2010

Emission Controls at Kosova's Thermal Power Plants, Current and Future Capabilities : [presentation given February 22, 2010]

Skender Isufi

AMERICAN UNIVERSITY IN KOSOVO

Master of Science Program in Energy & Resource Development Public Service

Project Title:

"Emission Controls at Kosova's Thermal Power Plants, Current and Future Capabilities"

"Submitted as a Capstone Project in partial fulfillment of a Master of Science Degree in Professional Studies at the RIT Center for Multidisciplinary Studies"

Skender ISUFI

Date of submission:
22nd of February, 2010

Acknowledgement

I would like to thank Professor Brian Bowen, my mentor, for his continuous and valuable advices and direction throughout this capstone. I would also like to emphasis the support and help of my colleagues at work Mr. Bashkim Gjurgjeala and Mr. Agim Morina.

Finally I am thankful to my wife and my sons for their patience and understanding.

Table of Contents

List of tables and figures

ABSTRACT

The operation of Kosova's Thermal Power Plants (TPP) from the time of their construction had the goal of supplying of Kosova with electricity and also sometimes exporting to parts of old Yugoslavia. This contributed significantly in developing the Kosova's economy but as with all coal-fired power plants it added to the problem of environmental pollution. This project provides great assistance for promoting environmental protection and assesses the best new power plant technologies available.

This capstone project assesses the levels of atmospheric emissions (dust, SO_2, CO_2 and NOx) from the existing TPP's in Kosova and the projections of future emissions until the existing plants are decommissioned and new power plants becomes operational. Also the project addresses the necessary measures to reduce the pollution and analyze the impact of atmospheric emissions on the environment from the proposed new TPP, which is planned to be constructed in Kosova in the next few years.

In order to represent a range of long-term planning option, this capstone project discusses the above from the perspective of four broad scenarios for the period 2010-2030. These four scenarios are:

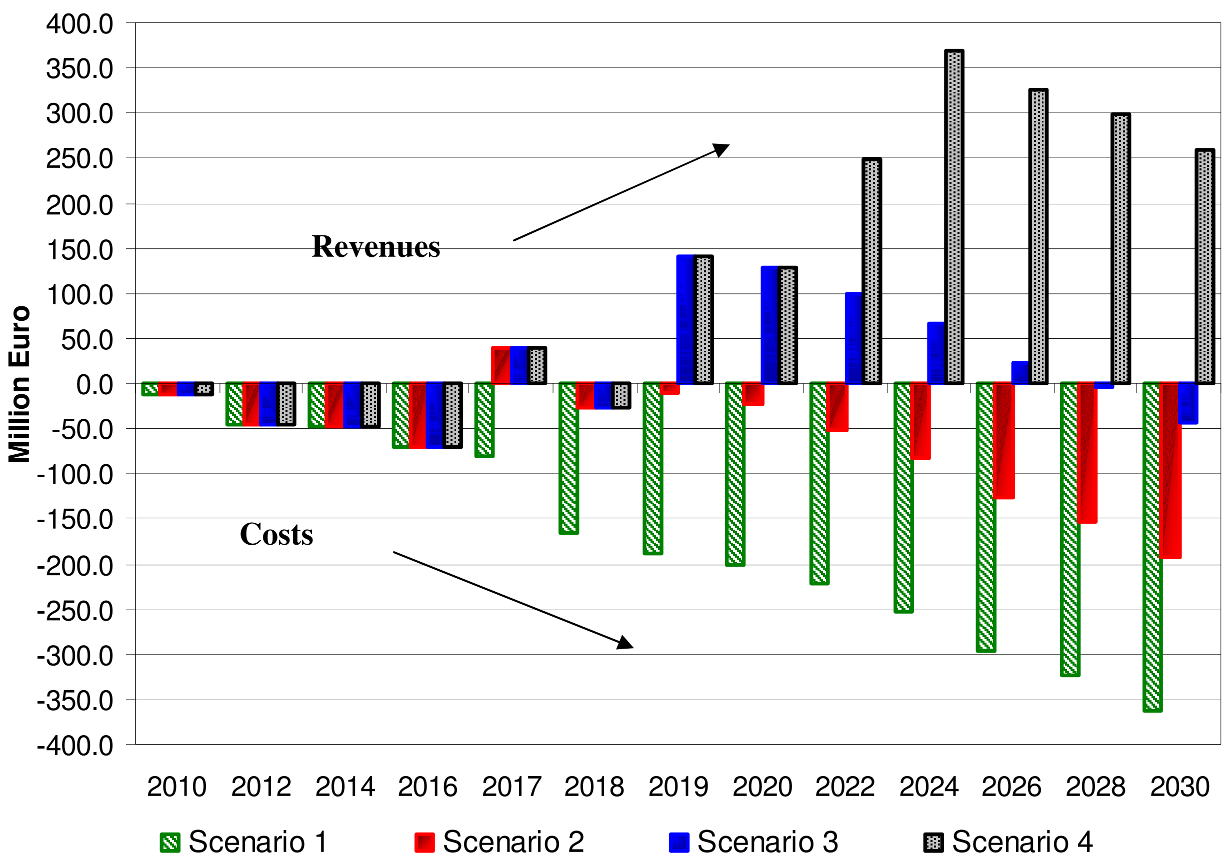
- Scenario 1 – the existing TPP (Kosova A and B) with no new generation capacity and without abatement measures;
- Scenario 2 – the existing TPP with abatement measures (upgrading the electrostatic precipitators - ESP, only for TPP B), construction of the new HPP Zhur 293MW and new TPP Kosova C with capacity 1x500MW;
- Scenario 3 – the existing TPP with abatement measures (upgrading the electrostatic precipitators - ESP, only for TPP B), construction of the new HPP Zhur 293MW and new TPP Kosova C with capacity 2x500MW; and

- Scenario 4 – the existing TPP with abatement measures (upgrading the electrostatic precipitators - ESP, only for TPP B), construction of the new HPP Zhur 293MW and new TPP Kosova C with capacity 4x500MW.

In all four scenarios it is assumed that TPP Kosova A will be decommissioned by 2017.

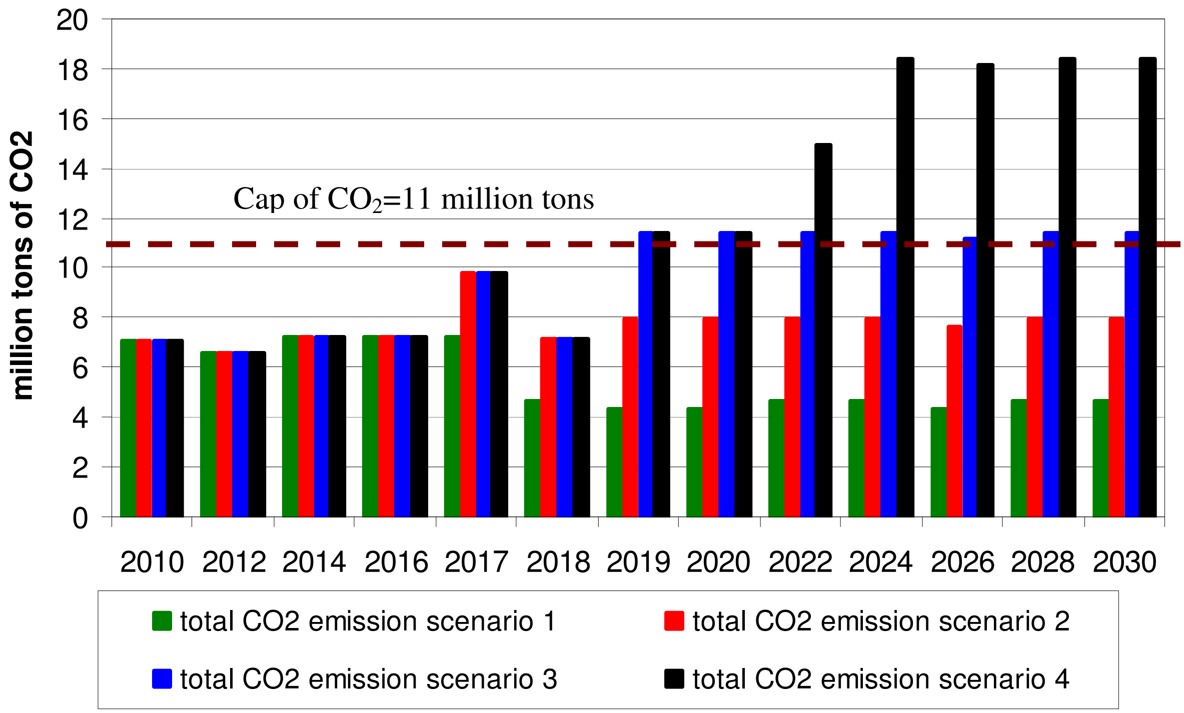
From the financial analysis of four scenarios presented in the capstone, the deficit or surplus of electricity may cost or benefit a considerable amount of money. The following figure presents the potential earnings from exports (scenario 3 and 4) and potential expenses from the electricity imports (scenario 1 and 2).

Costs or revenues from net import or net export of electricity for all scenarios



The total CO_2 emissions for all scenarios show that intensive power generation reflects higher emissions. The consequences of extending the limits of CO_2 emissions may cost the considerable expenses having in mind that the credits for CO_2 in the future will be high.

Cost of CO_2 allowances



CHAPTER 1

PROBLEM BACKGROUND

1.1. Brief Description of KEK

The Kosovo Energy Corporation–KEK consists of four main core divisions, Coal Production, Generation, Network and Supply Division, and other non-core divisions, necessary for a company to carry on the business like, Procurement Division, Financial Division, Legal and Human Resource Division. The Generation Division, the focus of interest for this Capstone, is responsible for electricity generation and consists of two Thermal Power Plants (TPP) Kosova A (with five units) and Kosova B (two units), the Engineering Department, Central Maintenance Department and Support Business Department. Generation Division has approximately 1600 employees.

The construction of units were done in the period from 1962-84 and the technology used was in accordance to the environmental standards of that period. The aging of units and their maintenance and rehabilitation was not followed by the new requirements regarding the environmental air emissions standards. The installed capacity of existing TPP's in Kosova is presented in the following table.

Table 1.1. Installed capacity of TPP Kosova A and Kosova B

Units	Year of commissioning	Installed capacity	Maximum Available Gross Capacity	Maximum Gross Capacity after 2009*
		(MW)	*(MW)*	*(MW)*
A1	1962	65	0	0
A2	1964	125	0	0
A3	1970	200	150	150
A4	1971	200	0	150
A5	1975	210	150	150
B1	1983	339	265	300
B2	1984	339	285	300

** – after replacement of low pressure turbine rotors in both units of TPP Kosova B planned for 2010 the power capacity of units B1 and B2 will be increased.*

The units A1 and A2 of the TPP Kosova A have been out of operation for a long time. Unit A1 is not in operations since 2007, while A2 since 2001. In the units A3, A4 and A5, there were implemented major overhauls in the years, 2006, 2007 and respectively 2008, and now they are operating with certain reliability with the maximum gross production capacity up to $150MW_e$ each, depending on the demand. The thermal capacity of units A3, A4 and A5 is about $550MW_{th}$ each. The operating and maintenance condition of Kosova A units is relatively good having in mind their aging. Their efficiency is relatively low 20-27%.

The units B1 and B2 belong to the second largest power plant in Kosova. The thermal capacity for a unit is about $850MW_{th}$ each. The original design gross power capacity is $339MW_e$ per unit. After recent investments, the total net maximum capacity will be $300MW_e$ each. Both units have operated more than 130,000 hours since their commissioning. The efficiency of these units is 30–35%.

The electricity production for the past eight years shows an increase in electricity generation in both power plants. On the other hand the demand growth is increasing rapidly. The domestic generation of electricity couldn't meet demand in Kosova therefore the need for imports of electricity were always present. In the Table 1.2., is presented the electricity generation from thermal power plants, hydro power plant Ujman, demand and net import (import-export).

