting from cca 3,200 mg/Nm^2 to 317,000 €/MW for TPP Ugljevik, with a capacity of 300 MW and SO_2 content in raw gas 16,200 mg/Nm^2 (the project implementation is currently on-going).

Table A2-3: List of FGD costs obtained from beneficiary countries

EnC Contracting Parties/TPP/TPPs unit	Fuel	Unit(s) capacity, MW	SO_2. in raw gas, mg/Nm^3	Applied technology	Cost of FGD mil. €	Specific FGD cost, X1000 €/MW	Remark
Albania							
TPP Viora	N.G.				N/A	N/A	N/A
Bosnia and Herzegovina							
TPP Ugljevik	BC	300	16,200	WLS	95.0	317	ELV≤200
TPP Tuzla 6	BC	215	3,946	SDA	20.5	95	ELV≤400
TPP Kakanj 6	BC	110	8,600	SDA	15.5	141	ELV≤1,080
TPP Kakanj 6	BC	110	8,600	WLS	27.1	246	ELV≤1,080
TPP Kakanj 7	BC	230	8,600	SDA	27.1	118	ELV≤516
TPP Kakanj 7	BC	230	8,600	WLS	47.9	208	ELV≤400
Croatia							
							N/A
FYR Macedonia							
TPP Bitola	L	3x225	3,900	FWLS	156	231	ELV ≤200
Oslomej	L	125	4,100	SDA	13	104	ELV<990 mg/Nm^3
Moldova							
							N/A
Montenegro							
TPP Pljevlja	L	220	600				Not provided
Serbia							
TPP Nikola Tesla A3- A6	L	305+308 308+308	2,000	FWLS	2x85	139	ELV≤400, 2 FGD systems. Incomplete Assessed increased 15 %
TPP Nikola Tesla B	L	2x650	2,001	FWLS	2x105	161	Published June, 2009, EPS green book
Kostolac B1&B2	L	2x350	6,060	FWLS	2x43	138	Incomplete. Missed gypsum handling system, WWTP etc.
Ukraine							
Prydniprovska 11	HC	310	3,200	NID	13.3	43	The value is not realistic
Orydniprovska 13&14	NC	2x285	3,200	NID	2x13.3	47	The value is not realistic
Starobeshivska5 to 13	HC	9x175		NID	17.4 to 20.5	100 to 117	Expected real values
Kosovo*							
TPP Kosovo B	L	2x339	620	SDA	50-110	74-162	

The general impression is that the cost data provided by the beneficiary countries is lower than expected. In several cases, the beneficiaries elaborated more than one technical and economical document on the FGD issue. The preparation was done by the consulting companies engaged by the investor or by potential suppliers of equipment or/and services. The beneficiaries provided the lowest values.

In the case of TPP Kostolac B, Serbia, the project is contracted with a Chinese company. It is not complete, because it does not include gypsum handling system (transport and storage), waste water treatment plant, etc. By adding the missing costs to the existing ones, the complete costs can increase with approximately 10 to 15 %, but these costs will still be low.

d) **Costs to be used in this Study**

The values that were used in this Study are cost values for FGD systems in TPPs, which have been previously provided by the beneficiaries. In the cases where costs do not include the complete FGD system (FGD plant and all auxiliaries), the costs will be previously corrected, and will also include the corrections related to the time when the values were derived.

For LCPs for which the beneficiaries have not provided the data the curves in the Figure A2-3 have been used. These curves represent the curves of best fit generated for the cost values discussed above. The main base values for their generation were the data obtained as the result of the recent studies, i.e. technical and economical document which includes complete project cost:

1. 317,000 €/MW from the Feasibility study elaborated in 2008 for TPP Ugljevik, capacity 300 MW, SO_2 concentration in raw flue gas 16 200 mg/Nm^3, and ELV = 400 mg/Nm^3,
2. 210,000 €/MW from KEMA study elaborated in 2010 for TPP Kakanj 7, capacity 230 MW, SO_2 concentration in raw flue gas 8,600 mg/Nm^3 and ELV = 400 mg/Nm^3,
3. 185,000 €/MW from Yokogawa Electric Corporation study elaborated in 2012 for TPP Bitola, unit capacity 225 MW, SO_2 concentration in raw flue gas 3,900 mg/Nm^3 and ELV = 400 mg/Nm^3 and
4. 155,000 €/MW for unit capacity of 300 MW, SO_2 concentration in raw flue gas cca 2,500 mg/Nm^3 and ELV = 400 mg/Nm^3.

The above values can be applied to the wet limestone (WLS) technology including gypsum production and ELV = 400mg/Nm^3. For ELV 200 mg/Nm^3 the values to be used will be 10 % higher than for ELV = 400 mg/Nm^3. For Spray drying FGD technology the cost value to be used in this study will be 60 % of the WLS technology.

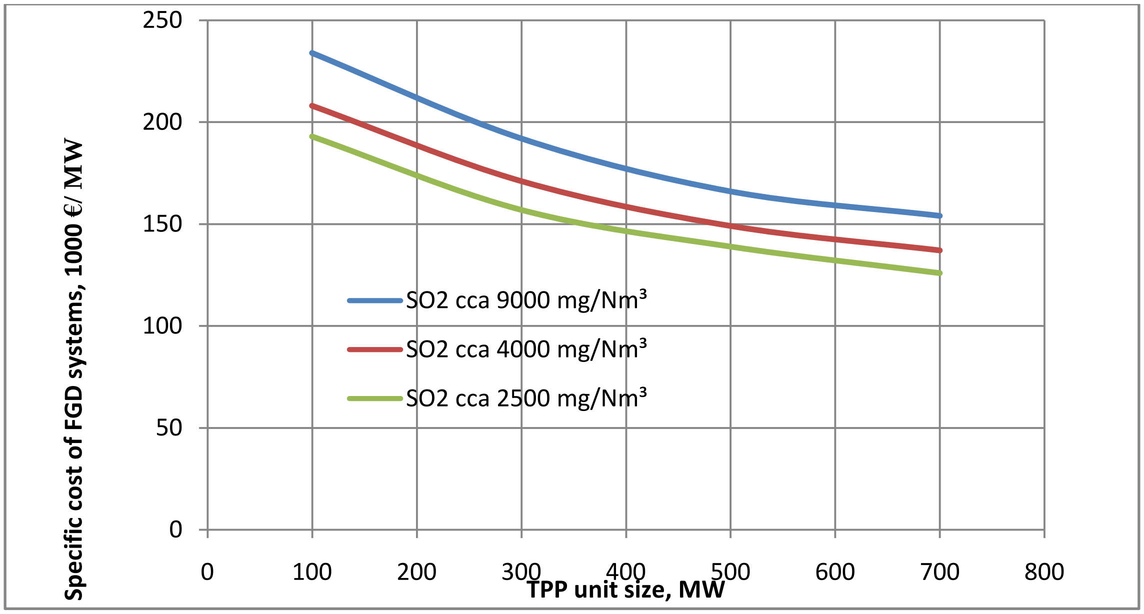


Figure A2-3: Specific costs of FGD systems depending on the unit size and SO_2 concentration in raw flue gas

The shape of the curve, showing the WLS FGD system cost changes vs. TPP unit capacity, is taken from Hao Naguyen et al.[26]

The operational costs are determined on the basis of analysis made by Ray Gansley[27] and KEMA[28]. The most representative average values for operational costs of the WLS FGD system efficiency 98 % are:

- For concentration of SO_2 cca 9,000 mg/Nm^3 3,2 €/MWh
- For concentration of SO_2 cca 2,500 mg/Nm^3 1.9 €/MWh

Operational cost of the Spray drying (SD) technology for the same SO_2 concentration and removal efficiency is ca. 25 % higher than for WLS technology. For Semi dry NID technology, for the same SO_2 concentration and removal efficiency, the operational cost is ca. 30 % higher than for WLS technology.

A.2.5. NO_x reduction costs

The specific costs of DeNO$_x$ techniques can vary significantly due to complexity of possible DeNO$_x$ techniques, individual characteristics of thermal power plants, type of used fuel and country in which the technique is implemented.

26 Hao Naguyen et al.: Analyses of Pollutant Control Costs in Coal based Electricity Generation, Technology Assessment Report 68, January 2008
27 Ray Gansley: Wet FGD system Overview and Operation, Alstom, December 2008
28 KEMA: Reducing Sulfur Dioxide and Nitrogen Oxides Emissions on TPP Kakanj, 2010

a) Data from references

In the SEEC study on the investments in environmental protection of South East Europe[29] the authors use the values of specific costs of different $DeNO_x$ technologies undertaken by EPRI, Mitsui Babcock and Chubu, which are presented in Table A2-4 below.

Table A2-4: Specific costs of $DeNO_x$ techniques

Source	Technique	NO_x reduction (%)	Average retrofit capital cost (€/kW)	O&M cost (€/kWh)
EPRI December 2000	OFA LNB LNB + OFA	15 – 30 40 – 60 50 – 70	5.7 15 22	~0.0005^
Mitsui	LNB	40 – 60	13.5	
Chubu December 2000	LNB	30	4.1	
	SNCR	20 - 50	8.3^	~0.0004^
	SCR Hot side Post FGD	 50 – 80 50 – 80	 66.5 96	0.0004 – 0.0012
Chubu E.P.Dec. 2000	SCR	< 90	42 - 53	~0.0007^

*Chubu/EPRI

In the Guidance document on control techniques for emissions of sulphur, NO_x, VOCs, dust (including PM_{10}, $PM_{2.5}$ and black carbon) from stationary sources are shown indicative specific capital and O&M costs for different $DeNO_x$ technologies, for EUROs 1999, Table A2-5.

Table A2-5: Efficiency and cost of the different $DeNO_x$ technologies

Control options	Typically achievable emission reduction	Process capacity (MWel)	Indicative capital cost € /kWel	Indicative operating cost €/kWh
SCR[1]	80-90%	Various	30-70 [2]	11-14 €/kWel/a[30]
SNCR	30-50%	Various	14	0.0011
Re-burning (Fuel staging)	50-75%	Various	42	0.0011
Flue gas recirculation	15-45 5	Various	14	0.00014
Low NO_x Burner	30-50 5	Various	14	0
1 It should be noted that the design of SCR is highly site-specific and this makes definition of capital cost difficult				

Robert Peltier in his Study on the air quality compliance[31] presents the variation of surveyed cost categories by unit size. In this reference are identified the costs of construction labour, equipment, materials, and project management-engineering-construction management (including complete SCR system). In analyses were included 72 individual units totalling 41 GW (representing 39% of installed SCR systems in the U.S. by MW at the time of the study) owned by eight large utilities. They included Southern Company, Duke, TVA, Progress Energy, Constellation Energy, Ameren, Ontario Hydro, and AEP. The sample also reflected the distribution of installations in the U.S., so the survey results can be considered a valid top-level view of system costs. The larger units were installed earlier: the average unit size retrofit before 2003 was 623 MW, vs. 466 MW since 2003, what influenced on the results. The variations of the average cost were:

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29 SEEC: Development of power generation in South East Europe, Implication for investments in environmental protection, Belgrade, April, 2005

30 J. Theloke, et all, (2007): Maßnahmen zur Einhaltung der Emissionshöchstmengen der NEC Richtlinie, Umweltbundesamt

31 Robert Peltier: Air Quality Compliance, Latest Costs for SO_2 and NO_x Removal, June 13, 2009

- Units capacity <300 MW 125,000 €/MW
- Unit capacity 301-600 111,000 €/MW
- Unit capacity 601-900 93,000 €/MW.

b) Data obtained from the beneficiary countries

Data obtained from the beneficiary countries are shown in Table A2-6.

Table A2-6: List of the costs of $DeNO_x$ techniques obtained from beneficiary countries

EnC Contracting Party /TPP/TPPs unit	Fuel	Unit(s) capacity, MW	NO_x in raw gas, mg/Nm^3	Applied technology	Cost of $DeNO_x$, mil. €	Specific $DeNO_x$ cost, X1000 €/MW	Remark
Albania							
TPP Viora	NG				N/A	N/A	N/A
Bosnia and Herzegovina							
TPP Tuzla 3	BC	110	312	LNB+OFA			
TPP Tuzla 4		200	344	LNB+OFA	2.2	11.0	
TPP Tuzla 5	BC	200	180	LNB+OFA	2.34	11.7	
TPP Tuzla 6	BC	215	350	LNB+OFA	2.6	12.1	ELV≤200 mg/Nm^3
TPP Kakanj 5	BC	110	1,036				
TPP Kakanj 6	BC	110	747	SCR	13.6	123.5	ELV≤600 mg/Nm^3
TPP Kakanj 6	BC	110	747	SCR+SNCR	7.2	65.5	ELV≤600 mg/Nm^3
TPP Kakanj 7	BC	230	794	SCR	20.5	89.1	ELV≤200 mg/Nm^3
TPP Kakanj 7	BC	230	794	SCR+SNCR	10.9	47.4	ELV≤200 mg/Nm^3
Croatia							
Plomin 2	HC	210		LNB+SCR	20.0	95.2	ELV≤200 mg/Nm
FYR Macedonia							
TPP Bitola	L	3x225	820	SCR	3x10	44,4	
Oslomej	L	125	360	LNB+OFA	6	48.0	
Moldova							
							N/A
Montenegro							
TPP Pljevlja	L	220	600				Not provided
Serbia							
TPP N. Tesla A3-A6	L	305+308 308+308	2,000				
TPP N. Tesala B	L	2x650	2,001				
Kostolac B1&B2	L	2x350	6,060				
Ukraine							
Zaporiska 1	HC	325	1,550				
Dobrotvirska 7	HC	150	785	SNCR	2.2	14.7	
Dobrotvirska	HC	150	785	SNCR	2.3	15.3	
Trypilska 2	HC	300					
Zmiivska 1	HC	175					
Slovianska 7	HC	800					
Kosovo*							
TPP Kosovo B	L	2x339	620	LNB+OFA+SNCR	2x13	38.4	

c) Data used in this study

Capital costs of primary measures of the $DeNO_x$ techniques are based on the data obtained from EPRI, CHUBU and Mitsui Babcock, presented as a function of NO_x reduction efficiency, and corrected to comply (as much as was possible) with the data obtained from beneficiary countries (the fact is that very limited amount of data was obtained from beneficiaries). Specific capital costs (€/kW) = $0.0643\ x\eta^{1.462}$ where η is $DeNO_x$ efficiency given in %.

O &M costs of primary measures are based on EPRI and CHUBU data and are assessed to be approximately 0.0006 EURO/kWh.

Capital costs of secondary measures: for SNCR the average capital costs is assessed to be about 10 EUR/kW, (actualized data of EPRI/Chubu).

For determination of the **specific capital costs for SCR** the authors of this study established the curves of the dependence of secondary measure cost versus unit size and NO_x removal efficiency presented in Figure A2-4. Usually the SCR technology is applied with LNB and in this case the capital cost can be lower for 10 to 15 %.

O&M costs of secondary measures: O&M costs depend on a number of factors such as the SCR arrangement, catalyst type, operating conditions such as flue gas volume, the required NO_x reduction, gas composition, flue gas temperature, operating hours per year, catalyst poisoning and others. Secondary $DeNO_x$ measures are usually applied in combination with LNB and OFA. When the SCR is applied with LNB the capital and operational and maintenance costs are reduced from 12 to 15 % (H. Naguyen et all[30]).

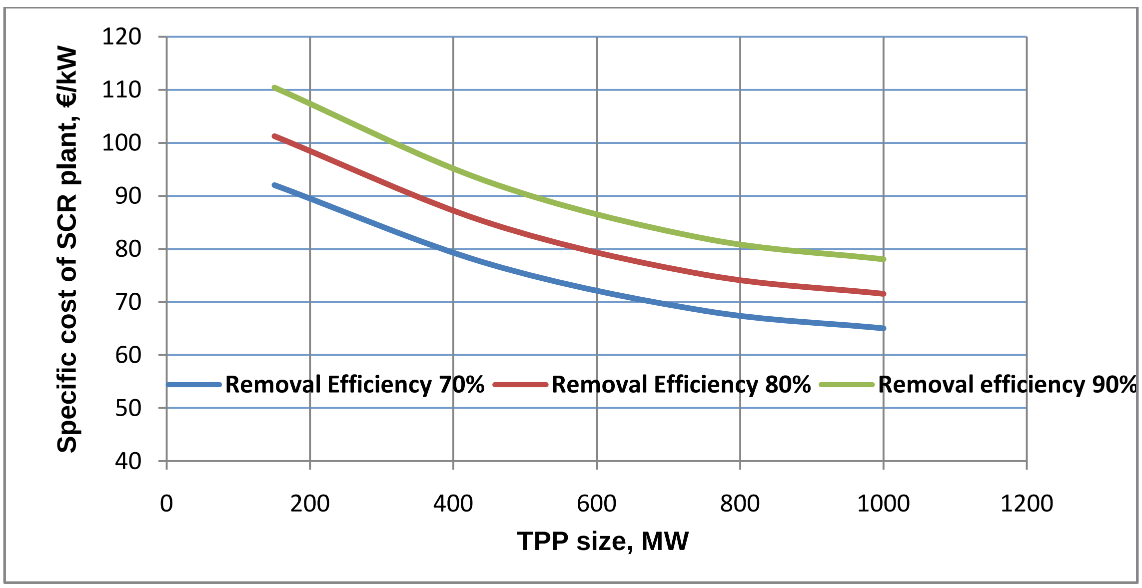

Figure A2-4: Specific capital cost of SCR system vs. TPP size and removal efficiency

For SCR the operational cost will be taken to vary linearly from 0.0006 €/kWh, at removal efficiency of 70 % to 0.0018 €/kWh for removal efficiency of 90 %. The costs are determined on the basis of the studoes of SEEC[32], as well as of the work of H. Naguyen et al. [33] . For SNCR the cost is assessed to vary linearly from 0.0004 to 0.001 €/kWh depending on the removal efficiency (20-50 %).