Table 1.2. The electricity generation and demand in Kosova, 2001-2008 [1]

	Year	2001	2002	2003	2004	2005	2006	2007	2008
Domestic Electricity Generation	***GWh***	**2,568**	**3,153**	**3,262**	**3,501**	**3,999**	**3,972**	**4,358**	**4,549**
TCA	*GWh*	1,025	1,134	1,582	864	645	899	1,249	1,235
TCB	*GWh*	1,452	1,939	1,629	2,524	3,244	2,973	3,016	3,260
Hydro	*GWh*	91	80	51	112	110	100	94	53
Thermo	*GWh*	2,477	3,073	3,211	3,389	3,889	3,871	4,264	4,495
Net import*	***GWh***	**544**	**168**	**358**	**445**	**260**	**286**	**267**	**417**
Available electricity**	***GWh***	**3,112**	**3,321**	**3,621**	**3,946**	**4,259**	**4,258**	**4,625**	**4,966**

** net import = import – export*
*** available electricity = domestic electricity generation + net import*

1.2. Type of fuel

The Kosova lignite resource is considered as one of most favorable lignite deposits in Europe due to its geological condition with coal seam thickness of 56-70m and limited overburden of 60-120m. The average stripping ratio is 1.7 cubic meter to 1 ton of lignite [3]. The total estimated reserves of approximately 10 billion tons represent one of the richest lignite sources in Europe, which will provide field for the expansion of future power generation.

The lignite is extracted in two opencast mines, Mirash and Bardh mine, with an average coal production of 7 to 8 million tones a year. For the past 40 years the mines were supplying coal to both power plants, and they are now in their end of life. For the next 3 to 4 years they will be emptied completely, and the lignite production will be done from the Sibovc South-West sector for Kosova B and respectively from the Sitnica sector for Kosova A Power Plant. Lignite is transported from the mines to the power plant storage yard with belt conveyers. The lignite consumption in both power plants, Kosova A and Kosova B, for the period 2001-2008 is presented in the following table.

Table. 1.3. Lignite consumption for TPP Kosova A and TPP Kosova, 2001-2008 [1]

	Year	2001	2002	2003	2004	2005	2006	2007	2008
Total Coal Consumption	*million ton*	**4.26**	**5.23**	**5.64**	**5.59**	**6.27**	**6.35**	**7.11**	**7.46**
TPP A	*million ton*	2.02	2.24	3.13	1.71	1.27	1.77	2.47	2.44
TPP B	*million ton*	2.23	2.98	2.50	3.88	4.99	4.57	4.64	5.02

The lignite of Kosova is characterized by high ash content and moderate sulphur content. Ash content is in the range 10-21%, while total sulfur content is 0.7-1.5% (organic sulfur is 0.1-0.5%)[2]. It is important to say that Kosova lignite contains also the calcium which in the combustion process creates natural desulphurization which reduces the impact of SO_2 emissions.

Samples from the lignite are taken daily and are analyzed at the Generation laboratory as well as in the INKOS laboratory for ash and water content. Based on these values is calculated the lower heat value as follows:

$$LHV = (100 – Ash (\%) – H_20 (\%)) x 314 - 4369 [kg/kJ]$$

Lower heat value of lignite is between 6500 - 9500kJ/kg.

In the Table 1.4 is presented comparison of characteristics of Kosova lignite with the lignite from some other countries.

Table 1.4. Lignite quality parameters for Kosova and some other countries [3]

Area	Ash	LHV*	Moisture	Sulphur	
	%	kJ/kg	%	% total	% combustible
Bardh mine	14.1	7860	47.7	0.98	0.34
Mirash West mine	14.4	7750	47.5	1.01	0.35
Mirash East (Sitnica)	19.9	7928	43.9	0.94	0.33
Sibovc mine	13.85	8149	47.8	0.91	0.32
Australia (Loy Yang mine)	1.5	8000	na	0.4	na
Bulgaria (Maritza mine)	12	6700	na	1.9	na
Germany (Rheine Lignite)	5	8900	na	0.3	na
Poland (Belchatov)	11	7800	na	0.6	na

**LHV-lower heat value*

The initial deformation temperature of ash during the combustion process is very important factor during the designing of steam generator. For the lignite of Kosova this temperature is in the range 910-1020ºC.

1.3. Kosovo's Power Plants and Environment

For the time when the power plants were constructed, the environmental protection requirements were not so much strict as they are today. The electrostatic precipitators (ESP) for Kosova B was designed to have dust emission of 260mg/Nm^3, while for units of Kosova A the ESP designed capacity for dust emission is 560mg/Nm^3. Actually there are no desulphurization equipments neither in Kosova A or B. Air emissions of dust (particulate matter), SO_2 and NOx from the units of Kosova A and Kosova B do not comply with the requirements of European Directive 2001/80/EC for Large Combustion Plants (LCP). Large Combustion Plants are combustion plants with the rated thermal input larger or equal to 50MW (irrespective to the fuel used, liquid, solid or gaseous).

In TPP Kosova A are not installed any measurement devices for continuous measurements of these pollutants. In TPP Kosova B the measuring device for dust emissions is installed but its operation is not reliable since the calibration of the device is not done. Therefore the emissions are calculated or estimated based on mass balance approach. Some indicative estimates are presented in the following table.

Table 1.5. Indicative emissions estimates for Kosova A and B [4]

	Dust emissions *(mg/Nm^3)*	NOx *(mg/Nm^3)*	SO_2 *(mg/Nm^3)*
For TPP Kosova A	700 – 1300	700	300
For TPP Kosova B	150 – 230	500	400

The problem of emission of greenhouse gas - CO_2 is inevitable within the operation of TPP's. This problem can be mitigated only be building the power capacities which do not use combustion process of fuels (in our case the impact of new HPP Zhur will be analyzed), or building the new capacities based on lignite fired TPP with higher efficiency, that means producing the same amount of electricity with lower consumption of lignite.

Regarding the emission limits from LCP according to the European Directive 2001/80/EC [5], the TPP of Kosova A and B falls in the group of "existing plants" and their emission limits will be as presented in the Table 1.6.

Table 1.6. The emission limits of LCP for solid fuels according to EU Directive [6]

	Dust emissions *(mg/Nm^3)*	NOx *(mg/Nm^3)*	SO_2 *(mg/Nm^3)*
Large Combustion Plants (LCP), >50 MW_{th}	<50	<500	<400
For TPP Kosova A	100	600	1200
For TPP Kosova B	50	500	400

1.4. Air Emission from Large Combustion Plants in Member States of European Union

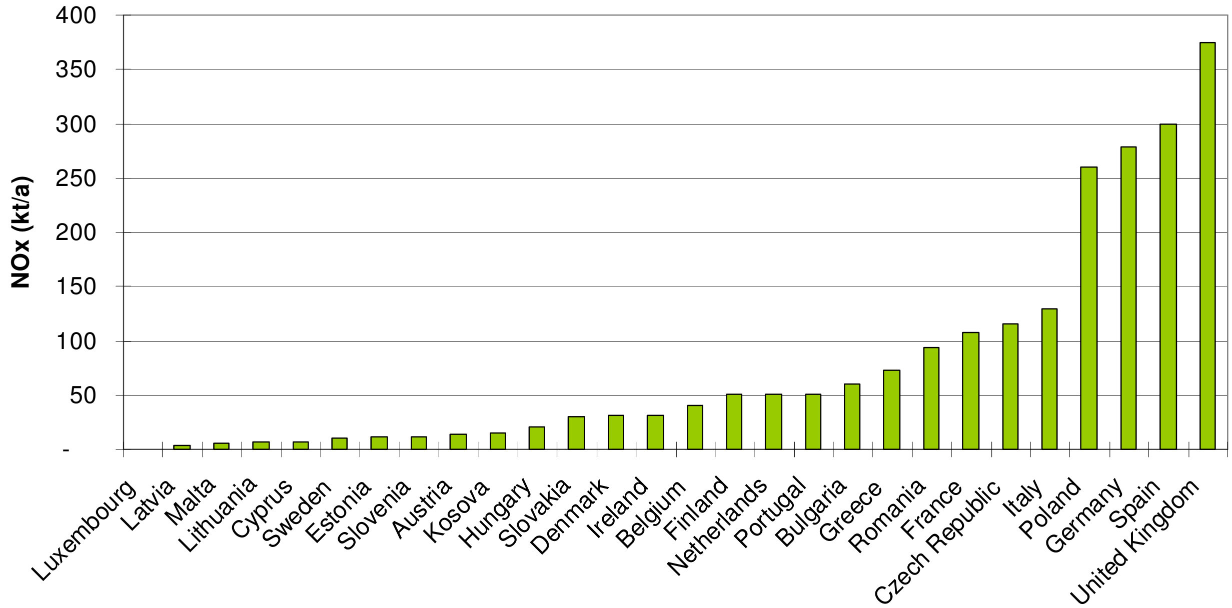
According to the European Commission report provided by Entec[6] for 2004 the total emissions of SO_2, NOx and dust from Large Combustion Plants-LCP under the Directive 2001/80/EC of European Union, from all Member States of EU are presented in the Table 1.7. The emissions of these pollutants from LCP of Kosova TPP are included in the table, with the purpose of presenting the Kosova position in this ranking.

Table 1.7. Total emission of SO_2, NOx and dust (in kilotons) for 2004 from LCP of European Union Member States [6] and Kosova

Countries of EU[6] and Kosova	SO_2 *kilotons*	NOx *kilotons*	Dust *kilotons*	Number of LCP facilities (>50MW_{th})
Austria	8	14	0.98	80
Belgium	49	41	4.64	99
Bulgaria	785	60	22.4	29
Cyprus	31	7	0.5	3
Czech Republic	159	116	5.43	123
Denmark	11	31	1.04	31
Estonia	78	12	17.7	13
Finland	40	51	2.91	189
France	214	108	11.8	268
Germany	230	279	12.5	606
Greece	372	73	52.2	37
Hungary	97	21	3.16	45
Ireland	49	31	9.83	18
Italy	193	130	7.02	401
Kosova	3.94	14.6	9.46	5
Latvia	2	3.3	0.05	22
Lithuania	16	6.5	0.28	37
Luxembourg	-	-	-	-
Malta	12	5.4	0.75	10
Netherlands	31	51	0.74	143
Poland	747	260	46.4	94
Portugal	103	51	3.47	23
Romania	493	94	26.1	176
Slovakia	73	30	8.56	73
Slovenia	40	12	2.31	8
Spain	1002	300	33.7	124
Sweden	7.6	10	0.7	156
United Kingdom	539	374	13	241

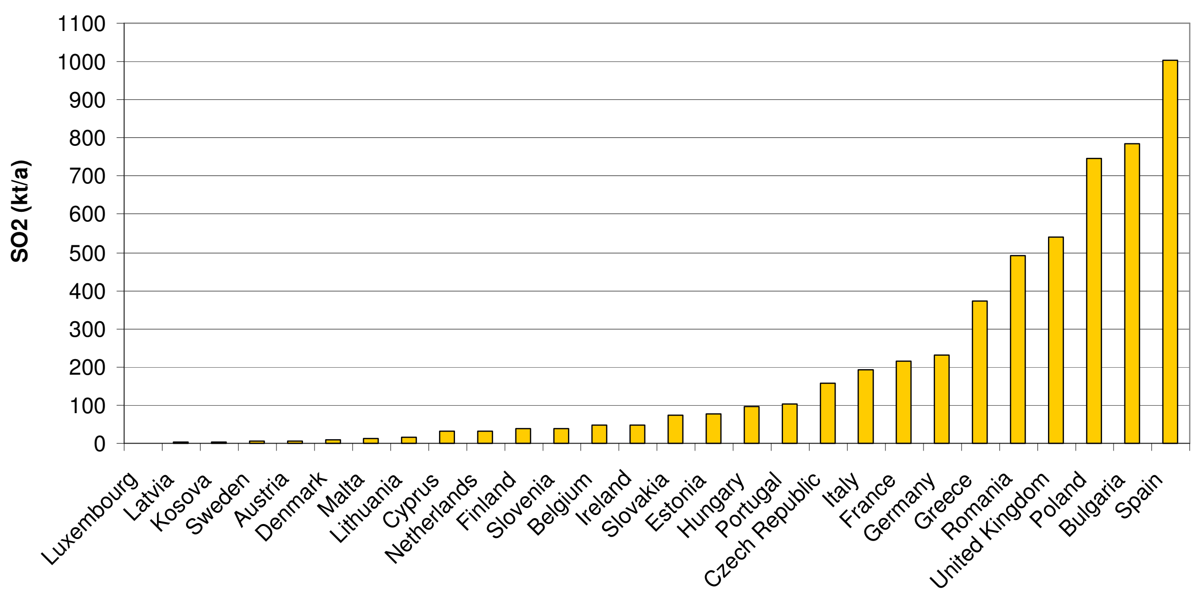
From the comparison of total emissions from LCP of Kosova with the emissions from LCP of 27 EU Member States it can be shown that SO_2 and NOx emissions are not too high, while dust emissions are higher.

Figure 1.1. Total NOx emissions (in kt/a)* for 2004 for reported LCP of EU Member States [6] and the Kosova LCP emission estimations



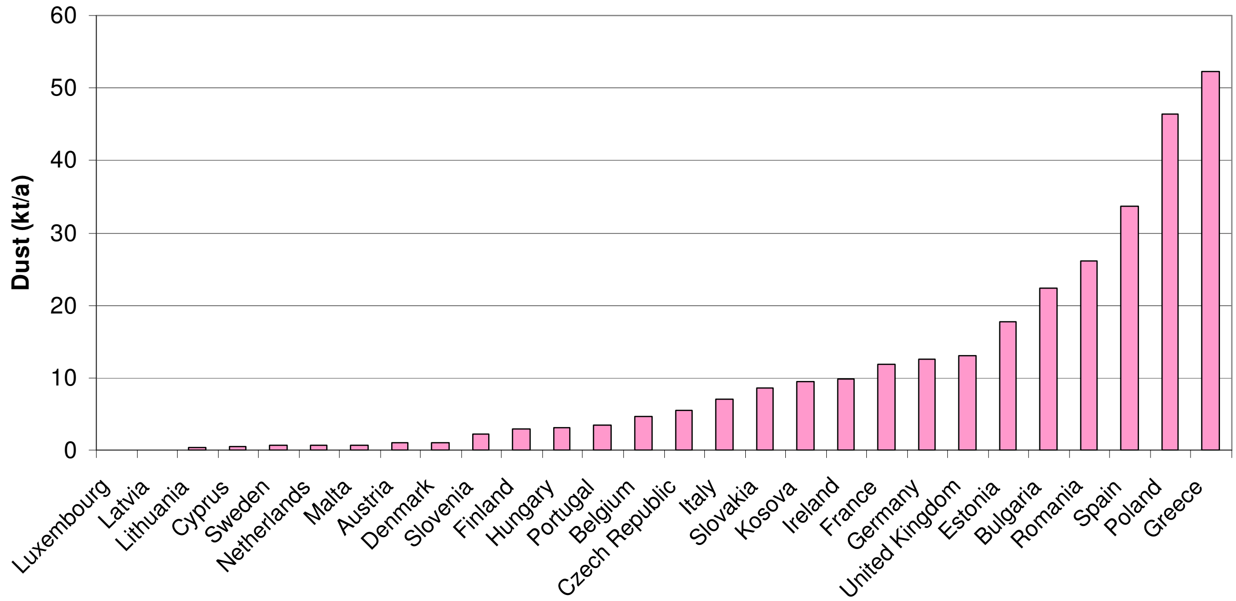
** kt/a – kilotons/year*

Figure 1.2. Total SO_2 emissions (in kt/a)* for 2004 for reported LCP of EU Member States [6] and the Kosova LCP emission estimations



** kt/a – kilotons/year*

Figure 1.3. Total dust emissions (in kt/a)* for 2004 for reported LCP of EU Member States [6] and the Kosova LCP emission estimations



** kt/a – kilotons/year*

In the Table 1.8 are presented the contribution of 25EU Member States to CO_2 emissions from combustion installations with capacity over $50MW_{th}$, based on The European Pollution Emission Register (EPER), emission inventory for the year 2004, and the CO_2 emission calculation from Kosova TPP for 2004.

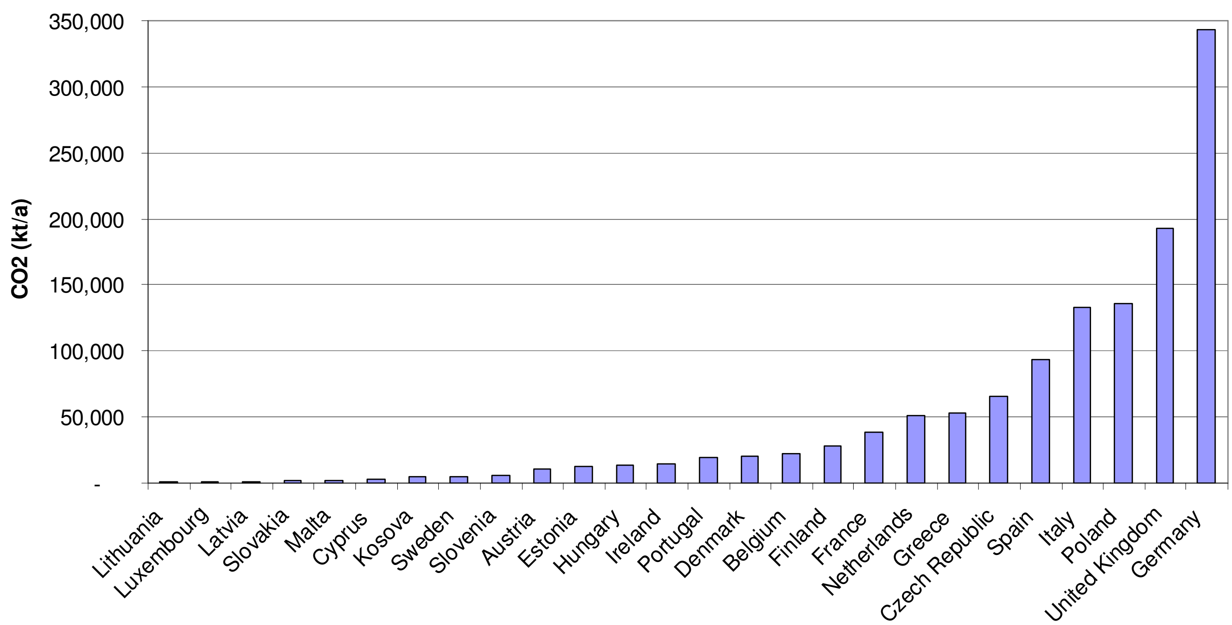
Table 1.8. Total CO_2 emission form combustion installation with capacity over $50MW_{th}$ based on EPER inventory[7] for 2004 and Kosova CO_2 estimation.

25 EU Member States[7] and Kosova	CO_2 emissions	Share
	million ton	%
Lithuania	0.52	0.04%
Luxembourg	0.98	0.08%
Latvia	1.16	0.09%
Slovakia	1.89	0.15%
Malta	1.96	0.15%
Cyprus	3.25	0.26%
Kosova	4.56	0.36%
Sweden	5.09	0.40%
Slovenia	6.09	0.48%
Austria	10.56	0.83%
Estonia	12.05	0.95%
Hungary	13.78	1.08%

Ireland	14.71	1.16%
Portugal	19.36	1.52%
Denmark	20.08	1.58%
Belgium	22.25	1.75%
Finland	28.02	2.20%
France	38.89	3.06%
Netherlands	51.56	4.06%
Greece	53.38	4.20%
Czech Republic	65.88	5.18%
Spain	93.69	7.37%
Italy	133.26	10.49%
Poland	135.92	10.70%
United Kingdom	193.20	15.20%
Germany	343.15	27.01%
Total	1,270.65	100%

The share of Kosova for CO_2 emission is relatively low, only 0.36%.

Figure 1.4. Total CO_2 (in kt/a)* emission form combustion installation with capacity over 50MW based on EPER inventory[7] for 2004 and Kosova CO_2 emission estimation.



** kt/a – kilotons/year*

CHAPTER 2

INTRODUCTION OF TYPES OF AIR EMISSIONS AND GREENHOUSE GASES

2.1. Nitrogen Oxides

Nitrogen oxides (NOx) are formed during combustion of fuel (in our case lignite) by the oxidation of molecules of nitrogen in combustion air and nitrogen contained in fuel itself, and mainly they are nitric oxide (NO) and nitrogen dioxide (NO_2) together referred as NOx.

According to the Power Station Emission Handbook [8] the NOx formation during combustion processes can be from three mechanisms;

- *thermal NOx – formation is highly dependent on gas temperature. Nitrogen is rapidly oxidized to NO and NO_2 once gas temperatures rise above 1700ºC formation of thermal NOx in coal fired boiler is dependent on two conditions occurring simultaneously in combustion zone: high temperature and an excess of combustion air. This mechanism is happening mostly with the combustion of natural gas.*
- *fuel NOx – is formed by oxidation of nitrogen compounds contained in coal. This formation mechanism is very complex and there is no direct correlation between nitrogen content and NOx emission. Coals with high nitrogen content may not necessarily be high NOx emitters, and*
- *prompt NOx – is formed at the flame front through reaction of hydrocarbon radicals. The contribution of prompt NOx to overall NOx is considered to be with low importance*

2.2. Sulfur Dioxide

Combustion of coal containing the sulfur results in emissions of SO_2. About 95% of the sulphur in the coal will be emitted as SO_2, the rest will be emitted as other forms of chemical compounds of sulphur.

Emission estimation of sulphur can be done using mass balance approach, emission factors, manual stack survey or by direct measurements.

Emission estimation of SO2 is determined by stoichiometric relation of chemical reactions[9],

$$S + O_2 = SO_2 \text{ or,}$$

$$1 \text{ mol } S + 1 \text{ mol } O_2 = 1 \text{ mol } SO_2$$

Having in regard that molecular mass of sulfur is S=32 while for oxygen is O=16 follows

$$32kg\ S + 32kg\ O_2 = 64kg\ SO_2,$$

respectively, dividing by 32 kg comes that for 1 kg S it is produced 64/32=2 kg SO_2.

2.3. Dust

Dust (particulate matters) from coal fired power plants depend on boiler firing configuration, boiler operation and from coal properties. The emission of dust for the coal with high percentage of ash depends more on the fuel ash content than on combustion efficiency. In contrast, the fuel with low ash content depend more on the combustion efficiency.

Controlling of the dust emissions in most coal-fired power stations are done by using the electrostatic precipitators (ESP) or fabric filters. The efficiency of ESP can collect nearly 99.9% of dust created from fuel combustion (the designed efficiency of ESP in TPP B is 99.14%) [9]. Dust emissions can be estimated through direct measurements or continuous monitoring systems.

2.4. Carbon dioxide CO_2

Carbon dioxide (CO_2) is a greenhouse gas and is generated as a by-product of the combustion of fossil fuels. The CO_2 emission is calculated from total lignite used and according to the analysis of carbon content in fuel. This method of calculation is used in KEK, and based on the book "Efficiency of TPP" by Bashkim Gjurgjeala[9], from the following formula is calculated CO_2:

*CO_2 [tons/year] = Amount of lignite consumed for a given period [tons/year] * average content of Carbon in fuel [kg C/kg of lignite] * 44/12*

2.5. Available Data for Air Emission form Power Plants of Kosova A and B

The results of the calculation performed by KEK Environmental Sector at the Generation Division, for emission estimates of NOx, SO_2, dust and CO_2 from units of TPP Kosova A and TPP Kosova B for the period 2004 till 2008 are presented in the Table 2.1.

Air emissions for the power plants are calculated based on lignite characteristics and combustion process parameters. Kosova B power plant is provided with equipment for online monitoring of particulate, but the equipment is not calibrated or maintained therefore the emission are based on calculations.

Table 2.1. Emissions (*in tons/year*) from Kosova A and B power plants, 2004-2008

	Years / Units		2004	2005	2006	2007	2008
TPP Kosova A	**A1**	*SO_2*	5	253	27	-	-
		NOx	25	313	54		
		Particulate	22	222	37		
		CO_2	9,190	11,831	19,795	-	-
	A3	*SO_2*	263	-	832	986	2,455
		NOx	1,290	-	1,597	2,926	3,122
		Particulate	2,103		-	3,572	3,751
		CO_2	466,858	-	596,727	1,099,478	1,156,058
	A4	*SO_2*	106	-	-	920	1,302
		NOx	523	-	-	2,590	1,901
		Particulate	886	-	-	3,321	2,688
		CO_2	189,381	-	-	960,520	700,089
	A5	*SO_2*	425	2,168	1,310	11	309
		NOx	2,090	2,687	2,513	60	249
		Particulate	3,301	3,498	3,846	125	344
		CO_2	756,111	1,019,102	916,408	21,284	93,331
TPP Kosova B	**B1**	*SO_2*	1,713	4,875	2,376	1,444	3,858
		NOx	5,934	5,474	5,159	6,514	6,313
		Particulate	2,691	2,341	3,374	1,000	2,202
		CO_2	1,876,681	1,768,446	1,646,275	2,089,314	2,009,463
	B2	*SO_2*	1,348	5,942	2,964	1,108	4,576
		NOx	4,672	6,672	6,097	4,843	6,988
		Particulate	2,119	2,853	3,935	2,093	3,485
		CO_2	1,477,701	2,155,334	1,962,599	1,534,868	2,245,182

CHAPTER 3

PROJECT DESCRIPTION

The literature review form different sources and types like, books, reports and internet helped me to understand the concept of air emissions, their types and methods of calculation.