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32 SEEC: Development of power generation in South East Europe, Implication for investments in environmental protection, Belgrade, April, 2005

33 Hao Naguyen et al.: Analyses of Pollutant Control Costs in Coal Based Electricity Generation, Technology Assessment Report 68, January 2008

Annex 3 European Union Directives - Environmental compliance costs

Table A3-1: Scenario 1 - LCPD compliance costs for Bosnia and Herzegovina

Code	Plant name	Fuel type	Power MW	Energy GWh/a	LCPD Scenario						
					Investment costs /million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Gacko	L	300	1,934	11.4	9.0	13.0	33.4	2,579	4,110	6,689
2	Ugljevik	L	300	2,176	14.0	8.4	85.5	107.9	2,611	10,097	12,708
3	Tuzla 3	L	110	473							
4	Tuzla 4	L	200	1,196	1.0	3.0	18.0	22.0	717	2,741	3,459
5	Tuzla 5	L	200	1,004	0.3	0.0	17.0	17.0	0	2,234	2,234
6	Tuzla 6	L	215	1,008	5.0	2.6	39.0	46.6	605	2,206	2,811
7	Kakanj 5	L	110	598	0.0	2.4	27.0	29.4	359	1,775	2,134
8	Kakanj 6	L	110	312	0.0	2.4	20.0	22.4	94	920	1,014
9	Kakanj 7	L	230	1,342	0.5	18.0	40.0	58.5	994	3,981	4,974
Total			1,775	10,044	31.9	45.8	259.5	337	7,959	28,064	36,022

Table A3-2: Scenario 2 - IED compliance costs for Bosnia and Herzegovina

Code	Plant name	Fuel tupe	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /million € /				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Gacko	L	300	1,934	14.0	9.0	14.3	37.3	2,579	4,110	6,689
2	Ugljevik	L	300	2,176	15.0	8.4	95.0	118.4	2,611	10,097	12,708
3	Tuzla 3	L	110	473							
4	Tuzla 4	L	200	1,196	2.0	3.0	20.0	25.0	717	2,741	3,459
5	Tuzla 5	L	200	1,004	1.0	0.0	19.0	20.0	0	2,234	2,234
6	Tuzla 6	L	215	1,008	0.0	2.6	44.0	46.6	605	2,206	2,811
7	Kakanj 5	L	110	598	0.0	6.2	30.0	36.2	966	1,775	2,741
8	Kakanj 6	L	110	312	0.0	5.7	22.0	27.7	457	920	1,377
9	Kakanj 7	L	230	1,342	1.5	18.0	44.0	63.5	2,008	3,981	5,988
Total			1,775	10,044	34	53	288	375	9,943	28,064	38,007

Table A3-3: Scenario 1 - LCPD compliance costs for Croatia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	LCPD Scenario						
					Investment costs /million € /				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	TPP Plomin 1	HC	125	915	0.0	0.0	0.0	0.0	0	0	0
2	TPP Plomin 2	HC	210	1,631	0.0	20.0	0.0	20.0	1,631	0	1,631
3	TPP Rijeka	FO	320	1,725	6.0	8.2	47.0	61.2	2,085	3,820	5,905
4	TPP Sisak A	FO	210	1,214	4.8	5.9	46.0	56.7	728	2,598	3,327
5	TPP Sisak B	FO	210	1,214	4.8	5.9	46.0	56.7	728	2,598	3,327
6	TPP Jertovac 1	NG	40	47	0.0	0.0	0.0	0.0	0	0	0
7	TPP Jertovac 2	NG	40	47	0.0	0.0	0.0	0.0	0	0	0
8	CHP Zagreb C	NG	120	469	2.7	2.8	19.0	24.5	281	1,003	1,284
9	CHP Zagreb K	NG	208	1,591	0.0	0.0	0.0	0.0	0	0	0
10	CHP Zagreb L	NG	112	866	0.0	0.0	0.0	0.0	0	0	0
11	CHP Zagreb EL-TO K6	NG	11	21	1.0	0.5	3.0	4.5	6	56	63
12	CHP Zagreb EL-TO K8	NG	30	82	1.1	0.3	3.0	4.4	24	217	242
13	CHP Zagreb EL-TO H	NG	25	161	0.0	0.0	0.0	0.0	0	0	0
14	CHP Zagreb EL-TO J	NG	25	161	0.0	0.0	0.0	0.0	0	0	0
15	CHP Osijek A	NG	46	256	0.0	0.0	0.0	0.0	0	0	0
16	CHP Osijek B	NG	25	42	0.0	0.0	0.0	0.0	0	0	0
17	CHP Osijek C	NG	25	21	0.0	0.0	0.0	0.0	0	0	0
Total			1,782	10,464	20	44	164	228	5,486	10,293	15,779

Table A3-4: Scenario 2 - IED compliance costs for Croatia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /mMillion €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	TPP Plomin 1	HC	125	915	0.0	0.0	0.0	0.0	0	0	0
2	TPP Plomin 2	HC	210	1,631	0.0	20.0	0.0	20.0	1,958	0	1,958
3	TPP Rijeka	FO	320	1,725	6.8	30.0	51.7	88.5	2,171	3,820	5,990
4	TPP Sisak A	FO	210	1,214	5.3	20.0	50.6	75.9	1,216	2,598	3,814
5	TPP Sisak B	FO	210	1,214	5.3	20.0	50.6	75.9	1,216	2,598	3,814
6	TPP Jertovac 1	NG	40	47	0.0	1.0	0.0	1.0	28	0	28

Code	Plant name	Fuel type	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /mMillion €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
7	TPP Jertovac 2	NG	40	47	0.0	1.0	0.0	1.0	28	0	28
8	CHP Zagreb C	NG	120	469	3.0	12.5	21.0	36.5	557	1,003	1,560
9	CHP Zagreb K	NG	208	1,591	0.0	0.0	0.0	0.0	0	0	0
10	CHP Zagreb L	NG	112	866	0.0	0.0	0.0	0.0	0	0	0
11	CHP Zagreb EL-TO K6	NG	11	21	1.1	1.0	5.0	7.1	6	45	52
12	CHP Zagreb EL-TO K8	NG	30	82	1.2	1.0	6.0	8.2	24	174	198
13	CHP Zagreb EL-TO H	NG	25	161	0.0	0.7	0.0	0.7	97	0	97
14	CHP Zagreb EL-TO J	NG	25	161	0.0	0.7	0.0	0.7	97	0	97
15	CHP Osijek A	NG	46	256	0.0	1.3	0.0	1.3	154	0	154
16	CHP Osijek B	NG	25	42	0.0	0.7	0.0	0.7	25	0	25
17	CHP Osijek C	NG	25	21	0.0	0.7	0.0	0.7	13	0	13
Total			1,782	10,464	23	111	185	318	7,590	10,238	17,828

Table A3-5: Scenario 1 - LCPD compliance costs for FYR Macedonia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	LCPD Scenario						
					Investment costs /million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Bitola 1	L	233	1,387	11.6	10.0	42.3	63.9	416	3,274	3,690
2	Bitola 2	L	233	1,387	11.6	10.0	42.3	63.9	416	3,024	3,440
3	Bitola 3	L	233	1,387	11.6	10.0	42.3	63.9	416	3,024	3,440
4	Oslomej	L	125	604	7.0	6.0	25.0	38.0	181	1,342	1,523
5	Negotino	FO	210	17	0.0	0.0	0.0	0.0	0	0	0
Total			1,034	4,783	42	36	152	230	1,430	10,664	12,094

Table A3-6: Scenario 2 IED - compliance costs for FYR Macedonia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Bitola 1	L	233	1,387	13.0	18.6	46.5	78.1	2,089	3,274	5,363
2	Bitola 2	L	233	1,387	13.0	18.6	46.5	78.1	2,098	3,024	5,122
3	Bitola 3	L	233	1,387	13.0	18.6	46.5	78.1	2,098	3,024	5,122
4	Oslomej	L	125	604	8.0	1.8	27.5	37.3	363	1,342	1,705
5	Negotino	FO	210	17	0.0	0.0	0.0	0.0	0	0	0
Total			1,034	4,783	47	58	167	272	6,648	10,664	17,312

Table A3-7: Scenario 2 - IED compliance costs for Moldova

Code	Plant name	Fuel type	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /million € /				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	CET-1, No 1	NG	12	59	0.0	0.0	0.0	0.0	0	0	0
2	CET-1, No 2	NG	12	59	0.0	0.1	0.0	0.1	18	0	18
3	CET-1, No 3	NG	10	49	0.0	0.1	0.0	0.1	15	0	15
4	CET-1, No 4	NG	27	132	0.0	0.0	0.0	0.0	0	0	0
5	CET-1, No 5	NG	5	24	0.0	0.0	0.0	0.0	0	0	0
6	CET-2, No 1	NG	80	398	0.0	0.6	0.0	0.6	119	0	119
7	CET-2, No 2	NG	80	371	0.0	0.6	0.0	0.6	111	0	111
8	CET-2, No 3	NG	80	371	0.0	0.6	0.0	0.6	111	0	111
Total			306	1,463	0	2	0	2	374	0	374

Table A3-8: Scenario 1 LCPD - compliance costs for Montenegro

Code	Plant name	Fuel type	Power MW	Energy GWh/a	LCPD Scenario						
					Investment costs /million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Pljevlja	Lignite	219	1,489	0.0	4.9	42.0	46.9	447	3,872	4,319
Total			219	1,489	0	5	42	47	447	3,872	4,319

Table A3-9: Scenario 2 - IED compliance Cocsts for Montenegro

Code	Plant name	Fuel type	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Pljevlja	Lignite	219	1,489	0	5	46	50.9	447	3,872	4,319
Total			219	1,489	0	5	46	51	447	3,872	4,319

Table A3-10: Scenario 1 - LCPD compliance costs for Serbia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	LCPD Scenario						
					Investment costs /Million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Nikola Tesla A1	L	210	1,231	1.7	4.0	16.0	22	739	2,216	2,955
2	Nikola Tesla A2	L	210	1,198	3.0	4.0	16.0	23	719	2,156	2,874
3	Nikola Tesla A3	L	305	1,923	10.5	5.7	39.0	55	1,154	3,460	4,614
4	Nikola Tesla A4	L	309	1,989	0.0	6.6	39.0	46	1,194	3,593	4,786
5	Nikola Tesla A5	L	309	1,999	0.0	6.6	39.0	46	1,199	3,611	4,810
6	Nikola Tesla A6	L	309	1,987	0.0	6.6	39.0	46	1,192	3,589	4,781
7	Nikola Tesla B1	L	620	4,151	9.4	13.6	64.0	87	2,491	7,539	10,030
8	Nikola Tesla B2	L	620	4,004	0.0	13.6	64.0	78	2,402	7,271	9,674
9	Kolubara 1	L	32	175	1.7	0.0	0.0	2	0	0	0
10	Kolubara 2	L	32	116	1.7	0.0	0.0	2	0	0	0
11	Kolubara 3	L	64	135	3.2	0.0	5.0	8	0	317	317
12	Kolubara 4	L	32	0	0.0	0.0	0.0	0	0	0	0
13	Kolubara 5	L	110	626	0.0	0.0	8.6	9	0	1,468	1,468
14	Morava	L	125	566	7.2	0.0	9.8	17	0	1,541	1,541
15	Kostolac A1	L	100	560	2.5	0.0	45.0	48	0	1,479	1,479
16	Kostolac A2	L	210	1,196	5.4	4.2	0.0	10	718	3,154	3,872
17	Kostolac B1	L	348	1,937	10.0	9.8	51.0	71	2,493	5,164	7,657
18	Kostolac B2	L	348	1,895	5.7	9.1	51.0	66	2,307	4,835	7,142
19	Novi Sad 1	NG	135	189	0.0	4.0	0.0	4	131	0	131
20	Novi Sad 2	NG	110	175	0.0	3.3	0.0	3	121	0	121
21	Zrenjanin	NG	110	66	0.0	3.3	0.0	3	45	0	45
22	Sr. Mitrovica 1	NG	32	123	0.0	1.0	0.0	1	74	0	74
Total			4,679	26,240	62	95	486	644	16,978	51,393	68,371

Table A3-11: Scenario 2 - IED compliance costs for Serbia

Code	Plant name	Fuel type	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Nikola Tesla A1	L	210	1,231	2.9	4.0	18.0	25	739	2,216	2,955
2	Nikola Tesla A2	L	210	1,198	3.7	4.0	17.0	25	719	2,156	2,874
3	Nikola Tesla A3	L	305	1,923	10.5	5.7	43.0	59	1,154	3,460	4,614
4	Nikola Tesla A4	L	309	1,989	0.0	6.6	43.0	50	1,194	3,593	4,786
5	Nikola Tesla A5	L	309	1,999	0.0	6.6	43.0	50	1,199	3,611	4,810
6	Nikola Tesla A6	L	309	1,987	0.0	6.6	43.0	50	1,192	3,589	4,781
7	Nikola Tesla B1	L	620	4,151	9.4	13.6	71.0	94	2,491	7,539	10,030
8	Nikola Tesla B2	L	620	4,004	0.0	13.6	71.0	85	2,402	7,271	9,674
9	Kolubara 1	L	32	175	0.0	0.0	0.0	0	0	0	0
10	Kolubara 2	L	32	116	0.0	0.0	0.0	0	0	0	0
11	Kolubara 3	L	64	135	3.6	0.8	7.0	11	40.4	254	294
12	Kolubara 4	L	32	0	0.0	0.0	0.0	0	0.0	0	0
13	Kolubara 5	L	110	626	0.4	2.2	9.5	12	375.8	1,175	1,550
14	Morava	L	125	566	8.0	3.4	11.0	22	0.0	1,233	1,233
15	Kostolac A1	L	100	560	2.8	2.0	50.0	55	335.9	1,479	1,815
16	Kostolac A2	L	210	1,196	5.9	4.2	0.0	10	717.8	3,154	3,872
17	Kostolac B1	L	348	1,937	11.0	9.8	55.0	76	0.0	5,164	5,164
18	Kostolac B2	L	348	1,895	6.5	9.1	55.0	71	2,306.6	4,835	7,142
19	Novi Sad 1	NG	135	189	0.0	5.9	0.0	6	554.1	0	554
20	Novi Sad 2	NG	110	175	0.0	4.8	0.0	5	513.0	0	513
21	Zrenjanin	NG	110	66	0.0	4.8	0.0	5	96.2	0	96
22	Sr. Mitrovica 1	NG	32	123	0.0	1.8	0.0	2	73.6	0	74
Total			4,679	26,240	65	110	537	711	16,103	50,728	66,830

Table A3-12: Scenario 1 - LCPD compliance costs for Ukraine

Code	Plant name	Fuel type	Power MW	Energy GWh/a	LCPD Scenario						
					Investment costs /Million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Prydniprovska 7	HC	150	439	5	13	17	35	439	1,113	1,552
2	Prydniprovska 8	HC	150	682	5	13	17	35	682	1,774	2,456
3	Prydniprovska 9	HC	150	0	2	13	17	32	0	0	0
4	Prydniprovska 10	HC	150	590	5	12	17	34	590	1,482	2,072
5	Prydniprovska 11	HC	310	1,186	9	24	36	69	1,186	3,068	4,253
6	Prydniprovska 12	HC	285	0	9	24	33	65	0	0	0
7	Prydniprovska 13	HC	285	774	12	24	33	68	774	1,967	2,741
8	Prydniprovska 14	HC	285	0	12	24	33	68	0	0	0
9	Kryvorizka 1	HC	282	1,106	6	24	32	62	1,106	2,942	4,047
10	Kryvorizka 2	HC	282	1,382	8	24	32	65	1,382	3,691	5,073
11	Kryvorizka 3	HC	282	0	0	24	34	58	0	0	0
12	Kryvorizka 4	HC	282	1,221	2	24	32	59	1,221	3,242	4,463
13	Kryvorizka 5	HC	282	1,221	6	25	32	63	1,221	3,294	4,515
14	Kryvorizka 6	HC	282	714	8	25	32	65	714	1,935	2,650
15	Kryvorizka 7	HC	282	0	7	25	32	64	0	0	0
16	Kryvorizka 8	HC	282	1,014	7	25	32	64	1,014	2,750	3,763
17	Kryvorizka 9	HC	282	0	6	25	32	63	0	0	0
18	Kryvorizka 10	HC	282	1,198	7	25	32	64	1,198	3,250	4,448
19	Zaporiska 1	HC	325	1,048	0	29	37	66	1,048	2,839	3,887
20	Zaporiska 2	HC	300	1,277	9	26	35	70	1,277	3,492	4,768
21	Zaporiska 3	HC	300	1,301	6	26	35	66	1,301	3,606	4,907
22	Zaporiska 4	HC	300	1,205	9	27	35	70	1,205	3,294	4,499
23	Zaporiska 5	NG	800	0	0	24	0	24	0	0	0
24	Zaporiska 6	NG	800	0	0	25	0	25	0	0	0
25	Zaporiska 7	NG	800	0	0	26	0	26	0	0	0
26	Starobeshivska 4	HC	175	715	5	2.0	20	25	429	1,252	1,681
27	Starobeshivska 5	HC	175	715	16	4	20	40	930	1,252	2,181
28	Starobeshivska 6	HC	175	715	14	4	20	38	930	1,252	2,181
29	Starobeshivska 7	HC	175	715	14	4	20	37	930	1,252	2,181
30	Starobeshivska 8	HC	175	715	14	4	20	37	930	1,252	2,181
31	Starobeshivska 9	HC	175	715	15	4	20	38	930	1,252	2,181
32	Starobeshivska 10	HC	175	715	16	4	20	39	930	1,252	2,181
33	Starobeshivska 11	HC	175	715	16	4	20	39	930	1,252	2,181
34	Starobeshivska 12	HC	175	715	10	4	20	34	930	1,252	2,181
35	Starobeshivska 13	HC	175	715	8	4	20	32	930	1,252	2,181
36	Slovianska 7	HC	800	3,269	22	52	95	169	4,250	5,721	9,971
37	Burshtynska 1	HC	195	915	5	6	25	36	1,209	2,590	3,800
38	Burshtynska 2	HC	185	397	5	5	24	34	523	1,121	1,644
39	Burshtynska 3	HC	185	662	5	5	24	34	851	1,874	2,725
40	Burshtynska 4	HC	195	884	5	5	25	36	1,153	2,519	3,672
41	Burshtynska 5	HC	195	465	8	5	26	39	598	1,351	1,949
42	Burshtynska 6	HC	185	986	5	5	24	34	1,242	2,811	4,053
43	Burshtynska 7	HC	185	508	5	5	24	34	671	1,484	2,156
44	Burshtynska 8	HC	195	806	8	5	26	39	1,052	2,393	3,444
45	Burshtynska 9	HC	195	961	5	6	25	36	1,282	2,712	3,993
46	Burshtynska 10	HC	195	930	5	6	25	36	1,251	2,637	3,887
47	Burshtynska 11	HC	195	992	5	5	25	35	1,191	2,798	3,989
48	Burshtynska 12	HC	195	667	2	5	25	32	811	1,884	2,695
49	Dobrotvirska 5	HC	100	402	3	1	11	15	241	1,178	1,419
50	Dobrotvirska 6	HC	100	402	3	1	11	15	241	1,178	1,419
51	Dobrotvirska 7	HC	150	786	6	13	17	35	471	2,377	2,848
52	Dobrotvirska 8	HC	150	568	8	13	17	37	341	1,719	2,060
53	Ladyzhinska 1	HC	300	874	8	24	33	65	874	2,228	3,101
54	Ladyzhinska 2	HC	300	1,092	7	24	33	64	1,092	2,812	3,904
55	Ladyzhinska 3	HC	300	1,262	7	24	33	64	1,262	3,290	4,552
56	Ladyzhinska 4	HC	300	752	7	24	33	64	752	1,931	2,684
57	Ladyzhinska 5	HC	300	582	7	24	33	64	582	1,516	2,098
58	Ladyzhinska 6	HC	300	558	7	24	33	64	558	1,446	2005
59	Trypilska 1	HC	300	1,250	11	22	31	64	1250	3,009	4260
60	Trypilska 2	HC	300	1,250	9	23	31	63	1250	3,026	4277
61	Trypilska 3	HC	300	1,250	11	22	31	64	1250	3,004	4255