Mr Agim Morina and Mr. Bashkim Gjurgjeala, senior engineers in Analysis Sector of Generation Division in KEK, had made a significant contribution for this Capstone to gather the data for air emissions from thermal power plants of Kosova.

During the conversations and discussions with them, I learned that the emission factors that are used for the calculation of total air emissions for SO_2, NOx and dust are different for the units in Kosova B and A.

The first step of setting the model for this capstone was to decide, which are the possible scenarios for analysis of future emissions?

Based on recommendations and experience of engineers from Analysis Sector has been set the following:

- the maximum gross power for existing units of TPP Kosova A and Kosova B;
- the time availability for existing units;
- specific lignite consumption;
- emissions factors for the different pollutants; and
- the formulas for calculating the gross electricity, net electricity, coal consumption and air emissions.

This was the second step of Capstone.

The third step was to evaluate different technologies for new thermal power plant, their characteristics, and emission factors. The final step was to conduct the calculations

3.1. First step – Defining the scenarios for building the model

The direction to solve the problem of emission control from thermal power plants was to create the model with four scenarios that are going to take into the consideration the existing Kosova power capacities (thermal and hydro) and new planned power capacities (thermal and hydro) for the time period 2010 till 2030.

These four scenarios are:

- Scenario 1 – the existing TPP (Kosova A and B) with no new generation capacities and without abatement measures;
- Scenario 2 – the existing TPP (Kosova A and B) with abatement measures (upgrading the electrostatic precipitators – ESP and installing the low NOx burners, only for TPP B), construction of the new HPP Zhur 293MW and new TPP Kosova C with capacity 1x500MW;
- Scenario 3 – the existing TPP with abatement measures (upgrading the electrostatic precipitators - ESP, only for TPP B), construction of the new HPP Zhur 293MW and new TPP Kosova C with capacity 2x500MW;
- Scenario 4 – the existing TPP with abatement measures (upgrading the electrostatic precipitators - ESP, only for TPP B), construction of the new HPP Zhur 293MW and new TPP Kosova C with full capacity 4x500MW.

3.2. Second Step – Defining the characteristics of existing units

In power plant Kosova A, the units A3, A4 and A4 will be in operation until 2017, when the process of decommissioning will start. In Kosova B both units, B1 and B2 will be in operation.

The maximum average gross capacity for each unit of Kosova A will be 125MW. For Kosova B the maximum average capacity is 270MW. The self-consumption of electricity for the units is 9% each. This is the electricity that is used to run the machines (belt conveyers, coal feeders, mills, ventilators, pumps etc).

The load factor for the unit A3 is 0.7, for A4 is 0.6 and for unit A5 is 0.3. That means that most of the time one unit will be standby unit. Only during the winter times or during the overhauls in Kosova B power plant all three units of Kosova A will be in full operation. For Kosova B units the load factor is 0.8.

Specific lignite consumption based on the experience is 1.75 tons of lignite for production of 1MWh electricity for Kosova A units, while for Kosova B units is 1.4t/MWh. This is due to higher efficiency of units in Kosova B.

Based on the discussions with Mr Agim Morina it indicated that emission factor for dust, SO2, NOx is as follows:

For Dust: 4.76 kg/MWh for Kosova A units and 1.54 kg/MWh, for Kosova B units.

For SO_2: 2.73 kg/MWh for Kosova A units and 2.45 kg/MWh, for Kosova B units

For NOx: 2.3 kg/MWh for Kosova A units and 2.7 kg/MWh, for Kosova B units.

In the following table are given formulas for calculations (for example unit A3)

Table 3.1. Description of formulas used for calculation for units of TPP Kosova A

Item	Designation	Unit	Result
[1]	Average gross power	*MW*	125
[2]	Number of hours per year	*hours*	8760
[3]	Load factor	-	0.7
[4]	Gross electricity production	*GWh*	([1] x [2] x [3])/1000=766.5
[5]	Net electricity production	*GWh*	0.9 x [4]=689.9
[6]	Specific lignite consumption	*ton/MWh*	1.75
[7]	Lignite consumption	*kiloton*	[6] x [4]=1341.4
[8]	Ash content in the lignite	*%*	16
[9]	Ash production	*kiloton*	[8]/100 x [7]=214.6
[10]	Percentage of dust before the ESP	*%*	85
[11]	Efficiency of ESP	*%*	98
[12]	Dust emission through the stack	*ton*	[9] x [10]/100x ((100-[11])/100) x 1000=3648.5
[12*]	Specific dust emission	*kg/MWh*	[12]/[4]=4.76
[13]	Carbon content in the lignite	*%*	23
[14]	CO_2 emission	*kiloton*	[7] x [13]/100 x 44/12=1131.2
[15]	Organic sulfur content	*%*	0.26

[16]	SO_2 production	*ton*	[7] x [15]/100 x 2 x 1000=6975.3
[17]	Rate of self desulfurization	%	70
[18]	SO_2 emission	*ton*	[17] x (1-[17]/100)=2092.6
[19]	Specific emission for NOx	*kg/MWh*	2.3
[20]	NOx emission	*ton*	[7] x [19]=3085.2

Same formulas are used for calculation of other units of Kosova A (the difference is only on the load factor)

For units in Kosova B (B1 or B2) the calculations are as follows

Table 3.2. Description of formulas used for calculation for units of TPP Kosova B

Item	Designation	*Unit*	Result
[1]	Average gross power	*MW*	270
[2]	Number of hours per year	*hours*	8760
[3]	Load factor	-	0.8
[4]	Gross electricity production	*GWh*	([1] x [2] x [3])/1000=1892.2
[5]	Net electricity production	*GWh*	0.9 x [4]=1702.9
[6]	Specific lignite consumption	*ton/MWh*	1.4
[7]	Lignite consumption	*kiloton*	[6] x [4]=2649
[8]	Ash content in the lignite	%	16
[9]	Ash production	*kiloton*	[8]/100 x [7]=424
[10]	Percentage of dust before the ESP	%	80
[11]	Efficiency of ESP	%	99.14
[12]	Dust emission through the stack	*ton*	[9] x [10]/100x ((100-[11])/100) x 1000=2916
[12*]	Specific dust emission	*kg/MWh*	[12]/[4]=1.54
[13]	Carbon content in the lignite	%	23
[14]	CO_2 emission	*kiloton*	[7] x [13]/100 x 44/12=2234
[15]	Organic sulfur content	%	0.25
[16]	SO_2 production	*ton*	[7] x [15]/100 x 2 x 1000=13245
[17]	Rate of self desulfurization	%	65
[18]	SO_2 emission	*ton*	[17] x (1-[17]/100)=4636
[19]	Specific emission for NOx	*kg/MWh*	2.7
[20]	NOx emission	*ton*	[7] x [19]=7152

3.3. Third step - Combustion Technologies for New Power Plant Units in Kosova

The new power plant units that are planned to be constructed in Kosova requires careful selection of technologies that will meet environmental criteria for emission described in earlier chapters, to be cost-effective, and technically acceptable for the type of lignite that Kosova has.

Available combustion technologies that are considered to be used for the future new power plant units are:

- pulverized firing with subcritical parameters
- pulverized firing with supercritical or ultra-supercritical steam parameters.
- circulating fluidized bed combustion, and
- integrated gasification combined cycle.

In order to be cost-effective, new plants should have high efficiencies, high availability and last but not least low emissions.

3.3.1. Subcritical Pulverized Coal Combustion – PC

Subcritical pulverized coal technology is one of the oldest technologies used worldwide for thermal power generation. The size of units can be up to 1000MW_e. The steam pressure parameter is below critical values 221 bar. The boilers can be designed for one type of coal (lignite, hard coal or brown coal) but once they are designed for a specific coal they can't shift to other type of coal since they are very sensitive to changes of fuel quality. Pulverized coal technology requires installation of equipments for emission controls/reduction since the air emissions; SO_2, NOx and dust are considerably high. Therefore flue gas desulfurization, low NOx burners and ESP are necessary to be installed in this type of lignite fired power plants.

The efficiency of subcritical pulverized firing combustion is rather lower compared to other technologies. This type of boiler is fairly simple to operate and maintain, they have higher availability compared to other technologies and there is long and successful experience in designing and operating with this technology [10].

3.3.2. Supercritical Pulverized Coal Plant - SCPC

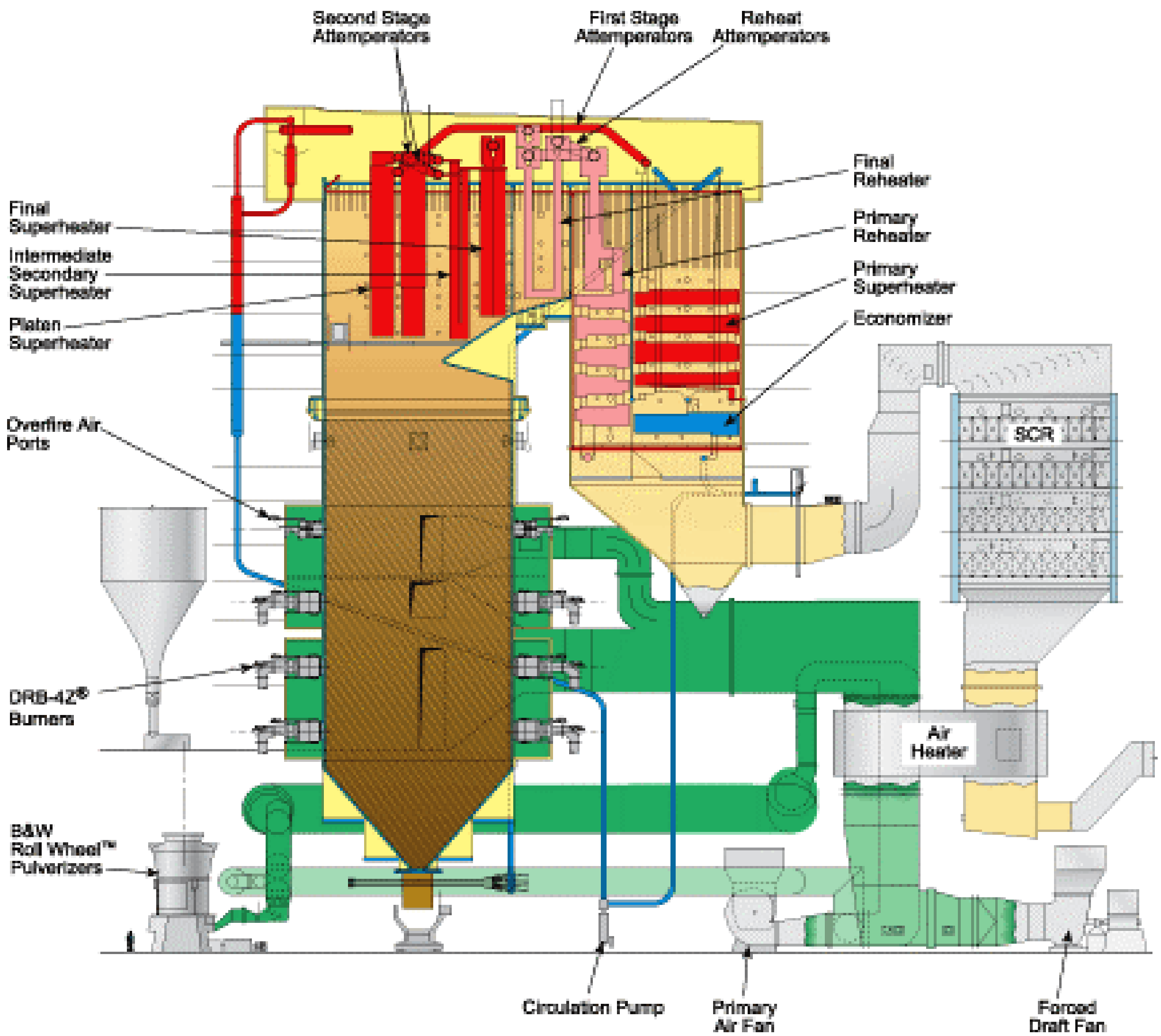
Supercritical pulverized coal technology is newer technology than subcritical. In general subcritical and supercritical boilers are similar, but supercritical boilers are designed to operate for higher fresh steam pressure, from 230-250 bar, and fresh steam temperatures up to 600ºC. The technology is in commercial stage and there are many power plants in operation worldwide. The efficiencies of supercritical PC boilers plants are higher than those of subcritical.