Code	Plant name	Fuel type	Power MW	Energy GWh/a	LCPD Scenario						
					Investment costs /Million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
62	Trypilska 4	HC	300	1,250	11	22	31	64	1,250	3,014	4,264
63	Trypilska 5	NG	300	0	0	22	0	22	0	0	0
64	Trypilska 6	NG	300	0	0	22	0	22	0	0	0
65	Zmiivska 1	HC	175	548	9	25	19	53	548	1,353	1,900
66	Zmiivska 2	HC	175	548	0	25	19	44	548	1,341	1,889
67	Zmiivska 3	HC	175	548	12	25	19	55	548	1,348	1,895
68	Zmiivska 4	HC	175	548	0	25	19	44	548	1,343	1,891
69	Zmiivska 5	HC	175	548	12	25	19	55	548	1,363	1,911
70	Zmiivska 6	HC	175	548	0	25	19	44	548	1,316	1,863
71	Zmiivska 7	HC	275	793	9	27	32	67	793	2,126	2,918
72	Zmiivska 8	HC	325	937	9	28	38	75	937	2,882	3,819
73	Zmiivska 9	HC	275	793	9	25	32	65	793	2,113	2,905
74	Zmiivska 10	HC	275	793	9	25	33	67	793	2,061	2,853
75	Vuglegirska 1	HC	300	1,359	9	24	35	69	1,359	3,967	5,326
76	Vuglegirska 2	HC	300	1,359	9	24	35	69	1,359	3,967	5,326
77	Vuglegirska 3	HC	300	1,359	9	24	35	69	1,359	3,967	5,326
78	Vuglegirska 4	HC	300	1,359	9	24	35	69	1,359	3,967	5,326
79	Vuglegirska 5	NG	800	0	0	65	0	65	0	0	0
80	Vuglegirska 6	NG	800	0	0	65	0	65	0	0	0
81	Vuglegirska 7	NG	800	0	0	65	0	65	0	0	0
82	Zuevvskaya 1	HC	325	1,606	10	28	38	75	1,606	4,854	6,460
83	Zuevvskaya 2	HC	320	1,660	10	28	38	75	1,660	5,010	6,670
84	Zuevvskaya 3	HC	300	1,606	10	25	37	72	1,606	4,729	6,335
85	Zuevvskaya 4	HC	325	1,740	0	26	38	64	1,740	5,136	6,875
86	Kurakhovskaya 3	HC	200	1,005	10	6	23	40	1,407	2,951	4,358
87	Kurakhovskaya 4	HC	210	1,003	8	7	25	39	1,410	2,974	4,384
88	Kurakhovskaya 5	HC	222	969	10	7	26	43	1,341	2,916	4,257
89	Kurakhovskaya 6	HC	210	640	6	6	25	36	859	1,897	2,756
90	Kurakhovskaya 7	HC	225	982	10	7	26	43	1,361	2,855	4,216
91	Kurakhovskaya 8	HC	210	674	0	6	25	31	921	2,006	2,928
92	Kurakhovskaya 9	HC	221	1,019	10	6	26	42	1,355	3,022	4,377
93	Luganskaya 9	HC	200	1,070	8	17	23	49	1,070	2,850	3,921
94	Luganskaya 10	HC	200	642	0	17	23	40	642	1,687	2,329
95	Luganskaya 11	HC	200	988	11	17	23	52	988	2,617	3,605
96	Luganskaya 12	HC	175	0	5	4	20	29	0	0	0
97	Luganskaya 13	HC	175	951	7	16	20	43	571	2,591	3,162
98	Luganskaya 14	HC	200	1,070	8	17	23	49	1,070	2,905	3,976
99	Luganskaya 15	HC	200	988	10	17	23	51	988	2,707	3,696
100	Bilotserkivska CHP	NG	120	494	0	0	0	0	0	0	0
101	Darnytska CHP 5,10	NG	50	212	0	0	0	0	0	0	0
102	Darnytska CHP 6-9	HC	110	453	2	2	0	5	272	1,059	1,330
103	Kaluska CHP 1, 2	HC	100	412	3	0	8	11	0	988	988
104	Kaluska CHP 3, 4	NG	100	425	0	0	0	0	127	0	127
105	Kyivska CHP-5	NG	540	1,147	0	9	0	9	688	0	688
105a	Kyivska CHP-5	FO	540	1,147	0	9	0	9	688	0	688
106	Kyivska CHP-6	NG	500	1,062	0	8	0	8	637	0	637
106a	Kyivska CHP-6	FO	500	1,062	0	10	9	19	637	0	637
107	Kramatorska CHP	HC	120	494	5*	0	11	11	0	1,288	1,288
108	Myronivska 4	HC	60	247	2	0	4	6	0	642	642
109	Myronivska 9	HC	115	616	4	0	9	13	185	1,504	1,689
110	Odeska CHP-2	NG	68	289	0	2	0	2	173	0	173
111	Sevastopolska CHP	NG	55	234	0	0	0	0	0	0	0
112	Simferopilska CHP	NG	278	1,181	0	0	0	0	0	0	0
113	Kharkivska CHP-2	HC	74	314	2	2	9	13	189	995	1,184
Total			29,368	88,669	709	1,871	2,558	5,139	88,879	213,173	302,053

Table A3-13: Scenario 2 - IED compliance costs for Ukraine

Code	Plant name	Fuel type	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /mMillion €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Prydniprovska 7	HC	150	439	5	14	19	38	513	1,113	1,625
2	Prydniprovska 8	HC	150	682	5	14	19	38	823	1,774	2,597
3	Prydniprovska 9	HC	150	0	2	14	19	36	0	0	0
4	Prydniprovska 10	HC	150	590	5	14	19	38	680	1,482	2,162
5	Prydniprovska 11	HC	310	1,186	11	26	39	77	1,449	3,068	4,517
6	Prydniprovska 12	HC	285	0	10	24	36	70	0	0	0
7	Prydniprovska 13	HC	285	774	14	24	36	74	960	1,967	2,927
8	Prydniprovska 14	HC	285	0	14	24	36	74		0	0
9	Kryvorizka 1	HC	282	1,106	7	24	36	67	1,410	2,942	4,352
10	Kryvorizka 2	HC	282	1,382	10	24	36	70	1,791	3,691	5,482
11	Kryvorizka 3	HC	282	0	1	24	36	61	0	0	0
12	Kryvorizka 4	HC	282	1,221	3	24	36	63	1,611	3,242	4,853
13	Kryvorizka 5	HC	282	1,221	7	25	36	68	1,633	3,294	4,927
14	Kryvorizka 6	HC	282	714	10	25	36	70	979	1,935	2,915
15	Kryvorizka 7	HC	282	0	9	25	36	69	0	0	0
16	Kryvorizka 8	HC	282	1,014	9	25	36	69	1,395	2,750	4,145
17	Kryvorizka 9	HC	282	0	7	25	36	67	0	0	0
18	Kryvorizka 10	HC	282	1,198	9	25	36	69	1,649	3,250	4,898
19	Zaporiska 1	HC	325	1,048	1	29	41	70	1,419	2,839	4,259
20	Zaporiska 2	HC	300	1,277	10	26	38	74	1,697	3,492	5,188
21	Zaporiska 3	HC	300	1,301	6	26	38	70	1,725	3,606	5,331
22	Zaporiska 4	HC	300	1,205	10	27	38	75	1,656	3,294	4,950
23	Zaporiska 5	NG	800	0	0	24	0	24	0	0	0
24	Zaporiska 6	NG	800	0	0	25	0	25	0	0	0
25	Zaporiska 7	NG	800	0	0	26	0	26	0	0	0
26	Starobeshivska 4	HC	175	715	5	30	22	57	930	1,252	2,181
27	Starobeshivska 5	HC	175	715	18	28	22	68	930	1,252	2,181
28	Starobeshivska 6	HC	175	715	16	28	22	66	930	1,252	2,181
29	Starobeshivska 7	HC	175	715	15	28	22	65	930	1,252	2,181
30	Starobeshivska 8	HC	175	715	15	28	22	65	930	1,252	2,181
31	Starobeshivska 9	HC	175	715	16	28	22	66	930	1,252	2,181
32	Starobeshivska 10	HC	175	715	17	28	22	67	930	1,252	2,181
33	Starobeshivska 11	HC	175	715	17	28	22	67	930	1,252	2,181
34	Starobeshivska 12	HC	175	715	11	28	22	61	930	1,252	2,181
35	Starobeshivska 13	HC	175	715	9	28	22	59	930	1,252	2,181
36	Slovianska 7	HC	800	3,269	25	52	104	181	4,250	5,721	9,971
37	Burshtynska 1	HC	195	915	6	6	28	39	1209	2,590	3,800
38	Burshtynska 2	HC	185	397	5	5	26	37	523	1,121	1,644
39	Burshtynska 3	HC	185	662	5	5	26	36	851	1,874	2,725
40	Burshtynska 4	HC	195	884	6	5	28	39	1,153	2,519	3,672
41	Burshtynska 5	HC	195	465	8	5	28	41	598	1,351	1,949
42	Burshtynska 6	HC	185	986	5	5	26	36	1,242	2,811	4,053
43	Burshtynska 7	HC	185	508	5	5	26	37	671	1,484	2,156
44	Burshtynska 8	HC	195	806	8	5	29	42	1,052	2,393	3,444
45	Burshtynska 9	HC	195	961	6	6	28	39	1,282	2,712	3,993
46	Burshtynska 10	HC	195	930	6	6	28	39	1,251	2,637	3,887
47	Burshtynska 11	HC	195	992	6	5	28	38	1,191	2,798	3,989
48	Burshtynska 12	HC	195	667	3	5	28	35	811	1,884	2,695
49	Dobrotvirska 5	HC	100	402	4	10	24	38	285	1,178	1,463
50	Dobrotvirska 6	HC	100	402	4	10	0	14	285	1,178	1,463
51	Dobrotvirska 7	HC	150	786	6	13	37	56	571	2,377	2,948
52	Dobrotvirska 8	HC	150	568	8	13	0	21	413	1,719	2,131
53	Ladyzhinska 1	HC	300	874	10	25	36	72	1,068	2,228	3,296
54	Ladyzhinska 2	HC	300	1,092	9	25	36	70	1,333	2,812	4,145
55	Ladyzhinska 3	HC	300	1,262	9	25	36	70	1,545	3,290	4,836
56	Ladyzhinska 4	HC	300	752	9	25	36	70	915	1,931	2,846
57	Ladyzhinska 5	HC	300	582	9	25	36	70	709	1,516	2,225
58	Ladyzhinska 6	HC	300	558	9	25	36	70	682	1,446	2,129
59	Trypilska 1	HC	300	1,250	13	22	34	70	802	3,009	3,811
60	Trypilska 2	HC	300	1,250	11	23	34	68	1,288	3,026	4,314
61	Trypilska 3	HC	300	1,250	13	22	34	70	829	3,004	3,833

Code	Plant name	Fuel type	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /mMillion €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
62	Trypilska 4	HC	300	1,250	13	22	34	70	809	3,014	3,822
63	Trypilska 5	NG	300	0	0	22	0	22	0	0	0
64	Trypilska 6	NG	300	0	0	22	0	22	0	0	0
65	Zmiivska 1	HC	175	548	12	25	21	57	500	1,353	1,853
66	Zmiivska 2	HC	175	548	0	25	21	46	502	1,341	1,843
67	Zmiivska 3	HC	175	548	14	25	21	60	488	1,348	1,836
68	Zmiivska 4	HC	175	548	0	25	21	46	472	1,343	1,816
69	Zmiivska 5	HC	175	548	14	25	21	60	443	1,363	1,806
70	Zmiivska 6	HC	175	548	0	25	21	46	379	1,316	1,695
71	Zmiivska 7	HC	275	793	11	27	35	72	1,108	2,126	3,234
72	Zmiivska 8	HC	325	937	11	28	42	81	1,450	2,882	4,332
73	Zmiivska 9	HC	275	793	11	25	35	70	1,046	2,113	3,159
74	Zmiivska 10	HC	275	793	11	25	36	72	1,042	2,061	3,103
75	Vuglegirska 1	HC	300	1,359	11	24	39	74	1,614	3,967	5,581
76	Vuglegirska 2	HC	300	1,359	11	24	39	74	1,614	3,967	5,581
77	Vuglegirska 3	HC	300	1,359	11	24	39	74	1,614	3,967	5,581
78	Vuglegirska 4	HC	300	1,359	11	24	39	74	1,614	3,967	5,581
79	Vuglegirska 5	NG	800	0	0	65	0	65	0	0	0
80	Vuglegirska 6	NG	800	0	0	65	0	65	0	0	0
81	Vuglegirska 7	NG	800	0	0	65	0	65	0	0	0
82	Zuevvskaya 1	HC	325	1,606	0	28	42	70	2,354	4,854	7,208
83	Zuevvskaya 2	HC	320	1,660	0	28	41	69	2,413	5,010	7,423
84	Zuevvskaya 3	HC	300	1,606	0	25	41	66	2,225	4,729	6,953
85	Zuevvskaya 4	HC	325	1,740	0	26	41	67	2,439	5,136	7,575
86	Kurakhovskaya 3	HC	200	1,005	15	6	26	47	1,407	2951	4,358
87	Kurakhovskaya 4	HC	210	1,003	10	7	27	44	1,410	2,974	4,384
88	Kurakhovskaya 5	HC	222	969	11	7	29	47	1341	2,916	4,257
89	Kurakhovskaya 6	HC	210	640	7	6	27	40	859	1,897	2,756
90	Kurakhovskaya 7	HC	225	982	12	7	29	48	1,361	2,855	4,216
91	Kurakhovskaya 8	HC	210	674	8	2	27	36	921	2,006	2,928
92	Kurakhovskaya 9	HC	221	1,019	13	6	29	47	1,355	3,022	4,377
93	Luganskaya 9	HC	200	1,070	10	17	23	50	1179	2,850	4,029
94	Luganskaya 10	HC	200	642	1	17	23	40	649	1,687	2,336
95	Luganskaya 11	HC	200	988	14	17	23	54	1,139	2,617	3,756
96	Luganskaya 12	HC	175	0	7	16	20	42	0	0	0
97	Luganskaya 13	HC	175	951	9	16	20	45	1,112	2,591	3,703
98	Luganskaya 14	HC	200	1,070	10	17	23	50	1,307	2,905	4,212
99	Luganskaya 15	HC	200	988	13	17	23	53	1,158	2,707	3,866
100	Bilotserkivska CHP	NG	120	494	0	4	0	4	296	0	296
101	Darnytska CHP 5,10	NG	50	212	0	5	0	5	212	0	212
102	Darnytska CHP 6-9	HC	110	453	3	11	13	27	453	1,059	1,512
103	Kaluska CHP 1, 2	HC	100	412	4	0	11	15	0	988	988
104	Kaluska CHP 3, 4	NG	100	425	0	10	0	10	425	0	425
105	Kyivska CHP-5	NG	540	1,147	0	35	0	35	1,147	0	1,147
105a	Kyivska CHP-5	FO	540	1,147	0	35	59	94	1,147	2,007	3,155
106	Kyivska CHP-6	NG	500	1,062	0	33	0	33	1,062	0	1,062
106a	Kyivska CHP-6	FO	500	1,062	0	32	55	87	1,062	2,656	3,718
107	Kramatorska CHP	HC	120	494	6	0	17	23	0	1,288	1,288
108	Myronivska 4	HC	60	247	2	2	7	11	330	642	972
109	Myronivska 9	HC	115	616	4	3	13	21	873	1,504	2,377
110	Odeska CHP-2	NG	68	289	0	8	0	8	289	0	289
111	Sevastopolska CHP	NG	55	234	0	1	0	1	140	0	140
112	Simferopilska CHP	NG	278	1,181	0	1	0	1	354	0	354
113	Kharkivska CHP-2	HC	74	314	3	2	10	15	444	995	1,439
Total			29,368	88,669	812	2,301	2,921	6,033	105,054	217,837	32,2890

NB: Units No 105-106 and 107-108 are presented with alternative fuels

Table A3-14: Scenario 1 - LCPD compliance costs for Kosovo*

Code	Plant name	Fuel type	Power MW	Energy GWh/a	LCPD Scenario						
					Investment costs /million €/				O&M costs /000 €/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Kosovo A3	L	200	590				0			0
2	Kosovo A4	L	200	590				0			0
3	Kosovo A5	L	210	606				0			0
4	Kosovo B1	L	339	1,083	10.0	13.0	16.0	39	1,617	2,063	3,680
5	Kosovo B2	L	339	1,083	10.0	13.0	16.0	39	1,627	2,060	3,688
Total			1,288	3,951	20	26	32	78	3,244	4,124	7,368

Table A3-15: Scenario 2 - IED compliance costs for Kosovo*

Code	Plant name	Fuel type	Power MW	Energy GWh/a	IED Scenario						
					Investment costs /million €/				O&M costs /000€/year/		
					Dust	NO_x	SO_2	Total	NO_x	SO_2	Total
1	Kosovo A3	L	200	590				0			0
2	Kosovo A4	L	200	590				0			0
3	Kosovo A5	L	210	606				0			0
4	Kosovo B1	L	339	1,083	11.5	13.0	17.6	42	1,617	2,063	3,680
5	Kosovo B2	L	339	1,083	11.5	13.0	17.6	42	1,627	2,060	3,688
Total			1,288	3,951	23	26	35	84	3,244	4124	7,368