Typical parameters plant design used presently and their steam parameters are given below[10]:

- subcritical: 16.7MPa/538ºC/538ºC
- supercritical: 24.2MPa/538ºC/565ºC, and
- ultra-supercritical with double reheat: 31MPa/600ºC/600ºC/600ºC.

The high steam pressures and temperatures require higher quality materials for the furnace water wall, superheat and reheat tubes, steam pipes between boiler and turbine, and blades of the first stages of high pressure and inter-medium pressure of turbine. Also the water chemistry (corrosion protection) is very important aspects of supercritical plant design and operation.

Figure. 3.1. Schematic view of supercritical pulverized combustion boiler [11]



Supercritical plants are commercially available in many countries including Chine, Germany, Denmark, Italy, Japan, Russia, and US (about 462 units operating worldwide)[10]. Ultra supercritical units are in demonstration stage.

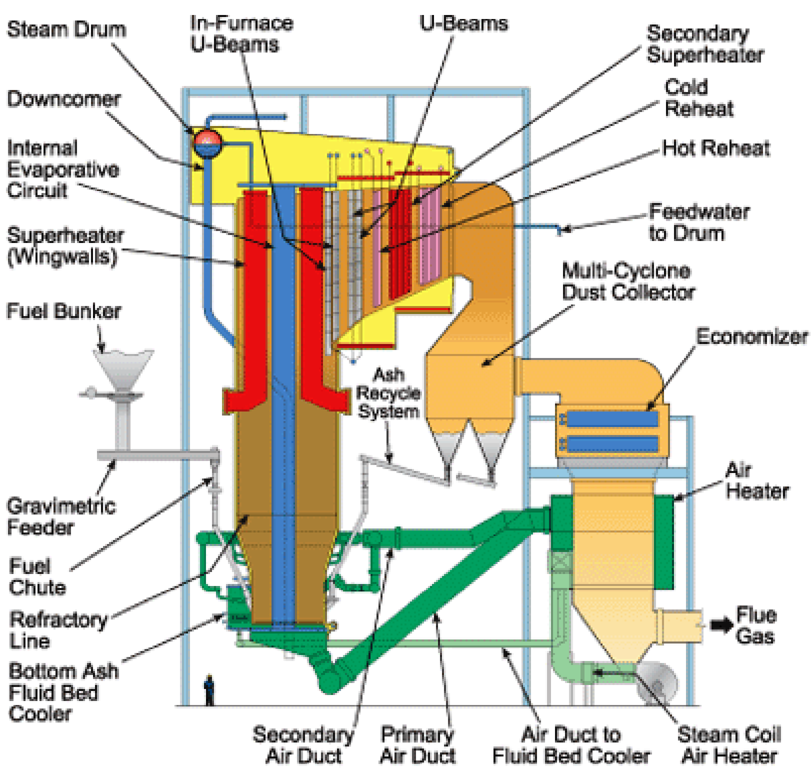
The higher efficiencies has major impact advantages as reduced coal consumption and reduced emissions of NOx, SO_2, particulates and CO_2 per MWh produced.

The capital costs of a supercritical are equal to or up to 8 % higher than a similar size subcritical plant.

3.3.3. Circulating Fluidized Bed Technology – CFB [10]

Circulating Fluidized Bed (CFB) combustion boilers (see figure 3.2) are very similar to conventional PC boilers in many respects. The majority of boiler components are similar. The difference of CFB relative to PC boiler stems from the lower operating temperature and the injection of limestone in the furnace to capture SO_2 emissions. Typical maximum furnace temperature in CFB boiler are in the 820-870^{o}C range, while PC boilers operate at 1200-1500^{o}C. This low combustion temperature limits the formation of NOx and its optimum temperature range for SO_2 capture. The injected limestone is converted in lime, a portion of which reacts with SO_2 to form calcium sulfate ($CaSO_4$), a dry solid, which is removed in the particulate collection equipment.

Figure. 3.2 Schematic view of Circulated Fluidized Bed Combustion [12]

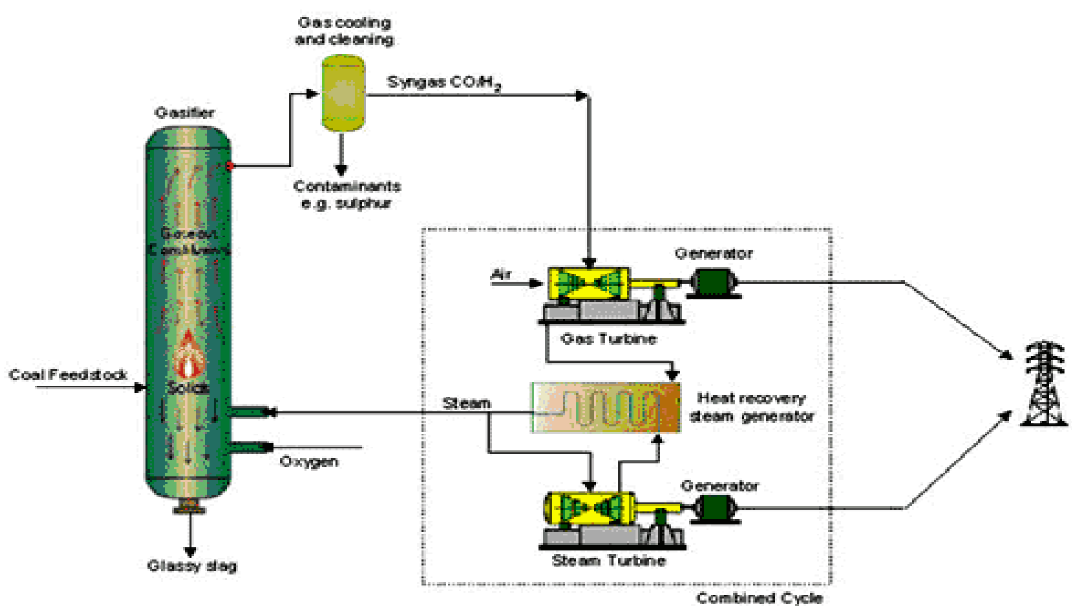


3.3.4. IGCC – Integrated Gasification Combined Cycle

The Integrated gasification combined cycle IGCC involves gasification of coal, and producing syngas (synthetic gas) cooled, cleaned and fired to a gas turbine. The hot exhaust from the gas turbine passes to a heat recovery steam generator (HRSG) where produces steam that drives a steam turbine. Power is produced from both the gas and steam turbines (this is a reason that are called combined cycle-CC). In general IGCC technology has been demonstrated up to 500MW in size and offered commercially.

Regarding air emissions, this technology is very successful in meeting air emission standards. Sulfur emissions can be almost completely eliminated (they are expected to be 40-115mg/Nm^3 at 6% O_2). NOx emissions have been controlled to levels below 125mg/Nm^3 at 6% O_2. Typical CO_2 emissions will be 12-15% lower than a comparably-sized PC plant with FGD.

Figure. 3.3. Schematic view of Integrated Gasification Combined Cycle [13]



The IGCC presents one of the future technologies for carbon capture ready plants.

3.3.5. Construction cost for coal fired power plants

Construction cost estimates for new coal-fired power plants are very uncertain and depends on many factors: type of coal, infrastructure, type of technology and the region where they are build. For the coal with lower heating value prices are higher because the boiler has to be bigger size to produce the same amount of steam compared to the coal with higher calorific value. When the infrastructure is already in place the construction costs are lower, compared to the greenfield projects. Similarly for the projects where the labor force wages for construction works are relatively low the project will cost lower compared to the regions where this rate is higher.
The demand for construction of power plants in China and India has influenced in increasing the costs of construction. In recent years the costs of construction have increased significantly.

.

The following examples illustrate the construction costs experienced in the recent years.

Name of power plant	Type of power plant	Place and year of construction	Capacity	Construction costs
RWE, Neurath[14]	Supercritical	Germany, start of construction in 2006	2x1100MW	€2.2 billion
Boxberg Saxony[15]	Supercritical	Germany, construction year started in 2007, planned to be finished in 2011	675MW	€890 million
Duke Energy, Cliffside[16]	Ultra - supercritical	North Caroline USA, construction started 2008, planned to be finished 2012	825MW	$ 1.8 billion
Martiza East 1[17]	Subcritical	Galabovo, Bulgaria, start of construction in 2006	2x335MW	€723 million
Kemper County[18]	IGCC	Mississippi, USA, not started	600MW	$1.8billion
Hempstead[18]	Ultra - supercritical	Arkansas, USA, under construction	600MW	$1.68 billion
Comanche 3 power station [19]	Supercritical	Pueblo, Colorado, USA, construction started 2006	750MW	$1.3 billion

Table. 3.3. Summary of Combustion Technologies [10]

	Type of technology		
	Supercritical Pulverized Coal Plant*	**CFB - Circulating Fluidized Bed Technology***	**IGCC –Integrated Gasification Combined Cycle**
Status	Supercritical: commercial, ultra supercritical: needs demonstration	Commercial up to 250-300MW	Commercial up to 500MW Fluidized bed: in demonstration stage
SO_2 reduction in %	4 - 12	>95	Up to 99
NOx reduction in %	4 - 12	30 ÷ 70 depending on coal (90 with SNCR (ammonia or urea))	80 - 90 (compared to PC with low NOx burners)
CO_2 in %	4 - 12	Negligible	10 - 20% potential reduction over comparably – sized PC plant with FGD
Efficiency in %	Supercritical 40 – 42% Ultra-supercritical ~ 48%	36-38	40-44 %
Capital costs	Supercritical: 1000-1300€/kW; ultra-supercritical: 1400-2000€/kW	600 – 1100$/kW [10](for new CFB plant in the size 100-250MW range)	up to 3300$/kW [20]
Fixed O&M costs ($/kW/year)	Supercritical: 25-32; ultra-supercritical: 30-35	30-70	30-45
Issues	Ultra-supercritical requires further demonstration. Lignite with low ash melting temperatures (under 1000ºC) are not suitable. Lower reliability compared to subcritical PC	Successful scale up to 400-600MW while maintaining its cost – effectiveness and emissions performance	High costs are the main barrier to widespread utilization of entrained and moving bed IGCC.

Note: Emissions reduction is based on comparison to this technology to a similar size subcritical pulverized coal boiler with low NOx burners, but without FGD

CHAPTER 4

CALCULATIONS OF ELECTRICITY GENERATIONS AND EMISSIONS ESTIMATES FOR ALL SCENARIOS

Based on threes steps described above have been done the calculations for alls scenarios to find out electricity generations and emission estimates for all scenarios. For all scenarios the demand growth is 4%.

For new units of thermal power plant "New Kosova" are used the following assumptions:

Table. 4.1. Description of formulas used for calculation for units of TPP "New Kosova"

Item	Designation	*Unit*	Result
[1]	Average gross power	*MW*	500
[2]	Number of hours per year	*hours*	8760
[3]	Load factor	-	0.85
[4]	Gross electricity production	*GWh*	([1] x [2] x [3])/1000=3723
[5]	Net electricity production	*GWh*	0.9 x [4]=3350.7
[6]	Specific lignite consumption	*ton/MWh*	1.1
[7]	Lignite consumption	*kiloton*	[6] x [4]=4095
[8]	Specific dust emission*	*kg/MWh*	0.14
[9]	Dust emission through the stack	*ton*	[4] x [8]=521
[10]	Specific emission of CO_2*	*t/MWh*	0.85
[11]	CO2 emission	*kiloton*	[4] x [10]=3481
[12]	Specific emission of SO_2*	*kg/MWh*	0.5
[13]	SO2 emission	*ton*	[4] x [12]=1852
[14]	Specific emission of NOx*	*kg/MWh*	1.0
[15]	NOx emission	*ton*	[4] x [14]=3723

* - specific emissions for dust, CO_2, SO_2 and NOx are based on the report "*Strategic Environmental and Social Assessment*" [4].

4.1. Scenario 1

The scenario one is based on electricity generation from the existing units of TPP Kosova A and Kosova B as well as from existing HPP Ujman. The calculations for electricity generation and emission estimates for Scenario 1 are based on the Table 3.1 and Table 3.2. The annual net electricity generation from HPP Ujman is 80GWh. For units A3 and A4 are planned the major overhauls in the year 2012 respectively 2013. Thus, during these years these two units will have less electricity generation

4.2. Scenario 2

The Scenario 2 takes into consideration the assumptions made in Scenario 1, with additional inputs. In this scenario it is foreseen that by 2017, to be put in the operation one new unit with capacity of 500MW of new Thermal Power Plant “New Kosova”. The load factor for new unit is 0.85. Also it is foreseen that by 2018 it will be build new HPP Zhur with capacity 293MW and annual electricity generation of 400GWh.

For units of TPP Kosova B it is foreseen that in 2017 respectively in 2018 will be implemented project for refurbishment of units with the focus in upgrading the electrostatic precipitators and installing the new low NOx lignite burners with the goal of meeting the air emissions standards set by EU Directive 2001/80.

4.3. Scenario 3

For this scenario it is foreseen that it will be build another new unit of new TPP “New Kosova” by the year 2019, with the same capacity as the first one, 500MW. The other assumptions are same as in the Scenario 2.

4.4. Scenario 4

Scenario four have same assumptions like Scenario 3 with addition of two units on new TPP “New Kosova” that will be build on years 2021, and 2023

The summary of technical information of scenarios is presented in the Table 4.2. In Tables 4.3 till 4.6 are presented the calculations of gross and net electricity production, and emission calculations for each scenario.

Table 4.2. Capacity of Power Plants for different Scenarios

	Existing capacity 2009	**2010 – 2015**	**2016 – 2020**	**2021 – 2025**	**2026 - 2030**
Scenario 1	• TPP A – two units in operation A3 and A5, with 125MW each • unit A4 starts operation in December after overhaul 125MW • TPP B – two units in operation, B1 (250MW) and B2 (280MW) • HPP Ujman, 35MW	• TPP A – three units in operation A3, A4 and A5, with 125MW each • TPP B – two units in operation, B1 and B2, with 300MW each • Demand growth 4%	• 2017 decommissioning of TPP A • TPP B – two units in operation, B1 and B2, with 300MW each • Demand growth 4%	• TPP B – two units in operation, B1 and B2, with 300MW each • Demand growth 4%	• TPP B – two units in operation, B1 and B2, with 300MW each • Demand growth 4%
Scenario 2	Same as in scenario one	Same as in scenario one	• 2017 decommissioning of TPP A • TPP B – two units in operation, B1 and B2, with 300MW each • In 2018 new HPP Zhur in operation, 293MW (2000h per year) • In 2017 in operation one new unit of TPP C, 500MW • Demand growth 4%	• TPP B – two units in operation, B1 and B2, with 300MW each • HPP Zhur in operation, 293MW (2000h per year) • In operation one new unit of TPP C, 500MW • Demand growth 4%	• TPP B – two units in operation, B1 and B2, with 300MW each • HPP Zhur in operation, 293MW (2000h per year) • In operation one new unit of TPP C, 500MW • Demand growth 4%

Scenario 3	Same as in scenario one	Same as in scenario one	• 2017 decommissioning of TPP A • TPP B – two units in operation, B1 and B2, with 300MW each • In 2018 new HPP Zhur in operation, 293MW (2000h per year) • In 2017 in operation one new unit of TPP C, 500MW • In 2019 second unit of TPPC in operation 500MW • Demand growth 4%	• TPP B – two units in operation, B1 and B2, with 300MW each • HPP Zhur in operation, 293MW (2000h per year) • TPP C - two units in operation, 500MW each • Demand growth 4%	• TPP B – two units in operation, B1 and B2, with 300MW each • HPP Zhur in operation, 293MW (2000h per year) • TPP C - two units in operation, 500MW each • Demand growth 4%
Scenario 4	Same as in scenario one	Same as in scenario one	Same as in scenario three	• TPP B – two units in operation, B1 and B2, with 300MW each • HPP Zhur in operation, 293MW (2000h per year) • TPP C - two units in operation, 500MW each • In 2021 third unit of TPPC in operation 500MW • In 2023 fourth unit of TPP C in operation 500MW • Demand growth 4%	• TPP B – two units in operation, B1 and B2, with 300MW each • HPP Zhur in operation, 293MW (2000h per year) • TPP C - four units in operation, 500MW each • Demand growth 4%

Table 4.3. **Scenario 1 –** Electricity production and emissions calculations of Power Plants units for the period 2009 till 2030

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2026	2030
Gross Electricity production																		
A3	*GWh*	765	767	767	**329**	767	767	767	767	767								
A4	*GWh*	59	657	657	767	**329**	657	657	657	657								
A5	*GWh*	697	329	329	548	548	329	329	329	329								
TPP A	***GWh***	**1521**	**1752**	**1752**	**1643**	**1643**	**1752**	**1752**	**1752**	**1752**								
B1	*GWh*	1775	1892	**1656**	1892	1892	1962	1962	1962	1962	1962	**1717**	1962	1962	1962	1962	1962	1962
B2	*GWh*	1934	1892	1892	**1656**	1892	1962	1962	1962	1962	1962	1962	**1717**	1962	1962	1962	**1717**	1962
TPP B	***GWh***	**3709**	**3784**	**3548**	**3548**	**3784**	**3924**	**3924**	**3924**	**3924**	**3924**	**3679**	**3679**	**3924**	**3924**	**3924**	**3679**	**3924**
Existing TPP		**5230**	**5536**	**5300**	**5190**	**5427**	**5676**	**5676**	**5676**	**5676**	**3924**	**3679**	**3679**	**3924**	**3924**	**3924**	**3679**	**3924**
Net production HPP Ujman	***GWh***	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**
Total gross energy production from TPP	***GWh***	**5230**	**5536**	**5300**	**5190**	**5427**	**5676**	**5676**	**5676**	**5676**	**3924**	**3679**	**3679**	**3924**	**3924**	**3924**	**3679**	**3924**
Coal consumption																		
TPP A	*kiloton*	2738	3066	3066	2874	2874	3066	3066	3066	3066	0	0	0	0	0	0	0	0
TPP B	*kiloton*	5378	5298	4967	4967	5298	5494	5494	5494	5494	5494	5151	5151	5494	5494	5494	5151	5494
Total coal for existing TPP	***kiloton***	**8116**	**8364**	**8033**	**7841**	**8172**	**8560**	**8560**	**8560**	**8560**	**5494**	**5151**	**5151**	**5494**	**5494**	**5494**	**5151**	**5494**
Emission calculations																		
SO2 emission TPPA	*ton*	4271	4783	4783	4484	4484	4783	4783	4783	4783	0	0	0	0	0	0	0	0
SO2 emission TPPB	*ton*	9412	9272	8692	8692	9272	9615	9615	9615	9615	9615	9014	9014	9615	9615	9615	9014	9615
Total SO2	*ton*	13683	14055	13475	13176	13756	14398	14398	14398	14398	9615	9014	9014	9615	9615	9615	9014	9615
NOx emission TPPA	*ton*	6297	7052	7052	6611	6611	7052	7052	7052	7052	0	0	0	0	0	0	0	0
NOx emission TPPB	*ton*	14521	14305	13411	13411	14305	14835	14835	14835	14835	14835	13907	13907	14835	14835	14835	13907	14835
Total NOx	*ton*	20818	21357	20462	20022	20916	21886	21886	21886	21886	14835	13907	13907	14835	14835	14835	13907	14835
CO2 emissions TPP A	*kiloton*	2309	2586	2586	2424	2424	2586	2586	2586	2586	0	0	0	0	0	0	0	0
CO2 emissions TPP B	*kiloton*	4536	4468	4189	4189	4468	4634	4634	4634	4634	4634	4344	4344	4634	4634	4634	4344	4634
Total CO2	*kiloton*	6845	7054	6774	6613	6892	7219	7219	7219	7219	4634	4344	4344	4634	4634	4634	4344	4634
Dust emissions TPP A	*ton*	7447	8340	8340	7818	7818	8340	8340	8340	8340	0	0	0	0	0	0	0	0
Dust emissions TPP B	*ton*	5920	5832	5468	5468	5832	6048	6048	6048	6048	6048	5670	5670	6048	6048	6048	5670	6048
Total Dust	*ton*	13367	14172	13807	13286	13650	14388	14388	14388	14388	6048	5670	5670	6048	6048	6048	5670	6048
Total net electricity production	*GWh*	4787	5063	4850	4751	4964	5189	5189	5189	5189	3612	3391	3391	3612	3612	3612	3391	3612
Demand for electricity (available electricity)	*GWh*	5118	5323	5536	5757	5988	6227	6476	6735	7005	7285	7576	7879	8194	8522	8863	9970	11663
Net import (import - export)	*GWh*	331	260	686	1006	1023	1038	1287	1546	1816	3673	4185	4488	4582	4910	5251	6578	8051

Table 4.4. **Scenario 2 -** Electricity production and emissions calculations of Power Plants units for the period 2009 till 2030

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2026	2030
Gross Electricity production																		
A3	*GWh*	765	767	767	329	767	767	767	767	767								
A4	*GWh*	59	657	657	767	329	657	657	657	657								
A5	*GWh*	697	329	329	548	548	329	329	329	329								
TPP A	***GWh***	**1521**	**1752**	**1752**	**1643**	**1643**	**1752**	**1752**	**1752**	**1752**								
B1	*GWh*	1775	1892	1656	1892	1892	1962	1962	1962	1226	1962	1962	1962	1962	1962	1962	1962	1962
B2	*GWh*	1934	1892	1892	1656	1892	1962	1962	1962	1962	1226	1962	1962	1962	1962	1962	1717	1962
TPP B	***GWh***	**3709**	**3784**	**3548**	**3548**	**3784**	**3924**	**3924**	**3924**	**3189**	**3189**	**3924**	**3924**	**3924**	**3924**	**3924**	**3679**	**3924**
Existing TPP		**5230**	**5536**	**5300**	**5190**	**5427**	**5676**	**5676**	**5676**	**4941**	**3189**	**3924**	**3924**	**3924**	**3924**	**3924**	**3679**	**3924**
Net production HPP Ujman	***GWh***	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**
Net elec. produc HPP Zhur	***GWh***									**0**	**400**	**400**	**400**	**400**	**400**	**400**	**400**	**400**
First new unit 500MW of TPPC	*GWh*	0	0	0	0	0	0	0	0	3723	3723	3723	3723	3723	3723	3723	3723	3723
Total from TPP C	***GWh***	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3723**	**3723**	**3723**	**3723**	**3723**	**3723**	**3723**	**3723**	**3723**
Total gross energy production from TPP	***GWh***	**5230**	**5536**	**5300**	**5190**	**5427**	**5676**	**5676**	**5676**	**8664**	**6912**	**7647**	**7647**	**7647**	**7647**	**7647**	**7402**	**7647**
Coal consumption																		
TPP A	*kiloton*	2738	3066	3066	2874	2874	3066	3066	3066	3066	0	0	0	0	0	0	0	0
TPP B1	*kiloton*	2485	2649	2318	2649	2649	2747	2747	2747	1656	2649	2649	2649	2649	2649	2649	2649	2649
TPP B2	*kiloton*	2708	2649	2649	2318	2649	2747	2747	2747	2747	1656	2649	2649	2649	2649	2649	2318	2649
TPP C	*kiloton*								0	4095	4095	4095	4095	4095	4095	4095	4095	4095
Total coal	***kiloton***	**7931**	**8364**	**8033**	**7841**	**8172**	**8560**	**8560**	**8560**	**11564**	**8400**	**9393**	**9393**	**9393**	**9393**	**9393**	**9062**	**9393**
Emission calculations																		
SO2 emission TPPA	*ton*	4271	4783	4783	4484	4484	4783	4783	4783	4783	0	0	0	0	0	0	0	0
SO2 emission TPPB	*ton*	9087	9272	8692	8692	9272	9615	9615	9615	7705	7533	9272	9272	9272	9272	9272	8692	9272
SO2 emission TPPC	*ton*	0	0	0	0	0	0	0	0	1862	1862	1862	1862	1862	1862	1862	1862	1862
Total SO2	*ton*	13358	14055	13475	13176	13756	14398	14398	14398	14349	9395	11133	11133	11133	11133	11133	10554	11133
NOx emission TPPA	*ton*	6297	7052	7052	6611	6611	7052	7052	7052	7052	0	0	0	0	0	0	0	0
NOx emission TPPB	*ton*	14020	14305	13411	13411	14305	14835	14835	14835	10066	6887	8477	8477	8477	8477	8477	7947	8477
NOx emission TPPC	*ton*	0	0	0	0	0	0	0	0	3723	3723	3723	3723	3723	3723	3723	3723	3723
Total NOx	*ton*	20318	21357	20462	20022	20916	21886	21886	21886	20841	10610	12200	12200	12200	12200	12200	11670	12200
CO2 emissions TPP A	*kiloton*	2309	2586	2586	2424	2424	2586	2586	2586	2586	0	0	0	0	0	0	0	0
CO2 emissions TPP B	*kiloton*	4379	4468	4189	4189	4468	4634	4634	4634	3713	3630	4468	4468	4468	4468	4468	4189	4468

Continuation of table 4.4.