Annex 4 Ranking of LCPs in accordance to the impact to the environment

A4.1. Ranking of estimated external costs of pollutants emission in 2014

Table A4-1.1: Albania – LCPs ranking related to the estimated external costs in 2014

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kWh
1	1	Vlora	NG	100	722	2	98	70	0.0	0.50	0.46	0.96	0.1

Table A4-1.2: Bosnia and Herzegovina - LCPs ranking related to the estimated external costs in 2014

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kWh
1	2	Ugljevik	L	300	2,176	2	4,937	159,958	1.0	37.9	1,110	1,149	52.8
2	7	Kakanj 5	L	110	598	30	2,785	21,055	0.0	21.4	146.1	168	28.0
3	9	Kakanj 7	L	230	1,342	1,036	4,756	46,917	0.5	36.5	325.6	363	27.0
4	8	Kakanj 6	L	110	312	27	1,016	10,523	0.0	7.8	73.0	81	25.9
5	6	Tuzla 6	L	215	1,008	129	1,508	17,003	0.1	11.6	118.0	130	12.9
6	4	Tuzla 4	L	200	1,196	460	2,030	12,807	0.2	15.6	88.9	105	8.8
7	3	Tuzla 3	L	110	473	71	881	4,499	0.0	6.8	31.2	38	8.0
8	5	Tuzla 5	L	200	1,004	281	903	9,505	0.1	6.9	66.0	73	7.3
9	1	Gacko	L	300	1,934	2,299	5,517	13,793	1.1	42.4	95.7	139	7.2

Table A4-1.3: Croatia - LCPs ranking related to the estimated external costs in 2014

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kWh
1	11	CHP Zagreb ELTOK6	NG	11	21	8	71	353	0.0	0.8	3.0	4	17.6
2	4	TPP Sisak A	FO	210	1,214	454	3,042	14,994	0.4	32.1	128.8	161	13.3
3	5	TPP Sisak B	FO	210	1,214	454	3,042	14,994	0.4	32.1	128.8	161	13.3
4	3	TPP Rijeka	FO	320	1,725	594	4,803	19,335	0.5	50.7	166.2	217	12.6
5	12	CHP Zagreb ELTOK8	NG	30	82	66	148	910	0.1	1.6	7.8	9	11.6
6	8	CHP Zagreb C	NG	120	469	129	1,056	4,218	0.1	11.2	36.2	48	10.1
7	1	TPP Plomin 1	HC	125	915	122	1,861	5,357	0.1	19.7	46.0	66	7.2
8	2	TPP Plomin 2	HC	210	1,631	116	1,888	873	0.1	19.9	7.5	28	1.7
9	13	CHP Zagreb ELTOH	NG	25	161	0	174	4	0.0	1.8	0.0	2	1.2
10	14	CHP Zagreb ELTOJ	NG	25	161	0	151	8	0.0	1.6	0.1	2	1.0
11	16	CHP Osijek B	NG	25	42	0	38	3	0.0	0.4	0.0	0	1.0
12	17	CHP Osijek C	NG	25	21	0	19	1	0.0	0.2	0.0	0	1.0
13	15	CHP Osijek A	NG	46	256	4	217	15	0.0	2.3	0.1	2	0.9
14	7	TPP Jertovac 2	NG	40	47	0	33	1	0.0	0.3	0.0	0	0.8
15	6	TPP Jertovac 1	NG	40	47	0	32	1	0.0	0.3	0.0	0	0.7
16	9	CHP Zagreb K	NG	208	1,591	20	123	20	0.0	1.3	0.2	1	0.1
17	10	CHP Zagreb L	NG	112	866	11	47	4	0.0	0.5	0.0	1	0.1

Table A4-1.4: FYR of Macedonia – LCPs ranking related to the estimated external costs in 2014

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kWh
1	1	Bitola 1	L	233	1,387	2,571	5,629	33,359	1.2	26.9	189.2	217	15.7
2	2	Bitola 2	L	233	1,387	4,448	5,699	27,104	2.0	27.3	153.7	183	13.2
3	3	Bitola 3	L	233	1,387	4,448	5,699	27,104	2.0	27.3	153.7	183	13.2
4	4	Oslomej	L	125	604	1,722	1,087	12,383	0.8	5.2	70.2	76	12.6
5	7	Kogel CHP	NG	30	185	4	72	0	0.0	0.3	0.0	0	0.2
6	6	Skopje CHP	NG	227	1394	28	456	2	0.0	2.2	0.0	2	0.2
7	5	Negotino	FO	210	17	0	0	0	0.0	0.0	0.0	0	0.0

Table A4-1.5: Moldova – LCPs ranking related to the estimated external costs in 2014

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kWh
1	7	CET-2, No2	NG	80	371	0	185	0	0.0	1.5	0.0	1.5	0.4
2	8	CET-2, No3	NG	80	371	0	170	0	0.0	1.4	0.0	1.4	0.4
3	6	CET-2, No1	NG	80	398	0	175	0	0.0	1.4	0.0	1.4	0.4
4	3	CET-1, No3	NG	10	49	0	21	0	0.0	0.2	0.0	0.2	0.4
5	2	CET-1, No2	NG	12	59	0	25	0	0.0	0.2	0.0	0.2	0.3
6	4	CET-1, No4	NG	27	132	0	49	0	0.0	0.4	0.0	0.4	0.3
7	1	CET-1, No1	NG	12	59	0	21	0	0.0	0.2	0.0	0.2	0.3
8	5	CET-1, No5	NG	5	24	0	7	0	0.0	0.1	0.0	0.1	0.2

Table A4-1.6: Montenegro – LCPs ranking related to the estimated external costs in 2014

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kW
1	1	Pljevlja	L	219	1,489	221	3,322	44,295	0.2	28.8	369.4	398.3	26.7

Table A4-1.7: Serbia - LCPsranking related to the estimated external costs in 2014

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit Cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kW
1	15	Kostolac A1	L	100	560	1,282	1,218	19,052	1.0	10.5	158.9	170	30.5
2	16	Kostolac A2	L	210	1,196	672	2,285	37,078	0.5	19.8	309.2	330	27.5
3	17	Kostolac B1	L	348	1,937	5,489	5,132	57,898	4.5	44.4	482.8	532	27.5
4	18	Kostolac B2	L	348	1,895	2,361	4,553	51,300	1.9	39.4	427.8	469	24.8
5	14	Morava	L	125	566	3,283	1,513	11,018	2.7	13.1	91.9	108	19.0
6	10	Kolubara 2	L	32	116	1,013	325	1,974	0.8	2.8	16.5	20	17.4
7	11	Kolubara 3	L	64	135	1,180	379	2,300	1.0	3.3	19.2	23	17.4
8	9	Kolubara 1	L	32	175	1,534	492	2,990	1.3	4.3	24.9	30	17.4
9	13	Kolubara 5	L	110	626	192	1,356	7,876	0.2	11.7	65.7	78	12.4
10	1	Nikola TeslaA1	L	210	1,231	852	2,336	11,901	0.7	20.2	99.2	120	9.8
11	2	Nikola TeslaA2	L	210	1,198	829	2,273	11,578	0.7	19.7	96.5	117	9.8
12	4	Nikola TeslaA4	L	309	1,989	353	3,973	18,855	0.3	34.4	157.2	192	9.6
13	8	Nikola TeslaB2	L	620	4,004	743	8,157	37,723	0.6	70.6	314.6	386	9.6
14	5	Nikola TeslaA5	L	309	1,999	351	3,957	18,776	0.3	34.3	156.6	191	9.6
15	6	Nikola TeslaA6	L	309	1,987	349	3,932	18,661	0.3	34.1	155.6	190	9.6
16	7	Nikola TeslaB1	L	620	4,151	763	8,378	38,742	0.6	72.6	323.1	396	9.5
17	3	Nikola TeslaA3	L	305	1,923	1,295	3,551	18,092	1.1	30.8	150.9	183	9.5
18	21	Zrenjanin	NG	110	66	2	248	41	0.0	2.1	0.3	2	3.8
19	20	Novi Sad2	NG	110	175	4	601	99	0.0	5.2	0.8	6	3.4
20	19	Novi Sad1	NG	135	189	4	649	107	0.0	5.6	0.9	7	3.4
21	22	Sr, Mitrovica1	NG	32	123	0	230	0	0.0	2.0	0.0	2	1.6
22	12	Kolubara 4	L	32	0	0	0	0	0.0	0.0	0.0	0	

Table A4-1.8: Ukraine – LCPs ranking related to the estimated external costs in 2014

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kWh
1	113	KharkivskaCHP2	HC	74	314	3,108	837	6,967	4	4	50	58	18.6
2	72	Zmiivska8	HC	325	937	925	7,093	16,995	1	38	122	161	17.2
3	89	Kurakhovskaya6	HC	210	640	9,898	1,520	12,148	13	8	87	108	16.9
4	82	Zuevvskaya1	HC	325	1,606	1,067	10,517	28,607	1	56	205	262	16.3
5	88	Kurakhovskaya5	HC	222	969	9,818	2,369	18,395	13	13	132	157	16.2
6	83	Zuevvskaya2	HC	320	1,660	1,161	10,567	29,282	2	57	209	268	16.1
7	87	Kurakhovskaya4	HC	210	1,003	10,962	2,571	18,563	14	14	133	161	16.0
8	91	Kurakhovskaya8	HC	210	674	6,228	1,611	12,507	8	9	89	106	15.7
9	86	Kurakhovskaya3	HC	200	1,005	10,815	2,531	18,025	14	14	129	157	15.6
10	52	Dobrotvirska8	HC	150	568	2,705	1,633	10,610	4	9	76	88	15.5
11	85	Zuevvskaya4	HC	325	1,740	284	10,326	29,707	0	55	213	268	15.4
12	92	Kurakhovskaya9	HC	221	1,019	7,711	2,302	18,738	10	12	134	156	15.3
13	49	Dobrotvirska5	HC	100	402	1,110	1,231	7,495	1	7	54	62	15.3
14	50	Dobrotvirska6	HC	100	402	1,110	1,231	7,495	1	7	54	62	15.3
15	51	Dobrotvirska7	HC	150	786	3,683	2,224	14,448	5	12	103	120	15.3

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kWh
16	84	Zuevvskaya3	HC	300	1,606	1,967	9,117	26,786	3	49	192	243	15.1
17	71	Zmiivska7	HC	275	793	7,504	5,140	11,535	10	28	83	120	15.1
18	90	Kurakhovskaya7	HC	225	982	6,937	2,402	17,084	9	13	122	144	14.7
19	99	Luganskaya15	HC	200	988	8,975	4,627	15,168	12	25	109	145	14.7
20	98	Luganskaya14	HC	200	1,070	10,424	5,265	15,825	14	28	113	155	14.5
21	77	Vuglegirska3	HC	300	1,359	1,889	5,947	22,603	2	32	162	196	14.4
22	78	Vuglegirska4	HC	300	1,359	1,887	5,941	22,580	2	32	162	196	14.4
23	75	Vuglegirska	HC	300	1,359	1,882	5,925	22,520	2	32	161	195	14.4
24	76	Vuglegirska2	HC	300	1,359	1,878	5,913	22,476	2	32	161	195	14.3
25	97	Luganskaya13	HC	175	951	8,324	4,331	14,037	11	23	100	134	14.1
26	43	Burshtynska7	HC	185	508	2,362	1,079	8,582	3	6	61	70	13.8
27	44	Burshtynska8	HC	195	806	2,160	1,634	13,846	3	9	99	111	13.7
28	41	Burshtynska5	HC	195	465	2,262	942	7,763	3	5	56	64	13.7
29	93	Luganskaya9	HC	200	1,070	10,262	4,567	14,977	13	24	107	145	13.5
30	21	Zaporiska3	HC	300	1,301	3,817	6,680	18,406	5	36	132	172	13.3
31	73	Zmiivska9	HC	275	793	7,128	4,130	10,292	9	22	74	105	13.3
32	95	Luganskaya11	HC	200	988	8,781	4,402	13,410	11	24	96	131	13.3
33	40	Burshtynska 4	HC	195	884	4,462	1,833	14,031	6	10	100	116	13.1
34	22	Zaporiska4	HC	300	1,205	3,509	6,669	16,417	5	36	117	158	13.1
35	39	Burshtynska3	HC	185	662	3,463	1,347	10,385	5	7	74	86	13.0
36	42	Burshtynska 6	HC	185	986	4,495	1,911	15,591	6	10	112	128	12.9
37	20	Zaporiska 2	HC	300	1,277	3,799	6,583	17,402	5	35	125	165	12.9
38	19	Zaporiska 1	HC	325	1,048	3,572	5,616	13,912	5	30	100	134	12.8
39	74	Zmiivska 10	HC	275	793	7,153	4,187	9,754	9	22	70	102	12.8
40	38	Burshtynska 2	HC	185	397	1,830	836	6,128	2	4	44	51	12.8
41	14	Kryvorizka 6	HC	282	714	3,785	3,785	9,141	5	20	65	91	12.7
42	18	Kryvorizka 10	HC	282	1,198	5,937	6,345	15,239	8	34	109	151	12.6
43	16	Kryvorizka 8	HC	282	1,014	4,684	5,364	12,882	6	29	92	127	12.5
44	94	Luganskaya 10	HC	200	642	1,912	2,528	8,775	2	14	63	79	12.3
45	46	Burshtynska 10	HC	195	930	165	2,018	14,347	0	11	103	114	12.2
46	13	Kryvorizka 5	HC	282	1,221	6,234	5,996	15,050	8	32	108	148	12.1
47	48	Burshtynska 12	HC	195	667	590	1,205	10,170	1	6	73	80	12.0
48	45	Burshtynska 9	HC	195	961	170	2,038	14,551	0	11	104	115	12.0
49	65	Zmiivska 1	HC	175	548	7,494	1,966	6,158	10	11	44	64	11.7
50	9	Kryvorizka 1	HC	282	1,106	5,226	5,079	13,397	7	27	96	130	11.7
51	37	Burshtynska 1	HC	195	915	3,929	1,769	12,973	5	9	93	107	11.7
52	2	Prydniprovska 8	HC	150	682	2,727	3,090	8,338	4	17	60	80	11.7
53	47	Burshtynska 11	HC	195	992	173	1,727	14,777	0	9	106	115	11.6
54	10	Kryvorizka 2	HC	282	1,382	5,800	6,336	16,420	8	34	117	159	11.5
55	66	Zmiivska 2	HC	175	548	7,565	1,963	5,950	10	11	43	63	11.5
56	108	Myronivska 4	HC	60	247	232	613	3,453	0	3	25	28	11.5
57	1	Prydniprovska 7	HC	150	439	1,794	1,990	5,189	2	11	37	50	11.4
58	69	Zmiivska 5	HC	175	548	6,768	1,741	6,141	9	9	44	62	11.3
59	67	Zmiivska 3	HC	175	548	7,265	1,881	5,934	9	10	42	62	11.3
60	58	Ladyzhinska 6	HC	300	558	3,377	2,425	6,349	4	13	45	63	11.3
61	57	Ladyzhinska 5	HC	300	582	2,932	2,517	6,710	4	13	48	65	11.2
62	68	Zmiivska 4	HC	175	548	7,074	1,843	5,897	9	10	42	61	11.2
63	7	Prydniprovska 13	HC	285	774	3,819	3,561	8,555	5	19	61	85	11.0
64	107	Kramatorska CHP	HC	120	494	918	945	6,727	1	5	48	54	11.0
65	12	Kryvorizka 4	HC	282	1,221	1,144	5,741	14,139	1	31	101	133	10.9
66	55	Ladyzhinska 3	HC	300	1,262	1,612	5,500	14,624	2	29	105	136	10.8
67	56	Ladyzhinska 4	HC	300	752	3,027	3,243	8,311	4	17	59	81	10.7
68	5	Prydniprovska 11	HC	310	1,186	4,955	5,030	13,094	6	27	94	127	10.7
69	4	Prydniprovska 10	HC	150	590	2,042	2,523	6,532	3	14	47	63	10.7
70	53	Ladyzhinska 1	HC	300	874	3,515	3,799	9,445	5	20	68	93	10.6
71	54	Ladyzhinska 2	HC	300	1,092	1,468	4,737	12,175	2	25	87	114	10.5
72	70	Zmiivska 6	HC	175	548	6,547	1,606	5,484	9	9	39	56	10.3
73	102	Darnytska CHP 6-9	HC	110	453	2,011	2,228	4,258	3	12	30	45	9.9
74	109	Myronivska 9	HC	115	616	460	1,725	6,972	1	9	50	60	9.7
75	103	Kaluska CHP 1, 2	HC	100	412	1,982	291	4,285	3	2	31	35	8.5
76	106	Kyivska CHP-6	NG	500	1,062	682	1,803	10,152	1	10	73	83	7.8
77	106a	Kyivska CHP-6	FO	500	1,062	535	2,007	8,108	1	11	58	69	6.5
78	60	Trypilska 2	HC	300	1,250	6,857	4,615	4,615	9	25	33	67	5.3