CO_2 emissions TPP C	*kiloton*	0	0	0	0	0	0	0	0	3481	3481	3481	3481	3481	3481	3481	3481	3481
Total CO_2	*kiloton*	6688	7054	6774	6613	6892	7219	7219	7219	9780	7111	7949	7949	7949	7949	7949	7670	7949
Dust emissions TPP A	*ton*	7447	8340	8340	7818	7818	8340	8340	8340	8340	0	0	0	0	0	0	0	0
Dust emissions TPP B	*ton*	5716	5832	5468	5468	5832	6048	6048	6048	687	1099	1099	1099	1099	1099	1099	1099	1099
Dust emissions TPP C	*ton*		0	0	0	0	0	0	0	521	521	521	521	521	521	521	521	521
Total Dust	*ton*	13163	14172	13807	13286	13650	14388	14388	14388	9548	1620	1620	1620	1620	1620	1620	1620	1620
Total net electricity production	*GWh*	4787	5063	4850	4751	4964	5189	5189	5189	7877	6700	7363	7363	7363	7363	7363	7142	7363
Demand for electricity (available electricity)	*GWh*	5118	5323	5536	5757	5988	6227	6476	6735	7005	7285	7576	7879	8194	8522	8863	9970	11663
Net import (import - export)	*GWh*	331	260	686	1006	1023	1038	1287	1546	-873	584	213	516	832	1159	1500	2828	4300

Table 4.5. **Scenario 3 -** Electricity production and emissions calculations of Power Plants units for the period 2009 till 2030

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2026	2030
Gross Electricity production																		
A3	*GWh*	765	767	767	**329**	767	767	767	767	767								
A4	*GWh*	59	657	657	767	**329**	657	657	657	657								
A5	*GWh*	697	329	329	548	548	329	329	329	329								
TPP A	***GWh***	**1521**	**1752**	**1752**	**1643**	**1643**	**1752**	**1752**	**1752**	**1752**								
B1	*GWh*	1775	1892	**1656**	1892	1892	1962	1962	1962	**1226**	1962	1962	1962	1962	1962	1962	1962	1962
B2	*GWh*	1934	1892	1892	**1656**	1892	1962	1962	1962	1962	**1226**	1962	1962	1962	1962	1962	**1717**	1962
TPP B	***GWh***	**3709**	**3784**	**3548**	**3548**	**3784**	**3924**	**3924**	**3924**	**3189**	**3189**	**3924**	**3924**	**3924**	**3924**	**3924**	**3679**	**3924**
Existing TPP		**5230**	**5536**	**5300**	**5190**	**5427**	**5676**	**5676**	**5676**	**4941**	**3189**	**3924**	**3924**	**3924**	**3924**	**3924**	**3679**	**3924**
Net production HPP Ujman	***GWh***	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**
Net elec. produc HPP Zhur	***GWh***									**0**	**400**	**400**	**400**	**400**	**400**	**400**	**400**	**400**
First unit 500MW TPPC	*GWh*	0	0	0	0	0	0	0	0	3723	3723	3723	3723	3723	3723	3723	3723	3723
Second unit 500MW TPPC	*GWh*	0	0	0	0	0	0	0	0	0	0	3723	3723	3723	3723	3723	3723	3723
Total from TPP C	***GWh***	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3723**	**3723**	**7446**	**7446**	**7446**	**7446**	**7446**	**7446**	**7446**
Total gross electric. production from TPP	***GWh***	**5230**	**5536**	**5300**	**5190**	**5427**	**5676**	**5676**	**5676**	**8664**	**6912**	**11370**	**11370**	**11370**	**11370**	**11370**	**11125**	**11370**
Coal consumption																		
TPP A	*kiloton*	2738	3066	3066	2874	2874	3066	3066	3066	3066	0	0	0	0	0	0	0	0
TPP B1	*kiloton*	2485	2649	2318	2649	2649	2747	2747	2747	1656	2649	2649	2649	2649	2649	2649	2649	2649
TPP B2	*kiloton*	2708	2649	2649	2318	2649	2747	2747	2747	2747	1656	2649	2649	2649	2649	2649	2318	2649
TPP C	*kiloton*								0	4095	4095	8191	8191	8191	8191	8191	8191	8191
Total coal		**7931**	**8364**	**8033**	**7841**	**8172**	**8560**	**8560**	**8560**	**11564**	**8400**	**13489**	**13489**	**13489**	**13489**	**13489**	**13158**	**13489**
Emission calculations																		
SO2 emission TPPA	*ton*	4271	4783	4783	4484	4484	4783	4783	4783	4783	0	0	0	0	0	0	0	0
SO2 emission TPPB	*ton*	9087	9272	8692	8692	9272	9615	9615	9615	7705	7533	9272	9272	9272	9272	9272	8692	9272
SO2 emission TPPC	*ton*	0	0	0	0	0	0	0	0	1862	1862	3723	3723	3723	3723	3723	3723	3723
Total	*ton*	13358	14055	13475	13176	13756	14398	14398	14398	14349	9395	12995	12995	12995	12995	12995	12415	12995
NOx emission TPPA	*ton*	6297	7052	7052	6611	6611	7052	7052	7052	7052	0	0	0	0	0	0	0	0
NOx emission TPPB	*ton*	14020	14305	13411	13411	14305	14835	14835	14835	10066	6887	8477	8477	8477	8477	8477	7947	8477
NOx emission TPPC	*ton*	0	0	0	0	0	0	0	0	3723	3723	7446	7446	7446	7446	7446	7446	7446
Total	*ton*	20318	21357	20462	20022	20916	21886	21886	21886	20841	10610	15923	15923	15923	15923	15923	15393	15923
CO2 emissions TPP A	*kiloton*	2309	2586	2586	2424	2424	2586	2586	2586	2586	0	0	0	0	0	0	0	0

Continues of table 4.5.

CO2 emissions TPP B	*kiloton*	4379	4468	4189	4189	4468	4634	4634	4634	3713	3630	4468	4468	4468	4468	4468	4189	4468
CO2 emissions TPP C	*kiloton*	0	0	0	0	0	0	0	0	3481	3481	6962	6962	6962	6962	6962	6962	6962
Total	*kiloton*	6688	7054	6774	6613	6892	7219	7219	7219	9780	7111	11430	11430	11430	11430	11430	11151	11430
Dust emissions TPP A	*ton*	7447	8340	8340	7818	7818	8340	8340	8340	8340	0	0	0	0	0	0	0	0
Dust emissions TPP B	*ton*	5716	5832	5468	5468	5832	6048	6048	6048	687	1099	1099	1099	1099	1099	1099	1099	1099
Dust emissions TPP C	*ton*		0	0	0	0	0	0	0	521	521	1042	1042	1042	1042	1042	1042	1042
Total	*ton*	13163	14172	13807	13286	13650	14388	14388	14388	9548	1620	2141	2141	2141	2141	2141	2141	2141
Total net electric. production	*GWh*	4787	5063	4850	4751	4964	5189	5189	5189	7877	6700	10713	10713	10713	10713	10713	10493	10713
Demand for electricity (available electricity)	*GWh*	5118	5323	5536	5757	5988	6227	6476	6735	7005	7285	7576	7879	8194	8522	8863	9970	11663
Net import (import - export)	*GWh*	331	260	686	1006	1023	1038	1287	1546	-873	584	-3137	-2834	-2519	-2191	-1850	-523	950

Table 4.6. **Scenario 4 -** Electricity production and emissions calculations of Power Plants units for the period 2009 till 2030

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2026	2030
Gross Electricity production																		
A3	*GWh*	765	767	767	**329**	767	767	767	767	767								
A4	*GWh*	59	657	657	767	**329**	657	657	657	657								
A5	*GWh*	697	329	329	548	548	329	329	329	329								
TPP A	***GWh***	**1521**	**1752**	**1752**	**1643**	**1643**	**1752**	**1752**	**1752**	**1752**								
B1	*GWh*	1775	1892	**1656**	1892	1892	1962	1962	1962	**1226**	1962	1962	1962	1962	1962	1962	1962	1962
B2	*GWh*	1934	1892	1892	**1656**	1892	1962	1962	1962	1962	**1226**	1962	1962	1962	1962	1962	**1717**	1962
TPP B	***GWh***	**3709**	**3784**	**3548**	**3548**	**3784**	**3924**	**3924**	**3924**	**3189**	**3189**	**3924**	**3924**	**3924**	**3924**	**3924**	**3679**	**3924**
Existing TPP		**5230**	**5536**	**5300**	**5190**	**5427**	**5676**	**5676**	**5676**	**4941**	**3189**	**3924**	**3924**	**3924**	**3924**	**3924**	**3679**	**3924**
Net production HPP Ujman	***GWh***	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**
Net elec. produc HPP Zhur	***GWh***									**0**	**400**	**400**	**400**	**400**	**400**	**400**	**400**	**400**
First unit 500MW TPPC	*GWh*	0	0	0	0	0	0	0	0	3723	3723	3723	3723	3723	3723	3723	3723	3723
Second unit 500MW TPPC	*GWh*	0	0	0	0	0	0	0	0	0	0	3723	3723	3723	3723	3723	3723	3723
Third unit 500MW TPPC	*GWh*	0	0	0	0	0	0	0	0	0	0	0	0	3723	3723	3723	3723	3723
Fourth unit 500MW TPPC	*GWh*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3723	3723	3723
Total from TPP C	***GWh***	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3723**	**3723**	**7446**	**7446**	**11169**	**11169**	**14892**	**14892**	**14892**
Total gross energy production from TPP	***GWh***	**5230**	**5536**	**5300**	**5190**	**5427**	**5676**	**5676**	**5676**	**8664**	**6912**	**11370**	**11370**	**15093**	**15093**	**18816**	**18571**	**18816**
Coal consumption																		
TPP A	*kiloton*	2738	3066	3066	2874	2874	3066	3066	3066	3066	0	0	0	0	0	0	0	0
TPP B1	*kiloton*	2485	2649	2318	2649	2649	2747	2747	2747	1656	2649	2649	2649	2649	2649	2649	2649	2649
TPP B2	*kiloton*	2708	2649	2649	2318	2649	2747	2747	2747	2747	1656	2649	2649	2649	2649	2649	2318	2649
TPP C	*kiloton*								0	4095	4095	8191	8191	12286	12286	16381	16381	16381
Total coal	***kiloton***	**7931**	**8364**	**8033**	**7841**	**8172**	**8560**	**8560**	**8560**	**11564**	**8400**	**13489**	**13489**	**17584**	**17584**	**21679**	**21348**	**21679**
SO2 emission TPPA	*ton*	4271	4783	4783	4484	4484	4783	4783	4783	4783	0	0	0	0	0	0	0	0
SO2 emission TPPB	*ton*	9087	9272	8692	8692	9272	9615	9615	9615	7705	7533	9272	9272	9272	9272	9272	8692	9272
SO2 emission TPPC	*ton*	0	0	0	0	0	0	0	0	1862	1862	3723	3723	5585	5585	7446	7446	7446
Total SO2	*ton*	13358	14055	13475	13176	13756	14398	14398	14398	14349	9395	12995	12995	14856	14856	16718	16138	16718
NOx emission TPPA	*ton*	6297	7052	7052	6611	6611	7052	7052	7052	7052	0	0	0	0	0	0	0	0
NOx emission TPPB	*ton*	14020	14305	13411	13411	14305	14835	14835	14835	10066	6887	8477	8477	8477	8477	8477	7947	8477
NOx emission TPPC	*ton*	0	0	0	0	0	0	0	0	3723	3723	7446	7446	11169	11169	14892	14892	14892
Total NOx	*ton*	20318	21357	20462	20022	20916	21886	21886	21886	20841	10610	15923	15923	19646	19646	23369	22839	23369