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kWh
79	61	Trypilska3	HC	300	1,250	6,486	3,348	3,348	8	18	24	50	4.0
80	62	Trypilska 4	HC	300	1,250	6,311	3,308	3,308	8	18	24	50	4.0
81	59	Trypilska 1	HC	300	1,250	5,004	3,294	3,294	7	18	24	48	3.8
82	110	Odeska CHP-2	NG	68	289	0	941	0	0	5	0	5	1.7
83	104	Kaluska CHP 3, 4	NG	100	425	0	476	0	0	3	0	3	0.6
84	101	Darnytska CHP 5,10	NG	50	212	0	207	0	0	1	0	1	0.5
85	100	Bilotserkivska CHP	NG	120	494	0	470	0	0	3	0	3	0.5
86	111	Sevastopolska CHP	NG	55	234	0	167	0	0	1	0	1	0.4
87	112	Simferopilska CHP	NG	278	1,181	0	458	0	0	2	0	2	0.2
88	26	Starobeshivska 4	HC	175	715	0	0	0	0	0	0	0	
89	27	Starobeshivska 5	HC	175	715	0	0	0	0	0	0	0	
90	28	Starobeshivska 6	HC	175	715	0	0	0	0	0	0	0	
91	29	Starobeshivska 7	HC	175	715	0	0	0	0	0	0	0	
92	30	Starobeshivska 8	HC	175	715	0	0	0	0	0	0	0	
93	31	Starobeshivska 9	HC	175	715	0	0	0	0	0	0	0	
94	32	Starobeshivska 10	HC	175	715	0	0	0	0	0	0	0	
95	33	Starobeshivska 11	HC	175	715	0	0	0	0	0	0	0	
96	34	Starobeshivska 12	HC	175	715	0	0	0	0	0	0	0	
97	35	Starobeshivska 13	HC	175	715	0	0	0	0	0	0	0	
98	36	Slovianska 7	HC	800	3,269	0	0	0	0	0	0	0	
99	105	Kyivska CHP-5	NG	540	1,147	0	0	0	0	0	0	0	
100	105a	Kyivska CHP-5	FO	540	1,147	0	0	0	0	0	0	0	
101	3	Prydniprovska 9	HC	150	0	0	0	0	0	0	0	0	
102	6	Prydniprovska 12	HC	285	0	0	0	0	0	0	0	0	
103	8	Prydniprovska 14	HC	285	0	0	0	0	0	0	0	0	
104	11	Kryvorizka 3	HC	282	0	0	0	0	0	0	0	0	
105	15	Kryvorizka 7	HC	282	0	0	0	0	0	0	0	0	
106	17	Kryvorizka 9	HC	282	0	0	0	0	0	0	0	0	
107	23	Zaporiska 5	NG	800	0	0	0	0	0	0	0	0	
108	24	Zaporiska 6	NG	800	0	0	0	0	0	0	0	0	
109	25	Zaporiska 7	NG	800	0	0	0	0	0	0	0	0	
110	63	Trypilska 5	NG	300	0	0	0	0	0	0	0	0	
111	64	Trypilska 6	NG	300	0	0	0	0	0	0	0	0	
112	79	Vuglegirska 5	NG	800	0	0	0	0	0	0	0	0	
113	80	Vuglegirska 6	NG	800	0	0	0	0	0	0	0	0	
114	81	Vuglegirska 7	NG	800	0	0	0	0	0	0	0	0	
115	96	Luganskaya 12	HC	175	0	0	0	0	0	0	0	0	

Table A4-1.9 Kosovo* - LCPs ranking related to the estimated external costs in 2014

Rank No	Code	Plant name	Fuel type	Power MW	Energy GWh/a	Emission - BAU			External costs - BAU				
						Pollutants emission, t/year			Total costs, million €/year				Unit cost
						Dust	NO_x	SO_2	Dust	NO_x	SO_2	Total	€c/kWh
1	2	Kosovo A4	L	200	590	2,969	2,802	2,374	2.4	24.3	19.8	46	7.9
2	3	Kosovo A5	L	210	606	189	2,850	2,481	0.2	24.7	20.7	46	7.5
3	1	Kosovo A3	L	200	590	200	2,651	2,443	0.2	23.0	20.4	43	7.4
4	4	Kosovo B1	L	339	1,083	2,537	4,777	,	2.2	42.2	30.8	75	6.9
5	5	Kosovo B2	L	339	1,083	2,688	4,873	3,699	2.1	41.4	31.5	75	6.9

NB: "0" Appears in case that no data are available or if the TPP is lying up

A4.2. Cost-Benefit Ranking for LCPD Scenario

Table A4-2.1: Albania - LCPs ranking related to the CBA implementation of LCPD

Rank No	Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	1	Vlora	NG	100				0.00		

Table A4-2.2: Bosnia and Herzegovina - LCPs ranking related to the CBA implementation of LCPD

Rank No	Code	Plant Name	Fuel type	Power MW	Costs		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	2	Ugljevik	L	300	107.9	12.7	243	14,463	14,220	59.5
2	9	Kakanj 7	L	230	58.5	5.0	111	4,415	4,304	39.6
3	7	Kakanj 5	L	110	29.4	2.1	52	1,769	1,717	33.9
4	8	Kakanj 6	L	110	22.4	1.0	33	842	808	25.4
5	6	Tuzla 6	L	215	46.6	2.8	76	1,453	1,377	19.0
6	4	Tuzla 4	L	200	22.0	3.5	59	1,038	979	17.6
7	5	Tuzla 5	L	200	17.0	2.2	41	680	639	16.7
8	1	Gacko	L	300	33.4	6.7	105	1,316	1,211	12.6
9	3	Tuzla 3	L	110						

Table A4-2.3: Croatia - LCPs ranking related to the CBA implementation of LCPD

Rank No	Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	3	TPP Rijeka	FO	320	61.2	5.9	124	2,411	2,287	19
2	4	TPP Sisak A	FO	210	56.7	3.3	92	1,738	1,646	19
3	5	TPP Sisak B	FO	210	56.7	3.3	92	1,738	1,646	19
4	8	CHP Zagreb C	NG	120	24.5	1.3	38	409	371	11
5	12	CHP Zagreb EL-TO K8	NG	30	4.4	0.2	7	62	55	9
6	11	CHP Zagreb EL-TO K6	NG	11	4.5	0.1	5	24	19	5
7	2	TPP Plomin 2	HC	210	20.0	1.6	37	115	78	3
8	1	TPP Plomin 1	HC	125						
9	6	TPP Jertovac 1	NG	40	0.0	0.0	0	0	0	
10	7	TPP Jertovac 2	NG	40	0.0	0.0	0	0	0	
11	9	CHP Zagreb K	NG	208	0.0	0.0	0	0	0	
12	10	CHP Zagreb L	NG	112	0.0	0.0	0	0	0	
13	13	CHP Zagreb EL-TO H	NG	25	0.0	0.0	0	0	0	
14	14	CHP Zagreb EL-TO J	NG	25	0.0	0.0	0	0	0	
15	15	CHP Osijek A	NG	46	0.0	0.0	0	0	0	
16	16	CHP Osijek B	NG	25	0.0	0.0	0	0	0	
17	17	CHP Osijek C	NG	25	0.0	0.0	0	0	0	

Table A4-2.4: FYR Macedonia - LCPs ranking related to the CBA implementation of LCPD

Rank No	Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	
1	1	Bitola 1	L	233	63.9	3.7	103	3,210	3,107	31
2	2	Bitola 2	L	233	63.9	3.4	100	2,627	2,527	26
3	3	Bitola 3	L	233	63.9	3.4	100	2,627	2,527	26
4	4	Oslomej	L	125	38.0	1.5	54	886	832	16
	5	Negotino	FO	210						
	6	Skopje CHP	NG	227						
	7	Kogel CHP	NG	30						

Table A4-2.5: Moldova - LCPs ranking related to the CBA implementation of LCPD

Rank No	Code	Plant name	Fuel tType	Power MW	Costs		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	1	CET-1, No 1	NG	12						
2	2	CET-1, No 2	NG	12						
3	3	CET-1, No 3	NG	10						
4	4	CET-1, No 4	NG	27						
5	5	CET-1, No 5	NG	5						
6	6	CET-2, No 1	NG	80						

7	7	CET-2, No 2	NG	80						
8	8	CET-2, No 3	NG	80						

Table A4-2.6: Montenegro - LCPs ranking related to the CBA implementation of LCPD

Rank No	Code	Plant name	Fuel type	Power MW	COSTS		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	1	Pljevlja	Lignite	219	46,9	4,3	93	4725	4632	51

Table A4-2.7: Serbia - LCPs ranking related to the CBA implementation of LCPD

Rank No	Code	Plant Name	Fuel Type	Power MW	COSTS		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	16	Kostolac A2	L	210	9.6	3.9	51	3,912	3,861	77.0
2	17	Kostolac B1	L	348	70.8	7.7	152	6,355	6,203	41.7
3	18	Kostolac B2	L	348	65.8	7.1	142	5,551	5,409	39.2
4	14	Morava	L	125	17.0	1.5	33	963	930	28.8
5	15	Kostolac A1	L	100	47.5	1.5	63	1,689	1,626	26.7
6	1	Nikola Tesla A1	L	210	21.7	3.0	53	1,179	1,126	22.2
7	13	Kolubara 5	L	110	8.6	1.5	24	530	506	21.9
8	2	Nikola Tesla A2	L	210	23.0	2.9	54	1,147	1,093	21.4
9	8	Nikola Tesla B2	L	620	77.6	9.7	180	3,860	3,679	21.4
10	7	Nikola Tesla B1	L	620	87.0	10.0	194	3,964	3,771	20.5
11	4	Nikola Tesla A4	L	309	45.6	4.8	97	1,902	1,805	19.7
12	5	Nikola Tesla A5	L	309	45.6	4.8	97	1,894	1,797	19.6
13	6	Nikola Tesla A6	L	309	45.6	4.8	96	1,882	1,786	19.5
14	3	Nikola Tesla A3	L	305	55.2	4.6	104	1,792	1,688	17.2
15	20	Novi Sad 2	NG	110	3.3	0.1	5	57	52	12.4
16	19	Novi Sad 1	NG	135	4.0	0.1	5	61	56	11.4
17	21	Zrenjanin	NG	110	3.3	0.0	4	23	20	6.2
18	11	Kolubara 3	L	64	8.2	0.3	12	55	43	4.7
19	22	Sr. Mitrovica 1	NG	32	1.0	0.1	2	8	6	4.3
20	9	Kolubara 1	L	32						
21	10	Kolubara 2	L	32						
22	12	Kolubara 4	L	32						

Table A4-2.8: Ukraine - LCPs ranking related to the CBA implementation of LCPD

Rank No	Code	Plant nfame	Fuel type	PowerMW	Costs		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	106a	Kyivska CHP-6	FO	500	18.8	0.6	25.6	742	716.2	29.0
2	85	Zuevvskaya 4	HC	325	63.5	6.9	136.6	3,353	3,216	24.5
3	83	Zuevvskaya 2	HC	320	75.0	6.7	145.9	3,366	3,220	23.1
4	87	Kurakhovskaya 4	HC	210	39.1	4.4	85.7	1,977	1,891	23.1
5	82	Zuevvskaya 1	HC	325	75.3	6.5	144.0	3,303	3,159	22.9
6	51	Dobrotvirska 7	HC	150	35.4	2.8	65.7	1,484	1,418	22.6
7	113	Kharkivska CHP-2	HC	74	12.6	1.2	25.2	567	542	22.5
8	86	Kurakhovskaya 3	HC	200	40.2	4.4	86.5	1,920	1,834	22.2
9	88	Kurakhovskaya 5	HC	222	42.8	4.3	88.1	1,935	1,847	22.0
10	84	Zuevvskaya 3	HC	300	72.0	6.3	139.4	3,034	2,895	21.8
11	92	Kurakhovskaya 9	HC	221	42.2	4.4	88.7	1,918	1,830	21.6
12	49	Dobrotvirska 5	HC	100	14.8	1.4	29.9	633	603	21.2
13	50	Dobrotvirska 6	HC	100	14.8	1.4	29.9	633	603	21.2
14	91	Kurakhovskaya 8	HC	210	30.9	2.9	62.0	1,305	1,243	21.0
15	98	Luganskaya 14	HC	200	48.6	4.0	90.9	1,890	1,799	20.8
16	89	Kurakhovskaya 6	HC	210	36.2	2.8	65.5	1,325	1,260	20.2
17	42	Burshtynska 6	HC	185	33.6	4.1	76.7	1,546	1,470	20.2
18	90	Kurakhovskaya 7	HC	225	43.1	4.2	87.9	1,761	1,673	20.0
19	99	Luganskaya 15	HC	200	50.9	3.7	90.2	1,769	1,679	19.6
20	97	Luganskaya 13	HC	175	43.3	3.2	76.9	1,500	1,423	19.5
21	93	Luganskaya 9	HC	200	48.5	3.9	90.2	1,752	1,661	19.4
22	77	Vuglegirska 3	HC	300	68.6	5.3	125.2	2,425	2,300	19.4
23	78	Vuglegirska 4	HC	300	68.6	5.3	125.2	2,423	2,297	19.3
24	75	Vuglegirska 1	HC	300	68.6	5.3	125.2	2,416	2,291	19.3
25	76	Vuglegirska 2	HC	300	68.6	5.3	125.2	2,411	2,286	19.3
26	40	Burshtynska 4	HC	195	35.5	3.7	74.6	1,407	1,332	18.9

Rank No	Code	Plant nfame	Fuel type	PowerMW	Costs		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
27	102	Darnytska CHP 6-9	HC	110	4.5	1.3	18.6	346	327	18.6
28	52	Dobrotvirska 8	HC	150	37.3	2.1	59.2	1,090	1,031	18.4
29	44	Burshtynska 8	HC	195	39.0	3.4	75.6	1,355	1,279	17.9
30	21	Zaporiska 3	HC	300	66.2	4.9	118.4	2,121	2,002	17.9
31	47	Burshtynska 11	HC	195	35.1	4.0	77.5	1,387	1,309	17.9
32	46	Burshtynska 10	HC	195	35.9	3.9	77.2	1,375	1,298	17.8
33	45	Burshtynska 9	HC	195	35.9	4.0	78.4	1,392	1,313	17.8
34	72	Zmiivska 8	HC	325	75.2	3.8	115.8	2,039	1,923	17.6
35	95	Luganskaya 11	HC	200	51.6	3.6	89.9	1,583	1,493	17.6
36	37	Burshtynska 1	HC	195	35.6	3.8	76.0	1,300	1,224	17.1
37	20	Zaporiska 2	HC	300	70.0	4.8	120.7	2,020	1,899	16.7
38	107	Kramatorska CHP	HC	120	15.5	1.3	29.2	486	457	16.7
39	39	Burshtynska 3	HC	185	33.6	2.7	62.6	1,041	978	16.6
40	18	Kryvorizka 10	HC	282	64.4	4.4	111.7	1,850	1,739	16.6
41	22	Zaporiska 4	HC	300	70.4	4.5	118.2	1,939	1,821	16.4
42	10	Kryvorizka 2	HC	282	64.7	5.1	118.7	1,935	1,816	16.3
43	13	Kryvorizka 5	HC	282	63.1	4.5	111.1	1,810	1,698	16.3
44	2	Prydniprovska 8	HC	150	34.6	2.5	60.7	959	898	15.8
45	48	Burshtynska 12	HC	195	32.4	2.7	61.1	964	903	15.8
46	19	Zaporiska 1	HC	325	65.9	3.9	107.2	1,645	1,538	15.3
47	12	Kryvorizka 4	HC	282	59.1	4.5	106.6	1,622	1,515	15.2
48	43	Burshtynska 7	HC	185	33.7	2.2	56.6	858	801	15.2
49	71	Zmiivska 7	HC	275	67.0	2.9	98.0	1,470	1,372	15.0
50	9	Kryvorizka 1	HC	282	62.2	4.0	105.2	1,578	1,473	15.0
51	16	Kryvorizka 8	HC	282	64.4	3.8	104.4	1,559	1,454	14.9
52	109	Myronivska 9	HC	115	12.7	1.7	30.7	457	427	14.9
53	55	Ladyzhinska 3	HC	300	63.9	4.6	112.3	1,639	1,526	14.6
54	94	Luganskaya 10	HC	200	40.3	2.3	65.1	943	878	14.5
55	108	Myronivska 4	HC	60	6.3	0.6	13.1	185	172	14.1
56	5	Prydniprovska 11	HC	310	69.0	4.3	114.2	1,527	1,413	13.4
57	73	Zmiivska 9	HC	275	65.0	2.9	95.9	1,281	1,185	13.4
58	4	Prydniprovska 10	HC	150	34.3	2.1	56.3	746	689	13.2
59	41	Burshtynska 5	HC	195	38.6	1.9	59.3	774	715	13.0
60	54	Ladyzhinska 2	HC	300	63.9	3.9	105.4	1,371	1,265	13.0
61	74	Zmiivska 10	HC	275	66.5	2.9	96.8	1,230	1,133	12.7
62	110	Odeska CHP-2	NG	68	2.2	0.2	4.0	51	47	12.5
63	103	Kaluska CHP 1, 2	HC	100	11.0	1.0	21.5	262	240	12.2
64	38	Burshtynska 2	HC	185	33.7	1.6	51.2	613	562	12.0
65	14	Kryvorizka 6	HC	282	65.1	2.6	93.3	1,112	1,018	11.9
66	1	Prydniprovska 7	HC	150	34.6	1.6	51.1	596	545	11.7
67	66	Zmiivska 2	HC	175	43.6	1.9	63.7	737	673	11.6
68	53	Ladyzhinska 1	HC	300	65.1	3.1	98.1	1,107	1,008	11.3
69	68	Zmiivska 4	HC	175	43.6	1.9	63.7	716	652	11.2
70	56	Ladyzhinska 4	HC	300	63.9	2.7	92.4	968	876	10.5
71	7	Prydniprovska 13	HC	285	68.3	2.7	97.5	1,020	922	10.5
72	65	Zmiivska 1	HC	175	53.1	1.9	73.3	755	682	10.3
73	70	Zmiivska 6	HC	175	43.6	1.9	63.4	649	585	10.2
74	69	Zmiivska 5	HC	175	55.1	1.9	75.4	728	653	9.7
75	67	Zmiivska 3	HC	175	55.1	1.9	75.3	726	651	9.7
76	57	Ladyzhinska 5	HC	300	63.9	2.1	86.2	786	700	9.1
77	58	Ladyzhinska 6	HC	300	63.9	2.0	85.2	756	671	8.9
78	60	Trypilska 2	HC	300	63.0	4.3	108.5	668	559	6.2
79	61	Trypilska 3	HC	300	63.8	4.3	109.0	441	332	4.0
80	62	Trypilska 4	HC	300	63.8	4.3	109.1	431	322	4.0
81	59	Trypilska 1	HC	300	63.8	4.3	109.1	408	299	3.7
82	104	Kaluska CHP 3, 4	NG	100	0.4	0.1	1.8	6	4	3.4
83	106	Kyivska CHP-6	NG	500	8.1	0.6	14.9	36	22	2.5
84	105	Kyivska CHP-5	NG	540	8.5	0.7	15.8			
85	105a	Kyivska CHP-5	FO	540	8.5	0.7	15.8			
86	3	Prydniprovska 9	HC	150	32.4	0.0	32.4			
87	6	Prydniprovska 12	HC	285	65.4	0.0	65.4			
88	8	Prydniprovska 14	HC	285	68.3	0.0	68.3			
89	11	Kryvorizka 3	HC	282	57.9	0.0	57.9			

Rank No	Code	Plant nfame	Fuel type	PowerMW	Costs		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
90	15	Kryvorizka 7	HC	282	64.4	0.0	64.4			
91	17	Kryvorizka 9	HC	282	63.3	0.0	63.3			
92	23	Zaporiska 5	NG	800	24.0	0.0	24.0			
93	24	Zaporiska 6	NG	800	25.0	0.0	25.0			
94	25	Zaporiska 7	NG	800	25.6	0.0	25.6			
95	26	Starobeshivska 4	HC	175	25.0	1.7	42.9			
96	27	Starobeshivska 5	HC	175	40.0	2.2	63.2			
97	28	Starobeshivska 6	HC	175	37.9	2.2	61.1			
98	29	Starobeshivska 7	HC	175	37.2	2.2	60.4			
99	30	Starobeshivska 8	HC	175	37.2	2.2	60.4			
100	31	Starobeshivska 9	HC	175	38.2	2.2	61.4			
101	32	Starobeshivska 10	HC	175	39.2	2.2	62.4			
102	33	Starobeshivska 11	HC	175	39.2	2.2	62.4			
103	34	Starobeshivska 12	HC	175	33.8	2.2	57.0			
104	35	Starobeshivska 13	HC	175	31.6	2.2	54.8			
105	36	Slovianska 7	HC	800	169.3	10.0	275.3			
106	63	Trypilska 5	NG	300	22.3	0.0	22.3			
107	64	Trypilska 6	NG	300	22.3	0.0	22.3			
108	79	Vuglegirska 5	NG	800	65.0	0.0	65.0			
109	80	Vuglegirska 6	NG	800	65.0	0.0	65.0			
110	81	Vuglegirska 7	NG	800	65.0	0.0	65.0			
111	96	Luganskaya 12	HC	175	29.3	0.0	29.3			
112	100	Bilotserkivska CHP	NG	120	0.0	0.0	0.0			
113	101	Darnytska CHP 5,10	NG	50	0.0	0.0	0.0			
114	111	Sevastopolska CHP	NG	55	0.0	0.0	0.0			
115	112	Simferopilska CHP	NG	278	0.0	0.0	0.0			

Table A4-2.9: Kosovo* - LCPs ranking related to the CBA implementation of LCPD

Rank No	Code	Plant name	Fuel type	Power MW	Costs		NPV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	5	Kosovo B2	L	339	39,0	3,7	78	600	521	7,7
2	4	Kosovo B1	L	339	39,0	3,7	78	594	516	7,6
3	1	Kosovo A3	L	200						
4	2	Kosovo A4	L	200						
5	3	Kosovo A5	L	210						

NB: "0" Appears in case that no data are available or if the TPP is lying up

A4.3. Benefit-Cost Ranking for IED Scenario

Table A4-3.1: Albania - LCPs ranking related to the CBA implementation of IED

Rank No	Code	Plant name	Fuel type	Power MW	Costs		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	1	Vlora	NG	100						

Table A4-3.2: BiH - LCPs ranking related to the CBA implementation of IED

Rank No	Code	Plant Name	Fuel type	Power MW	Costs		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	2	Ugljevik	L	300	118.4	12.7	254	17,847	17,594	70.4
2	9	Kakanj 7	L	230	63.5	6.0	127	5,242	5,115	41.2
3	7	Kakanj 5	L	110	36.2	2.7	65	2,323	2,257	35.5
4	8	Kakanj 6	L	110	27.7	1.4	42	1,155	1,112	27.3
5	6	Tuzla 6	L	215	46.6	2.8	76	1,814	1,738	23.7
6	5	Tuzla 5	L	200	20.0	2.2	44	966	922	22.1
7	4	Tuzla 4	L	200	25.0	3.5	62	1,343	1,281	21.7
8	1	Gacko	L	300	37.3	6.7	108	1,592	1,483	14.7
9	3	Tuzla 3	L	110						

Table A4-3.3: Croacia - LCPs ranking related to the CBA implementation of IED

Rank No	Code	Plant name	Fuel type	Power MW	Costs		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	3	TPP Rijeka	FO	320	89	6	152	2,686.2	2,534.0	17.6
2	4	TPP Sisak A	FO	210	76	4	116	1,972.4	1,856.0	16.9
3	5	TPP Sisak B	FO	210	76	4	116	1,972.4	1,856.0	16.9
4	8	CHP Zagreb C	NG	120	37	2	53	582.4	529.3	11.0
5	12	CHP Zagreb EL-TOK8	NG	30	8	0	10	100.3	90.0	9.7
6	13	CHP Zagreb EL-TOH	NG	25	1	0	2	15.2	13.5	8.8
7	14	CHP Zagreb EL-TOJ	NG	25	1	0	2	12.1	10.4	7.0
8	15	CHP Osijek A	NG	46	1	0	3	18.5	15.5	6.3
9	11	CHP Zagreb EL-TO K6	NG	11	7	0	8	40.1	32.5	5.2
10	16	CHP Osijek B	NG	25	1	0	1	3.0	2.0	3.1
11	2	TPP Plomin 2	HC	210	20	2	41	115.0	74.2	2.8
12	7	TPP Jertovac 2	NG	40	1	0	1	2.8	1.5	2.2
13	6	TPP Jertovac 1	NG	40	1	0	1	2.7	1.4	2.1
14	17	CHP Osijek C	NG	25	1	0	1	1.5	0.7	1.8
15	1	TPP Plomin 1	HC	125						
16	9	CHP Zagreb K	NG	208						
17	10	CHP Zagreb L	NG	112						

Table A4-3.4: FYR Macedonia - LCPs ranking related to the CBA implementation of IED

Rank No	Code	Plant Name	Fuel type	Power MW	COSTS		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	1	Bitola 1	L	233	78	5	135	3,345	3,209	24.7
2	2	Bitola 2	L	233	78	5	133	2,761	2,629	20.8
3	3	Bitola 3	L	233	78	5	133	2,761	2,629	20.8
4	4	Oslomej	L	125	37	2	55	1,168	1,112	21.1
5	5	Negotino	FO	210						
	6	Skopje CHP	NG	227						
	7	Kogel CHP	NG	30						

Table A4-3.5: Moldova - LCPs ranking related to the CBA implementation of IED

Rank No	Code	Plant Name	Fuel type	Power MW	Costs		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	7	CET-2, No 2	NG	80	0.6	0.1	1.8	7.3	5.5	4.1
2	8	CET-2, No 3	NG	80	0.6	0.1	1.8	5.6	3.8	3.1
3	6	CET-2, No 1	NG	80	0.6	0.1	1.9	5.3	3.4	2.8
4	3	CET-1, No 3	NG	10	0.1	0.0	0.2	0.3	0.1	1.5
5	2	CET-1, No 2	NG	12	0.1	0.0	0.2	0.3	0.1	1.3
6	1	CET-1, No 1	NG	12						
7	4	CET-1, No 4	NG	27						
8	5	CET-1, No 5	NG	5						

Table A4-3.6: Montenegro - LCPs ranking related to the CBA implementation of IED

Rank No	Code	Plant Name	Fuel type	Power MW	Costs		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	1	Pljevlja	Lignite	219	51	4.3	96.8	4,886	4,789	50

Table A4-3.7: Serbia - LCPs ranking related to the CBA implementation of IED

Rank No	Code	Plant Name	Fuel type	Power MW	COSTS		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	16	Kostolac A2	L	210	10.1	4	51	4,044	3,993	79
2	17	Kostolac B1	L	348	75.8	5	131	6,557	6,426	50
3	18	Kostolac B2	L	348	70.6	7	147	5,748	5,601	39
4	14	Morava	L	125	22.4	1	36	1,285	1,249	36
5	13	Kolubara 5	L	110	12.1	2	29	870	841	30
6	15	Kostolac A1	L	100	54.8	2	74	2,094	2,019	28
7	1	Nikola Tesla A1	L	210	24.9	3	56	1,311	1,254	23
8	2	Nikola Tesla A2	L	210	24.7	3	55	1,275	1,220	23
9	8	Nikola Tesla B2	L	620	84.6	10	187	4,259	4,071	23
10	7	Nikola Tesla B1	L	620	94.0	10	201	4,374	4,173	22
11	4	Nikola Tesla A4	L	309	49.6	5	101	2,106	2,005	21
12	5	Nikola Tesla A5	L	309	49.6	5	101	2,097	1,996	21
13	6	Nikola Tesla A6	L	309	49.6	5	100	2,084	1,984	21
14	3	Nikola Tesla A3	L	305	59.2	5	108	1,992	1,884	18
15	11	Kolubara 3	L	64	9.4	0	13	221	208	18
16	20	Novi Sad 2	NG	110	4.8	1	10	144	134	14
17	19	Novi Sad 1	NG	135	5.9	1	12	156	144	13
18	22	Sr. Mitrovica 1	NG	32	1.8	0	3	21	18	8
19	21	Zrenjanin	NG	110	4.8	0	6	30	24	5
	9	Kolubara 1	L	32						
	10	Kolubara 2	L	32						
	12	Kolubara 4	L	32						

Table A4-3.8: Ukraine - LCPs ranking related to the CBA implementation of IED

Rank No	Code	Plant Name	Fuel type	Power MW	COSTS		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	50	Dobrotvirska 6	HC	100	13.7	1	29	780	751	26.7
2	52	Dobrotvirska 8	HC	150	21.0	2	44	1,132	1,088	25.9
3	113	Kharkivska CHP-2	HC	74	14.7	1	30	745	715	24.8
4	85	Zuevvskaya 4	HC	325	67.3	8	148	3,476	3,328	23.5
5	83	Zuevvskaya 2	HC	320	69.3	7	148	3,481	3,333	23.5
6	82	Zuevvskaya 1	HC	325	69.6	7	146	3,416	3,269	23.4
7	87	Kurakhovskaya 4	HC	210	43.6	4	90	2,053	1,963	22.8
8	84	Zuevvskaya 3	HC	300	66.1	7	140	3,146	3,006	22.5
9	88	Kurakhovskaya 5	HC	222	46.8	4	92	2,009	1,916	21.8
10	86	Kurakhovskaya 3	HC	200	47.0	4	93	1,996	1,903	21.4
11	92	Kurakhovskaya 9	HC	221	47.4	4	94	1,995	1,901	21.2
12	98	Luganskaya 14	HC	200	50.1	4	95	1,972	1,878	20.8
13	42	Burshtynska 6	HC	185	36.4	4	80	1,617	1,538	20.3
14	97	Luganskaya 13	HC	175	44.8	4	84	1,710	1,626	20.3

Rank No	Code	Plant Name	Fuel type	Power MW	COSTS		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
15	91	Kurakhovskaya 8	HC	210	36.0	3	67	1,356	1,289	20.2
16	89	Kurakhovskaya 6	HC	210	40.1	3	69	1,376	1,306	19.8
17	93	Luganskaya 9	HC	200	50.0	4	93	1,834	1,741	19.7
18	90	Kurakhovskaya 7	HC	225	48.1	4	93	1,835	1,742	19.7
19	99	Luganskaya 15	HC	200	53.0	4	94	1,846	1,752	19.6
20	40	Burshtynska 4	HC	195	38.5	4	78	1,471	1,393	19.0
21	77	Vuglegirska 3	HC	300	73.7	6	133	2,522	2,389	19.0
22	78	Vuglegirska 4	HC	300	73.7	6	133	2,519	2,386	18.9
23	75	Vuglegirska 1	HC	300	73.7	6	133	2,512	2,379	18.9
24	76	Vuglegirska 2	HC	300	73.7	6	133	2,508	2,375	18.8
25	107	Kramatorska CHP	HC	120	23.2	1	37	675	638	18.3
26	47	Burshtynska 11	HC	195	38.1	4	81	1,456	1,376	18.1
27	46	Burshtynska 10	HC	195	38.9	4	80	1,441	1,361	18.0
28	45	Burshtynska 9	HC	195	38.9	4	81	1,460	1,378	17.9
29	44	Burshtynska 8	HC	195	42.4	3	79	1,412	1,333	17.9
30	95	Luganskaya 11	HC	200	53.9	4	94	1,657	1,563	17.7
31	51	Dobrotvirska 7	HC	150	56.4	3	88	1,541	1,453	17.6
32	21	Zaporiska 3	HC	300	70.3	5	127	2,211	2,084	17.4
33	37	Burshtynska 1	HC	195	38.6	4	79	1,360	1,281	17.2
34	39	Burshtynska 3	HC	185	36.4	3	65	1,089	1,023	16.7
35	72	Zmiivska 8	HC	325	81.2	4	127	2,103	1,976	16.5
36	20	Zaporiska 2	HC	300	74.4	5	130	2,108	1,979	16.3
37	108	Myronivska 4	HC	60	11.0	1	21	347	326	16.3
38	103	Kaluska CHP 1, 2	HC	100	15.0	1	26	410	384	16.1
39	18	Kryvorizka 10	HC	282	69.1	5	121	1,930	1,808	15.9
40	109	Myronivska 9	HC	115	20.8	2	46	732	686	15.9
41	22	Zaporiska 4	HC	300	74.8	5	127	2,023	1,895	15.9
42	48	Burshtynska 12	HC	195	35.1	3	64	1,012	948	15.9
43	10	Kryvorizka 2	HC	282	69.5	5	128	2,024	1,897	15.8
44	13	Kryvorizka 5	HC	282	67.5	5	120	1,889	1,769	15.8
45	2	Prydniprovska 8	HC	150	38.4	3	66	1,008	942	15.3
46	94	Luganskaya 10	HC	200	40.3	2	65	993	928	15.2
47	43	Burshtynska 7	HC	185	36.5	2	59	895	835	15.1
48	19	Zaporiska 1	HC	325	70.1	4	115	1,718	1,602	14.9
49	12	Kryvorizka 4	HC	282	62.8	5	114	1,700	1,586	14.9
50	9	Kryvorizka 1	HC	282	66.6	4	113	1,651	1,539	14.6
51	49	Dobrotvirska 5	HC	100	37.9	1	53	780	727	14.6
52	16	Kryvorizka 8	HC	282	69.1	4	113	1,626	1,513	14.4
53	71	Zmiivska 7	HC	275	72.3	3	107	1,532	1,425	14.4
54	55	Ladyzhinska 3	HC	300	70.0	5	121	1,724	1,603	14.2
55	41	Burshtynska 5	HC	195	40.9	2	62	808	746	13.1
56	73	Zmiivska 9	HC	275	70.3	3	104	1,337	1,234	12.9
57	5	Prydniprovska 11	HC	310	76.8	5	125	1,606	1,481	12.9
58	102	Darnytska CHP 6-9	HC	110	27.1	2	43	555	512	12.9
59	4	Prydniprovska 10	HC	150	38.4	2	61	788	727	12.8
60	54	Ladyzhinska 2	HC	300	70.0	4	114	1,445	1,330	12.7
61	74	Zmiivska 10	HC	275	72.0	3	105	1,288	1,183	12.3
62	66	Zmiivska 2	HC	175	45.5	2	65	779	714	12.0
63	38	Burshtynska 2	HC	185	36.5	2	54	642	588	11.9
64	68	Zmiivska 4	HC	175	45.5	2	65	758	693	11.7
65	14	Kryvorizka 6	HC	282	69.9	3	101	1,159	1,058	11.5
66	1	Prydniprovska 7	HC	150	38.4	2	56	629	574	11.3
67	53	Ladyzhinska 1	HC	300	71.5	3	107	1,166	1,059	10.9
68	70	Zmiivska 6	HC	175	45.5	2	64	691	627	10.9
69	65	Zmiivska 1	HC	175	57.3	2	77	798	721	10.4
70	7	Prydniprovska 13	HC	285	74.0	3	105	1,074	969	10.2
71	56	Ladyzhinska 4	HC	300	70.0	3	100	1,019	919	10.2
72	69	Zmiivska 5	HC	175	59.8	2	79	770	691	9.7
73	67	Zmiivska 3	HC	175	59.8	2	79	768	689	9.7
74	57	Ladyzhinska 5	HC	300	70.0	2	94	826	732	8.8
75	58	Ladyzhinska 6	HC	300	70.0	2	93	794	701	8.6
76	106a	Kyivska CHP-6	FO	500	87.1	4	127	843	717	6.7

Rank No	Code	Plant Name	Fuel type	Power MW	COSTS		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
77	60	Trypilska 2	HC	300	68.3	4	114	757	643	6.6
78	110	Odeska CHP-2	NG	68	7.8	0	11	65	54	6.0
79	61	Trypilska 3	HC	300	69.5	4	110	531	420	4.8
80	62	Trypilska 4	HC	300	69.5	4	110	521	411	4.7
81	59	Trypilska 1	HC	300	69.5	4	110	497	387	4.5
82	100	Bilotserkivska CHP	NG	120	3.6	0	7	24	17	3.5
83	111	Sevastopolska CHP	NG	55	1.2	0	3	7	4	2.6
84	104	Kaluska CHP 3, 4	NG	100	9.5	0	14	26	12	1.9
85	101	Darnytska CHP 5,10	NG	50	4.5	0	7	11	4	1.6
86	112	Simferopilska CHP	NG	278	1.4	0	5	7	2	1.4
87	106	Kyivska CHP-6	NG	500	32.6	1	44	59	15	1.4
88	3	Prydniprovska 9	HC	150	35.6	0	36			
89	6	Prydniprovska 12	HC	285	70.4	0	70			
90	8	Prydniprovska 14	HC	285	74.0	0	74			
91	11	Kryvorizka 3	HC	282	60.5	0	61			
92	15	Kryvorizka 7	HC	282	69.1	0	69			
93	17	Kryvorizka 9	HC	282	67.1	0	67			
94	23	Zaporiska 5	NG	800	24.0	0	24			
95	24	Zaporiska 6	NG	800	25.0	0	25			
96	25	Zaporiska 7	NG	800	25.6	0	26			
97	26	Starobeshivska 4	HC	175	56.5	2	80			
98	27	Starobeshivska 5	HC	175	68.0	2	91			
99	28	Starobeshivska 6	HC	175	65.6	2	89			
100	29	Starobeshivska 7	HC	175	64.9	2	88			
101	30	Starobeshivska 8	HC	175	64.9	2	88			
102	31	Starobeshivska 9	HC	175	66.0	2	89			
103	32	Starobeshivska 10	HC	175	66.5	2	90			
104	33	Starobeshivska 11	HC	175	66.5	2	90			
105	34	Starobeshivska 12	HC	175	61.1	2	84			
106	35	Starobeshivska 13	HC	175	58.7	2	82			
107	36	Slovianska 7	HC	800	180.8	10	287			
108	63	Trypilska 5	NG	300	22.3	0	22			
109	64	Trypilska 6	NG	300	22.3	0	22			
110	79	Vuglegirska 5	NG	800	65.0	0	65			
111	80	Vuglegirska 6	NG	800	65.0	0	65			
112	81	Vuglegirska 7	NG	800	65.0	0	65			
113	96	Luganskaya 12	HC	175	42.3	0	42			
114	105	Kyivska CHP-5	NG	540	35.0	1	47			
115	105a	Kyivska CHP-5	FO	540	94.0	3	128			

Table A.4-3.9: Kosovo* - LCPs ranking related to the CBA implementation of IED

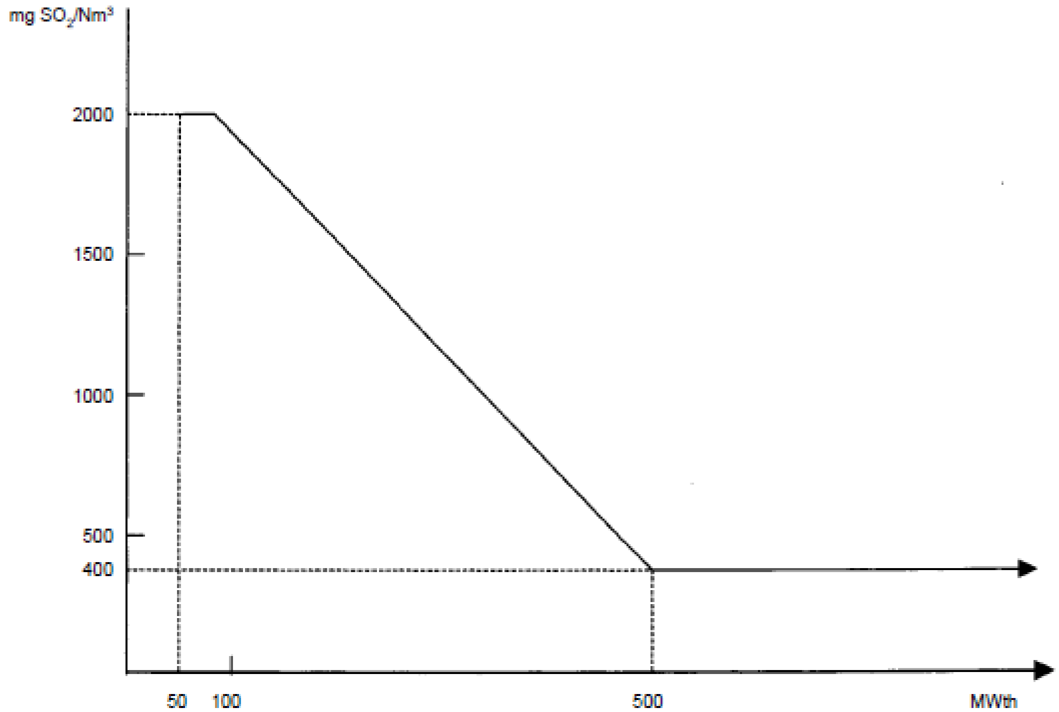
Rank No	Code	Plant Name	Fuel type	Power MW	COSTS		PV			B/C
					Investments	O&M	C	B	B-C	
					Mil, €	Mil, €/y	Mil, €	Mil, €	Mil, €	-
1	4	Kosovo B1	L	339	42.1	4	81	728	647	9
2	5	Kosovo B2	L	339	42.1	4	81	733	652	9
3	1	Kosovo A3	L	200						
4	2	Kosovo A4	L	200						
5	3	Kosovo A5	L	210						

Annex 5 Requirements of LCP Directive and IE Directive

Requirements from the LCP Directive

EMISSION LIMIT VALUES FOR SO_2
Solid fuel

A, SO_2 emission limit values expressed in mg/Nm^3 (O_2 content 6 %) to be applied by new and existing plants pursuant to Article 4(1) and 4(3) respectively:



NB, Where the emission limit values above cannot be met due to the characteristics of the fuel, a rate of desulphurization of at least 60 % shall be achieved in the case of plants with a rated thermal input of less than or equal to 100 MWth, 75 % for plants greater than 100 MWth and less than or equal to 300 MWth and 90 % for plants greater than 300 MWth, For plants greater than 500 MWth, a desulphurization rate of at least 94 % shall apply or a desulphurization rate of at least 92 % where a contract for the fitting of flue gas desulphurization or lime injection equipment has been entered into, and work on its installation has commenced, before 1 January 2001,

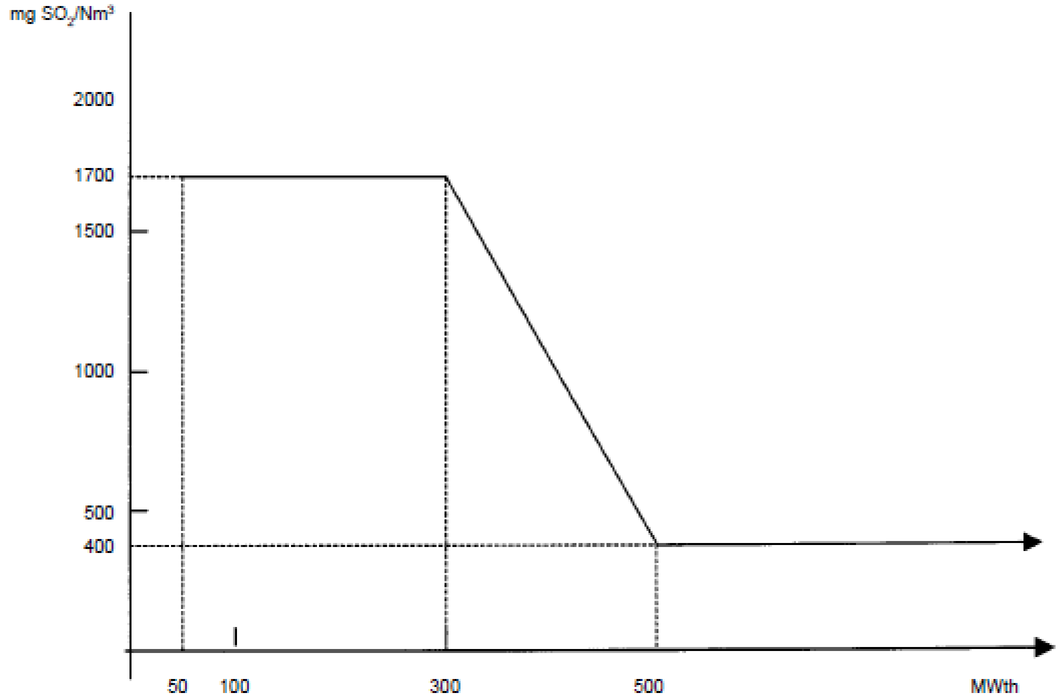
B, SO_2 emission limit values expressed in mg/Nm^3 (O_2 content 6 %) to be applied by new plants pursuant to Article 4(2) with the exception of gas turbines,

Type of fuel	50 to 100 MWth	100 to 300 MWth	> 300 MWth
Biomass	200	200	200
General case	850	200 (1)	200
(1) Except in the case of the "Outermost Regions" where 850 to 200 mg/Nm3 (linear decrease) shall apply,			

NB, Where the emission limit values above cannot be met due to the characteristics of the fuel, installations shall achieve 300 mg/Nm3 SO_2, or a rate of desulphurisation of at least 92 % shall be achieved in the case of plants with a rated thermal input of less than or equal to 300 MWth and in the case of plants with a rated thermal input greater than 300 MWth a rate of desulphurisation of at least 95 % together with a maximum permissible emission limit value of 400 mg/Nm^3 shall apply,

EMISSION LIMIT VALUES FOR SO_2
Liquid fuels

A, SO_2 emission limit values expressed in mg/Nm^3 (O_2 content 3 %) to be applied by new and existing plants pursuant to Article 4(1) and 4(3), respectively:



B, SO_2 emission limit values expressed in mg/Nm^3 (O_2 content 3 %) to be applied by new plants pursuant to Article 4(2) with the exception of gas turbines

50 to 100 MWth	100 to 300 MWth	> 300 MWth
850	400 to 200 (linear decrease) (1)	200
(1) Except in the case of the 'Outermost Regions' where 850 to 200 mg/Nm^3 (linear decrease) shall apply,		

In the case of two installations with a rated thermal input of 250 MWth on Crete and Rhodes to be licensed before 31 December 2007 the emission limit value of 1 700 mg/Nm^3 shall apply,

EMISSION LIMIT VALUES FOR SO_2
Gaseous fuels

A, SO_2 emission limit values expressed in mg/Nm^3 (O_2 content 3 %) to be applied by new and existing plants pursuant to Article 4(1) and 4(3), respectively:

Type of fuel	Limit values (mg/Nm^3)
Gaseous fuels in general	35
Liquefied gas	5
Low calorific gases from gasification of refinery residues, coke oven gas, blast-furnace gas	800
Gas from gasification of coal	(1)
(1) The Council will fix the emission limit values applicable to such gas at a later stage on the basis of proposals from the Commission to be made in the light of further technical experience,	

B, SO_2 emission limit values expressed in mg/Nm^3 (O_2 content 3 %) to be applied by new plants pursuant to Article 4(2):

Gaseous fuels in general	35
Liquefied gas	5
Low calorific gases from coke oven	400
Low caloric gases from blast furnace	200

EMISSION LIMIT VALUES FOR NO_X (MEASURED AS NO_2)

A, NO_x emission limit values expressed in mg/Nm^3 (O_2 content 6 % for solid fuels, 3 % for liquid and gaseous fuels) to be applied by new and existing plants pursuant to Article 4(1) and 4(3), respectively:

Type of fuel: Limit	values [1] (mg/Nm^3)
Solid [2], [3]: 50 to 500 MWth: >500 MWth: From 1 January 2016 50 to 500 MWth: >500 MWth:	600 500 600 200
Liquid: 50 to 500 MWth: >500 MWth:	450 400
Gaseous: 50 to 500 MWth: >500 MWth:	300 200

(1) Except in the case of the ‘Outermost Regions’ where the following values shall apply:
Solid in general: 650
Solid with < 10 % vol comps: 1 300
Liquid: 450
Gaseous: 350

(2) Until 31 December 2015 plants of a rated thermal input greater than 500 MW, which from 2008 onwards do not operate more than 2 000 hours a year (rolling average over a period of five years), shall:
- , in the case of plant licensed in accordance with Article 4(3)(a), be subject to a limit value for nitrogen oxide emissions (measured as NO_2) of 600 mg/Nm³;
- , In the case of plant subject to a national plan under Article 4(6), have their contribution to the national plan assessed on the basis of a limit value of 600 mg/Nm^3,

From 1 January 2016 such plants, which do not operate more than 1 500 hours a year (rolling average over a period of five years), shall be subject to a limit value for nitrogen oxide emissions (measured as NO_2) of 450 mg/Nm^3,

(3) Until 1 January 2018 in the case of plants that in the 12 month period ending on 1 January 2001 operated on, and continue to operate on, solid fuels whose volatile content is less than 10 %, 1 200 mg/Nm^3 shall apply,

B, NO_x emission limit values expressed in mg/Nm^3 to be applied by new plants pursuant to Article 4(2) with the exception of gas turbines

Solid fuels (O_2 content 6 %)

Type of fuel	50 to 100 MWth	100 to 300 MWth	> 300 MWth
Biomass	400	300	200
General case	400	200 (1)	200

(1) Except in the case of the “Outermost Regions” where 300 mg/Nm^3 shall apply,

Liquid fuels (O_2 content 3 %)

50 to 100 MWth	100 to 300 MWth	> 300 MWth
400	200 (1)	200
(1) Except in the case of the " Outermost Regions" where 300 mg/Nm^3 shall apply,		

In the case of two installations with a rated thermal input of 250 MWth on Crete and Rhodes to be licensed before 31 December 2007 the emission limit value of 400 mg/Nm^3 shall apply,

Gaseous fuels (O_2 content 3 %)

	50 to 300 MWth	> 300 MWth
Natural gas (Note 1)	150	100
Other gases	200	200

Gas Turbines

NO_x emissions limit values expressed in mg/Nm^3 (O_2 content 15 %) to be applied by a single gas turbine unit pursuant to Article 4(2) (the limit values apply only above 70 % load):

	> 50 MWth (thermal input at ISO conditions)
Natural gas (Note 1)	50 (Note 2)
Liquid fuels (Note 3)	120
Gaseous fuels (other than natural gas)	120

Gas turbines for emergency use that operate less than 500 hours per year are excluded from these limit values, The operator of such plants is required to submit each year to the competent authority a record of such used time,

Note 1: Natural gas is naturally occurring methane with not more than 20 % (by volume) of inerts and other constituents,

Note 2: 75 mg/Nm3 in the following cases, where the efficiency of the gas turbine is determined at ISO base load conditions:

- gas turbines, used in combined heat and power systems having an overall efficiency greater than 75 %;
- gas turbines used in combined cycle plants having an annual average overall electrical efficiency greater than 55 %;
- gas turbines for mechanical drives,

For single cycle gas turbines not falling into any of the above categories, but having an efficiency greater than 35 % - determined at ISO base load conditions ¯ the emission limit value shall be 50*g/35 where g is the gas turbine efficiency expressed as a percentage (and at ISO base load conditions),

Note 3: This emission limit value only applies to gas turbines firing light and middle distillates,

EMISSION LIMIT VALUES FOR DUST

A, Dust emission limit values expressed in mg/Nm^3 (O_2 content 6 % for solid fuels, 3 % for liquid and gaseous fuels) to be applied by new and existing plants pursuant to Article 4(1) and 4(3), respectively:

Type of fuel	Rated thermal input (MW)	Emission limit values (mg/Nm^3)
Solid	≥500 < 500	50 (2) 100
Liquid (1)	all plants	50
Gaseous	all plants	5 as a rule 10 for blast furnace gas 50 for gases produced by the steel industry which can be used elsewhere

(1) A limit value of 100 mg/Nm3 may be applied to plants with a rated thermal input of less than 500 MWth burning liquid fuel with an ash content of more than 0,06 %,
(2) A limit value of 100 mg/Nm^3 may be applied to plants licensed pursuant to Article 4(3) with a rated thermal input greater than or equal to 500 MWth burning solid fuel with a heat content of less than 5 800 kJ/kg (net calorific value), a moisture content greater than 45 % by weight, a combined moisture and ash content greater than 60 % by weight and a calcium oxide content greater than 10 %,

B, Dust emission limit values expressed in mg/Nm3 to be applied by new plants, pursuant to Article 4(2) with the exception of gas turbines:

Solid fuels (O_2 content 6 %)

50 to 100 MWth	> 100 MWth
50	30

Liquid fuels (O_2 content 3 %)

50 to 100 MWth	> 100 MWth
50	30

In the case of two installations with a rated thermal input of 250 MWth on Crete and Rhodes to be licensed before 31 December 2007 the emission limit value of 50 mg/Nm3 shall apply,

Gaseous fuels (O2 content 3 %)

As a rule	5
For blast furnace gas	10
For gases produced by the steel industry which can be used elsewhere	30

METHODS OF MEASUREMENT OF EMISSIONS

A, Procedures for measuring and evaluating emissions from combustion plants,

1, Until 27 November 2004

Concentrations of SO_2, dust, NO_x shall be measured continuously in the case of new plants for which a license is granted pursuant to Article 4(1) with a rated thermal input of more than 300 MW, However, monitoring of SO2 and dust may be confined to discontinuous measurements or other appropriate determination procedures in cases where such measurements or procedures, which must be verified and approved by the competent authorities, may be used to obtain concentration,

In the case of new plants for which a license is granted pursuant to Article 4(1) not covered by the first subparagraph, the competent authorities may require continuous measurements of those three pollutants to be carried out where considered necessary, Where continuous measurements are not required, discontinuous measurements or appropriate determination procedures as approved by the competent authorities shall be used regularly to evaluate the quantity of the above-mentioned substances present in the emissions,

2, From 27 November 2002 and without prejudice to Article 18(2)

The competent authorities shall require continuous measurements of concentrations of SO_2, NO_x, and dust from waste gases from each combustion plant with a rated thermal input of 100 MW or more,

By way of derogation from the first subparagraph, continuous measurements may not be required in the following cases:
- for combustion plants with a life span of less than 10 000 operational hours;
- for SO_2 and dust from natural gas burning boilers or from gas turbines firing natural gas;
- for SO_2 from gas turbines or boilers firing oil with known sulphur content in cases where there is no desulphurization equipment;
- for SO_2 from biomass firing boilers if the operator can prove that the SO_2 emissions can under no circumstances be higher than the prescribed emission limit values,

Where continuous measurements are not required, discontinuous measurements shall be required at least every six months, As an alternative, appropriate determination procedures, which must be verified and approved by the competent authorities, may be used to evaluate the quantity of the above mentioned pollutants present in the emissions, Such procedures shall use relevant CEN standards as soon as they are available, If CEN standards are not available ISO standards, national or international standards which will ensure the provision of data of an equivalent scientific quality shall apply,

3, In the case of plants which must comply with the desulphurization rates fixed by Article 5(2) and Annex III, the requirements concerning SO_2 emission measurements established under paragraph 2 of this point shall apply, Moreover, the sulphur content of the fuel which is introduced into the combustion plant facilities must be regularly monitored, 4, The competent authorities shall be informed of substantial changes in the type of fuel used or in the mode of operation of the plant, They shall decide whether the monitoring requirements laid down in paragraph 2 are still adequate or require adaptation,

5, The continuous measurements carried out in compliance with paragraph 2 shall include the relevant process operation parameters of oxygen content, temperature, pressure and water vapor content, The continuous measurement of the water vapour content of the exhaust gases shall not be necessary, provided that the sampled exhaust gas is dried before the emissions are analyzed,

Representative measurements, i,e, sampling and analysis, of relevant pollutants and process parameters as well as reference measurement methods to calibrate automated measurement systems shall be carried out in accordance with CEN standards as soon as they are available, If CEN standards are not available ISO standards, national or international standards which will ensure the provision of data of an equivalent scientific quality shall apply,

Continuous measuring systems shall be subject to control by means of parallel measurements with the reference methods at least every year,

6, The values of the 95 % confidence intervals of a single measured result shall not exceed the following percentages of the emission limit values:

Sulphur dioxide	20 %
Nitrogen oxides	20 %
Dust	30 %

The validated hourly and daily average values shall be determined from the measured valid hourly average values after having subtracted the value of the confidence interval specified above,

Any day in which more than three hourly average values are invalid due to malfunction or maintenance of the continuous measurement system shall be invalidated, If more than ten days over a year are invalidated for such situations the competent authority shall require the operator to take adequate measures to improve the reliability of the continuous monitoring system,

B, Determination of total annual emissions of combustion plants

Until and including 2003 the competent authorities shall obtain determination of the total annual emissions of SO_2 and NO_x from new combustion plants, When continuous monitoring is used, the operator of the combustion plant shall add up separately for each pollutant the mass of pollutant emitted each day, on the basis of the volumetric flow rates of waste gases, Where continuous monitoring is not in use, estimates of the total annual emissions shall be determined by the operator on the basis of paragraph A,1 to the satisfaction of the competent authorities,

Member States shall communicate to the Commission the total annual SO_2 and NO_x emissions of new combustion plants at the same time as the communication required under paragraph C,3 concerning the total annual emissions of existing plants, Member States shall establish, starting in 2004 and for each subsequent year, an inventory of SO_2, NO_x and dust emissions from all combustion plants with a rated thermal input of 50 MW or more, The competent authority shall obtain for each plant operated under the control of one operator at a given location the following data:

- the total annual emissions of SO_2, NO_x and dust (as total suspended particles),
- the total annual amount of energy input, related to the net calorific value, broken down in terms of the five categories of fuel: biomass, other solid fuels, liquid fuels, natural gas, other gases,

A summary of the results of this inventory that shows the emissions from refineries separately shall be communicated to the Commission every three years within twelve months from the end of the three-year period considered, The yearly plant-by-plant data shall be made available to the Commission upon request, The Commission shall make available to the Member States a summary of the comparison and evaluation of the national inventories within twelve months of receipt of the national inventories,

Commencing on 1 January 2008 Member States shall report annually to the Commission on those existing plants declared for eligibility under Article 4(4) along with the record of the used and unused time allowed for the plants' remaining operational life,

C, Determination of the total annual emissions of existing plants until and including 2003,

1. Member States shall establish, starting in 1990 and for each subsequent year until and including 2003, a complete emission inventory for existing plants covering SO_2 and NO_x:
   - on a plant by plant basis for plants above 300 MWth and for refineries;
   - on an overall basis for other combustion plants to which this Directive applies,
2. The methodology used for these inventories shall be consistent with that used to determine SO_2 and NO_x emissions from combustion plants in 1980,
3. The results of this inventory shall be communicated to the Commission in a conveniently aggregated form within nine months from the end of the year considered, The methodology used for establishing such emission inventories and the detailed base information shall be made available to the Commission at its request,
4. The Commission shall organize a systematic comparison of such national inventories and, if appropriate, shall submit proposals to the Council aiming at harmonizing emission inventory methodologies, for the needs of an effective implementation of this Directive,

Requirements from the IE Directive

ANNEX V

Technical provisions relating to combustion plants

PART 1

*Emission limit values for combustion plants referred to in Article 30(2)*1,

1. All emission limit values shall be calculated at a temperature of 273,15 K, a pressure of 101,3 kPa and after correction for the water vapour content of the waste gases and at a standardised O_2 content of 6 % for solid fuels, 3 % for combustion plants, other than gas turbines and gas engines using liquid and gaseous fuels and 15 % for gas turbines and gas engines, 2,
2. Emission limit values (mg/Nm3) for SO2 for combustion plants using solid or liquid fuels with the exception of gas turbines and gas engines

Total rated thermal input (MW)	Coal and lignite and other solid fuels	Biomass	Peat	Liquid fuels
50-100	400	200	300	350
100-300	250	200	300	250
> 300	200	200	200	200

Combustion plants, using solid fuels which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003, and which do not operate more than 1 500 operating hours per year as a rolling average over a period of 5 years, shall be subject to an emission limit value for SO2 of 800 mg/Nm3,

Combustion plants using liquid fuels, which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003, and which do not operate more than 1 500 operating hours per year as a rolling average over a period of 5 years, shall be subject to an emission limit value for SO2 of 850 mg/Nm3 in case of plants with a total rated thermal input not exceeding 300 MW and of 400 mg/Nm3 in case of plants with a total rated thermal input greater than 300 MW,

A part of a combustion plant discharging its waste gases through one or more separate flues within a common stack, and which does not operate more than 1 500 operating hours per year as a rolling average over a period of 5 years, may be subject to the emission limit values set out in the preceding two paragraphs in relation to the total rated thermal input of the entire combustion plant, In such cases the emissions through each of those flues shall be monitored separately,

3. Emission limit values (mg/Nm3) for SO2 for combustion plants using gaseous fuels with the exception of gas turbines and gas engines

In general	35
Liquefied gas	5
Low calorific gases from coke oven	400
Low calorific gases from blast furnace	200

Combustion plants, firing low calorific gases from gasification of refinery residues, which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003, shall be subject to an emission limit value for SO2 of 800 mg/Nm3,

4. Emission limit values (mg/Nm3) for NO_x for combustion plants using solid or liquid fuels with the exception of gas turbines and gas engines

Total rated thermal input (MW)	Coal and lignite and other solid fuels	Biomass and peat	Liquid fuels
50-100	300 450 in case of pulverised lignite combustion	300	450
100-300	200	250	200 (1)
> 300	200	200	150 (1)

Note: (1) The emission limit value is 45o mg/Nm3 for the firing of distillation and conversion residues from the refining of crude-oil for own consumption in combustion plants with a total rated thermal input not exceeding 500 MW which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003,

Combustion plants in chemical installations using liquid production residues as non-commercial fuel for own consumption with a total rated thermal input not exceeding 500 MW which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003, shall be subject to an emission limit value for NO_x of 450 mg/Nm^3,

Combustion plants using solid or liquid fuels with a total rated thermal input not exceeding 500 MW which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003, and which do not operate more than 1 500 operating hours per year as a rolling average over a period of 5 years, shall be subject to an emission limit value for NO_x of 450 mg/Nm^3,

Combustion plants using solid fuels with a total rated thermal input greater than 500 MW, which were granted a permit before 1 July 1987 and which do not operate more than 1 500 operating hours per year as a rolling average over a period of 5 years, shall be subject to an emission limit value for NO_x of 450 mg/Nm^3,

Combustion plants using liquid fuels, with a total rated thermal input greater than 500 MW which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003, and which do not operate more than 1 500 operating hours per year as a rolling average over a period of 5 years, shall be subject to an emission limit value for NO_x of 400 mg/Nm^3,

A part of a combustion plant discharging its waste gases through one or more separate flues within a common stack, and which does not operate more than 1 500 operating hours per year as a rolling average over a period of 5 years, may be subject to the emission limit values set out in the preceding three paragraphs in relation to the total rated thermal input of the entire combustion plant, In such cases the emissions through each of those flues shall be monitored separately,

5. Gas turbines (including combined cycle gas turbines (CCGT)) using light and middle distillates as liquid fuels shall be subject to an emission limit value for NO_x of 90 mg/Nm^3 and for CO of 100 mg/Nm^3,

   Gas turbines for emergency use that operate less than 500 operating hours per year are not covered by the emission limit values set out in this point, The operator of such plants shall record the used operating hours,

6. Emission limit values (mg/Nm^3) for NO_x and CO for gas fired combustion plants

	NO_x	CO
Combustion plants firing natural gas with the exception of gas turbines and gas engines	100	100
Combustion plants firing blast furnace gas, coke oven gas or low calorific gases from gasification of refinery residues, with the exception of gas turbines and gas engines	200 (4)	—
Combustion plants firing other gases, with the exception of gas turbines and gas engines	200 (4)	—
Gas turbines (including CCGT), using natural gas (1) as fuel	50 (2) (3)	100
Gas turbines (including CCGT), using other gases as fuel	120	—
Gas engines	100	100

Notes:

(1) Natural gas is naturally occurring methane with not more than 20 % (by volume) of inerts and other constituents,

(2) 75 mg/Nm3 in the following cases, where the efficiency of the gas turbine is determined at ISO base load conditions:

I. Gas turbine, used in combined heat and power systems having an overall efficiency greater than 75 %,

II. Gas turbine, used in combined cycle plants having an annual average overall electrical efficiency greater than 55 %,

III. Gas turbine for mechanical drives,

(3) For single cycle gas turbines not falling into any of the categories mentioned under note (2), but having an efficient greater than 35 % - determined at ISO base load conditions – the emission limit value for NO_x shall be 50 xη/35 where η is the gas turbine efficiency at ISO base load conditions expressed as a percentage,

(4) 300 mg/Nm^3 for such combustion plants with a total rated thermal input not exceeded 50 MW which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date provided that the plant was put into operation no later than 27 November 2003,

For gas turbines (including CCGT), the NOx and CO emission limit values set out in the table contained in this point apply only above 70 % load,

For gas turbines (including CCGT) which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003, and which do not operate more than 1 500 operating hours per year as a rolling average over a period of 5 years, the emission limit value for NO_x is 150 mg/Nm3 when firing natural gas and 200 mg/Nm^3 when firing other gases or liquid fuels,

A part of a combustion plant discharging its waste gases through one or more separate flues within a common stack, and which does not operate more than 1 500 operating hours per year as a rolling average over a period of 5 years, may be subject to the emission limit values set out in the preceding paragraph in relation to the total rated thermal input of the entire combustion plant, In such cases the emissions through each of those flues shall be monitored separately,

Gas turbines and gas engines for emergency use that operate less than 500 operating hours per year are not covered by the emission limit values set out in this point, The operator of such plants shall record the used operating hours,

7. Emission limit values (mg/Nm^3) for dust for combustion plants using solid or liquid fuels with the exception of gas turbines and gas engines

Total rated thermal input (MW)	Coal and lignite and other solid fuels	Biomass and peat	Liquid fuels (1)
50-100	30	30	30
100-300	25	20	25
> 300	20	20	20

Note:

(1) The emission limit value is 50 mg/Nm^3 for the firing of distillation and conversion residues from the refining of crude oil for own consumption in combustion plants which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003,

8. Emission limit values (mg/Nm3) for dust for combustion plants using gaseous fuels with the exception of gas turbines and gas engines

In general	5
Blast furnace gas	10
Gases produced by the steel industry which can be used elsewhere	30

PART 2

*Emission limit values for combustion plants referred to in Article 30(3)*1,

1. All emission limit values shall be calculated at a temperature of 273,15 K, a pressure of 101,3 kPa and after correction for the water vapor content of the waste gases and at a standardized O_2 content of 6 % for solid fuels, 3 % for combustion plants other than gas turbines and gas engines using liquid and gaseous fuels and 15 % for gas turbines and gas engines,

   In case of combined cycle gas turbines with supplementary firing, the standardized O_2 content may be defined by the competent authority, taking into account the specific characteristics of the installation concerned,

2. Emission limit values (mg/Nm^3) for SO_2 for combustion plants using solid or liquid fuels with the exception of gas turbines and gas engines

Total rated thermal input (MW)	Coal and lignite and other solid fuels	Biomass	Peat	Liquid fuels
50-100	400	200	300	350
100-300	200	200	300 250 in case of fluidized bed combustion	200
> 300	150 200 in case of circulating or pressurized fluidized bed combustion	150	150 200 in case of fluidized bed combustion	150

3. Emission limit values (mg/Nm3) for SO_2 for combustion plants using gaseous fuels with the exception of gas turbines and gas engines

In general	35
Liquefied gas	5
Low calorific gases from coke oven	400
Low calorific gases from blast furnace	200

4. Emission limit values (mg/Nm^3) for NO^x for combustion plants using solid or liquid fuels with the exception of gas turbines and gas engines

Total rated thermal input (MW)	Coal and lignite and other solid fuels	Biomass and peat	Liquid fuels
50-100	300 400 in case of pulverized lignite combustion	250	300
100-300	200	200	150
> 300	150 200 in case of pulverized lignite combustion	150	100

5. Gas turbines (including CCGT) using light and middle distillates as liquid fuels shall be subject to an emission limit value for NO_x of 50 mg/Nm^3 and for CO of 100 mg/Nm^3

   Gas turbines for emergency use that operate less than 500 operating hours per year are not covered by the emission limit values set out in this point, The operator of such plants shall record the used operating hours,

6. Emission limit values (mg/Nm^3) for NO_x and CO for gas fired combustion plants

	NO_x	CO
Combustion plants other than gas turbines and gas engines	100	100
Gas turbines (including CCGT)	50 (1)	100
Gas engines	75	100

Note:

(1) For single cycle gas turbines having efficiency greater than 35 % - determined at ISO base load conditions – the emission limit value of NO_x, shall be 50 50xη/35 where η is the gas turbine efficiency at ISO base load conditions expressed as percentage,

For gas turbines (including CCGT), the NOx and CO emission limit values set out in this point apply only above 70 % load,

Gas turbines and gas engines for emergency use that operate less than 500 operating hours per year are not covered by the emission limit values set out in this point, The operator of such plants shall record the used operating hours,

7. Emission limit values (mg/Nm3) for dust for combustion plants using solid or liquid fuels with the exception of gas turbines and gas engines

Total rated thermal input (MW)	
50-300	20
> 300	10 20 for biomass and peat

8. Emission limit values (mg/Nm3) for dust for combustion plants using gaseous fuels with the exception of gas turbines and gas engines

In general	5
Blast furnace gas	10
Gases produced by the steel industry which can be used elsewhere	30

PART 3

Emission monitoring

1. The concentrations of SO_2, NO_x and dust in waste gases from each combustion plant with a total rated thermal input of 100 MW or more shall be measured continuously,
   The concentration of CO in waste gases from each combustion plant firing gaseous fuels with a total rated thermal input of 100 MW or more shall be measured continuously, 2,
2. The competent authority may decide not to require the continuous measurements referred to in point 1 in the following cases:
   (a) for combustion plants with a life span of less than 10 000 operational hours;
   (b) for SO_2 and dust from combustion plants firing natural gas;
   (c) for SO_2 from combustion plants firing oil with known sulphur content in cases where there is no waste gas desulphurisation equipment;
   (d) for SO_2 from combustion plants firing biomass if the operator can prove that the SO_2 emissions can under no circumstances be higher than the prescribed emission limit values,
3. Where continuous measurements are not required, measurements of SO_2, NO_x, dust and, for gas fired plants, also of CO shall be required at least once every 6 months,
4. For combustion plants firing coal or lignite, the emissions of total mercury shall be measured at least once per year,
5. As an alternative to the measurements of SO_2 and NO_x referred to in point 3, other procedures, verified and approved by the competent authority, may be used to determine the SO_2 and NO_x emissions, Such procedures shall use relevant CEN standards or, if CEN standards are not available, ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality,
6. The competent authority shall be informed of significant changes in the type of fuel used or in the mode of operation of the plant, The competent authority shall decide whether the monitoring requirements laid down in points 1 to 4 are still adequate or require adaptation,
7. The continuous measurements carried out in accordance with point 1 shall include the measurement of the oxygen content, temperature, pressure and water vapor content of the waste gases, The continuous measurement of the water vapor content of the waste gases shall not be necessary, provided that the sampled waste gas is dried before the emissions are analyzed,
8. Sampling and analysis of relevant polluting substances and measurements of process parameters as well as the quality assurance of automated measuring systems and the reference measurement methods to calibrate those systems shall be carried out in accordance with CEN standards, If CEN standards are not available, ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality shall apply,
   The automated measuring systems shall be subject to control by means of parallel measurements with the reference methods at least once per year,
   The operator shall inform the competent authority about the results of the checking of the automated measuring systems,
9. At the emission limit value level, the values of the 95 % confidence intervals of a single measured result shall not exceed the following percentages of the emission limit values:

Carbon monoxide	10 %
Sulphur dioxide	20 %
Nitrogen oxides	20 %
Dust	30 %

10. The validated hourly and daily average values shall be determined from the measured valid hourly average values after having subtracted the value of the confidence interval specified in point 9,
    Any day in which more than three hourly average values are invalid due to malfunction or maintenance of the automated measuring system shall be invalidated, If more than 10 days over a year are invalidated for such situations the competent authority shall require the operator to take adequate measures to improve the reliability of the automated measuring system,
11. In the case of plants which must comply with the rates of desulphurisation referred to in Article 31, the sulphur content of the fuel which is fired in the combustion plant shall also be regularly monitored, The competent authorities shall be informed of substantial changes in the type of fuel used,

PART 4

Assessment of compliance with emission limit values 1,

1. In the case of continuous measurements, the emission limit values set out in Parts 1 and 2 shall be regarded as having been complied with if the evaluation of the measurement results indicates, for operating hours within a calendar year, that all of the following conditions have been met:
   (a) no validated monthly average value exceeds the relevant emission limit values set out in Parts 1 and 2;
   (b) no validated daily average value exceeds 110 % of the relevant emission limit values set out in Parts 1 and 2;
   (c) in cases of combustion plants composed only of boilers using coal with a total rated thermal input below 50 MW, no validated daily average value exceeds 150 % of the relevant emission limit values set out in Parts 1 and 2,
   (d) 95 % of all the validated hourly average values over the year do not exceed 200 % of the relevant emission limit values set out in Parts 1 and 2,

   The validated average values are determined as set out in point 10 of Part 3,

   For the purpose of the calculation of the average emission values, the values measured during the periods referred to in Article 30(5) and (6) and Article 37 as well as during the start-up and shut-down periods shall be disregarded,

2. Where continuous measurements are not required, the emission limit values set out in Parts 1 and 2 shall be regarded as having been complied with if the results of each of the series of measurements or of the other procedures defined and determined according to the rules laid down by the competent authorities do not exceed the emission limit values,

PART 5

Minimum rate of desulphurisation

1. Minimum rate of desulphurisation for combustion plants referred to in Article 30(2)

Total rated thermal input (MW)	Minimum rate of desulphurisation	
	Plants which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003	Other plants
50-100	80 %	92 %
100-300	90 %	92 %
> 300	96 % (1)	96 %

Note:

(1) For combustion plants firing oil shale, the minimum rate of desulphurisation is 95 %,

2. Minimum rate of desulphurisation for combustion plants referred to in Article 30(3)

Total rated thermal input (MW)	Minimum rate of desulphurisation
50-100	93 %
100-300	93 %
> 300	97 %

PART 6

Compliance with rate of desulphurisation

The minimum rates of desulphurisation set out in Part 5 of this Annex shall apply as a monthly average limit value.

PART 7

Average emission limit values for multi-fuel firing combustion plants within a refinery

Average emission limit values (mg/Nm^3) for SO_2 for multi-fuel firing combustion plants within a refinery, with the exception of gas turbines and gas engines, which use the distillation and conversion residues from the refining of crude-oil for own consumption, alone or with other fuels:

(a) for combustion plants which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003: 1 000 mg/Nm^3;

(b) for other combustion plants: 600 mg/Nm^3,

These emission limit values shall be calculated at a temperature of 273,15 K, a pressure of 101,3 kPa and after correction for the water vapor content of the waste gases and at a standardized O_2 content of 6 % for solid fuels and 3 % for liquid and gaseous fuels.