Continues of table 4.6

CO2 emissions TPP A	*kiloton*	2309	2586	2586	2424	2424	2586	2586	2586	2586	0	0	0	0	0	0	0	0
CO2 emissions TPP B	*kiloton*	4379	4468	4189	4189	4468	4634	4634	4634	3713	3630	4468	4468	4468	4468	4468	4189	4468
CO2 emissions TPP C	*kiloton*	0	0	0	0	0	0	0	0	3481	3481	6962	6962	10443	10443	13924	13924	13924
Total CO2	*kiloton*	6688	7054	6774	6613	6892	7219	7219	7219	9780	7111	11430	11430	14911	14911	18392	18113	18392
Dust emissions TPP A	*ton*	7447	8340	8340	7818	7818	8340	8340	8340	8340	0	0	0	0	0	0	0	0
Dust emissions TPP B	*ton*	5716	5832	5468	5468	5832	6048	6048	6048	687	1099	1099	1099	1099	1099	1099	1099	1099
Dust emissions TPP C	*ton*		0	0	0	0	0	0	0	521	521	1042	1042	1564	1564	2085	2085	2085
Total Dust	*ton*	13163	14172	13807	13286	13650	14388	14388	14388	9548	1620	2141	2141	2663	2663	3184	3184	3184
Total net electricity production	*GWh*	4787	5063	4850	4751	4964	5189	5189	5189	7877	6700	10713	10713	14064	14064	17415	17194	17415
Demand for electricity (available electricity)	*GWh*	5118	5323	5536	5757	5988	6227	6476	6735	7005	7285	7576	7879	8194	8522	8863	9970	11663
Net import (import - export)	*GWh*	331	260	686	1006	1023	1038	1287	1546	-873	584	-3137	-2834	-5870	-5542	-8552	-7224	-5752

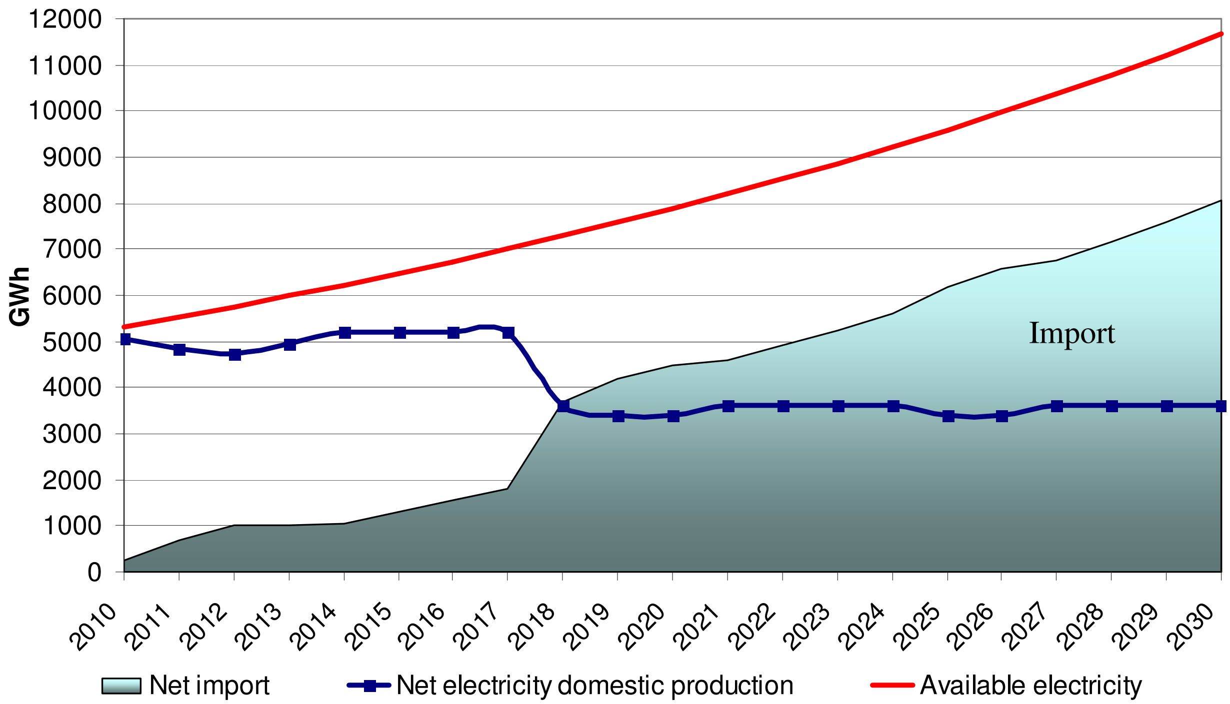
CHAPTER 5

PROJECT FINDINGS

5.1. Electricity production and demand for all scenarios

In Scenario 1 the demand for electricity can't be followed by domestic production therefore for the whole period of study the electricity sector will be depended on import of electricity. After the 2017 when the Kosova A will be decommissioned the need for import will grow faster. The units of Kosova B will cover only the half of the demand for electricity for the year 2017. By the year 2030 the demand is three times higher than generation from Kosova B power plant.

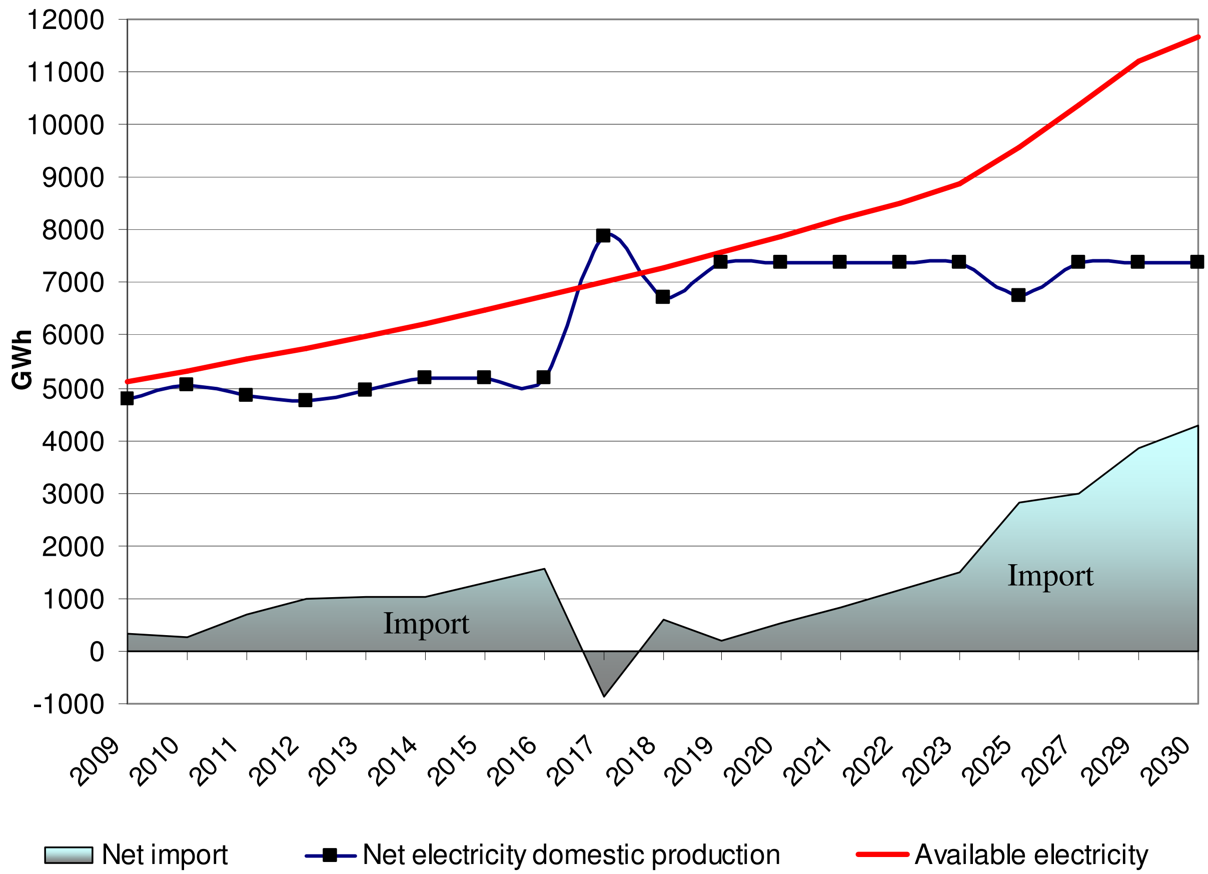
Figure. 5.1. Electricity production and gross demand for Scenario 1



Available electricity = domestic production + import - export

In Scenario 2 the period from 2010 till 2017 is the same as in Scenario 1. By this scenario the construction of HPP Zhur with 293MW, in 2018 and the first unit of "New Kosova" with power capacity 500MW the demand for electricity is going to be lower compared to the scenario 1. Thus, in the year 2017 it will be possible to export electricity in amount of 873GWh. From the year 2024 till 2030, the demand will be nearly 20-30% higher than the electricity production. Therefore the need for electricity import will be present (see figure 5.2).

Figure. 5.2. Electricity production and gross demand for Scenario 2

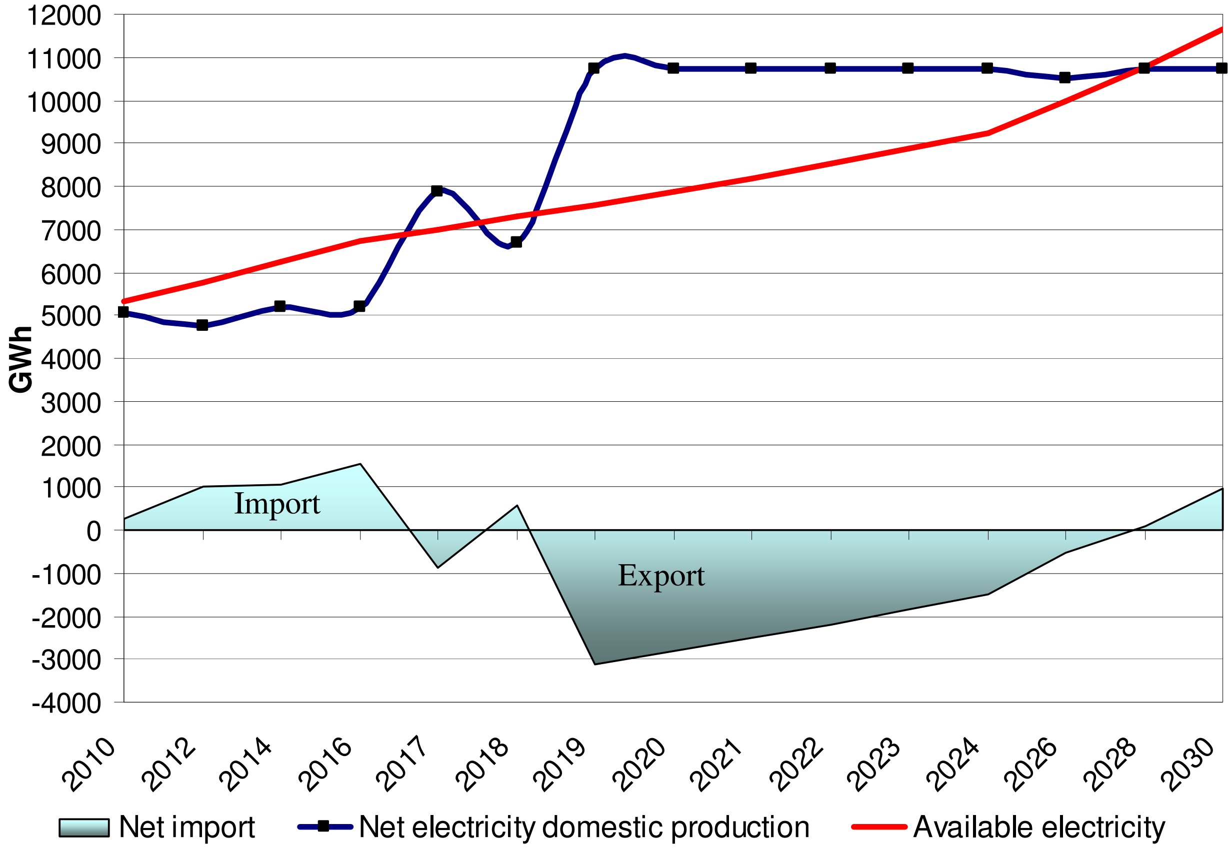


Available electricity = domestic production + import - export

Scenario 3 shows the better situation for exporting the electricity compared to the scenario 2. Again, same as in previous two scenarios the period 2010 till 2017 is categorized with moderate net import. The construction of two new units of new thermal power plant "New Kosova" and HPP Zhur, The period from 2017 till 2029 will be very favorable for exporting the electricity. This can generate considerable income. In 2030 demand starts to increase and by this time it will be necessary to introduce new units. It has to be taken in consideration that units of Kosova B will need to be decommissioned from 2030, since they are going to reach the end of their life time.

The share of electricity production from thermal power plants compared to electricity produced by hydro power plants is 95/5 %, which shows slight improvement compared to current situation which is 97/3 %.

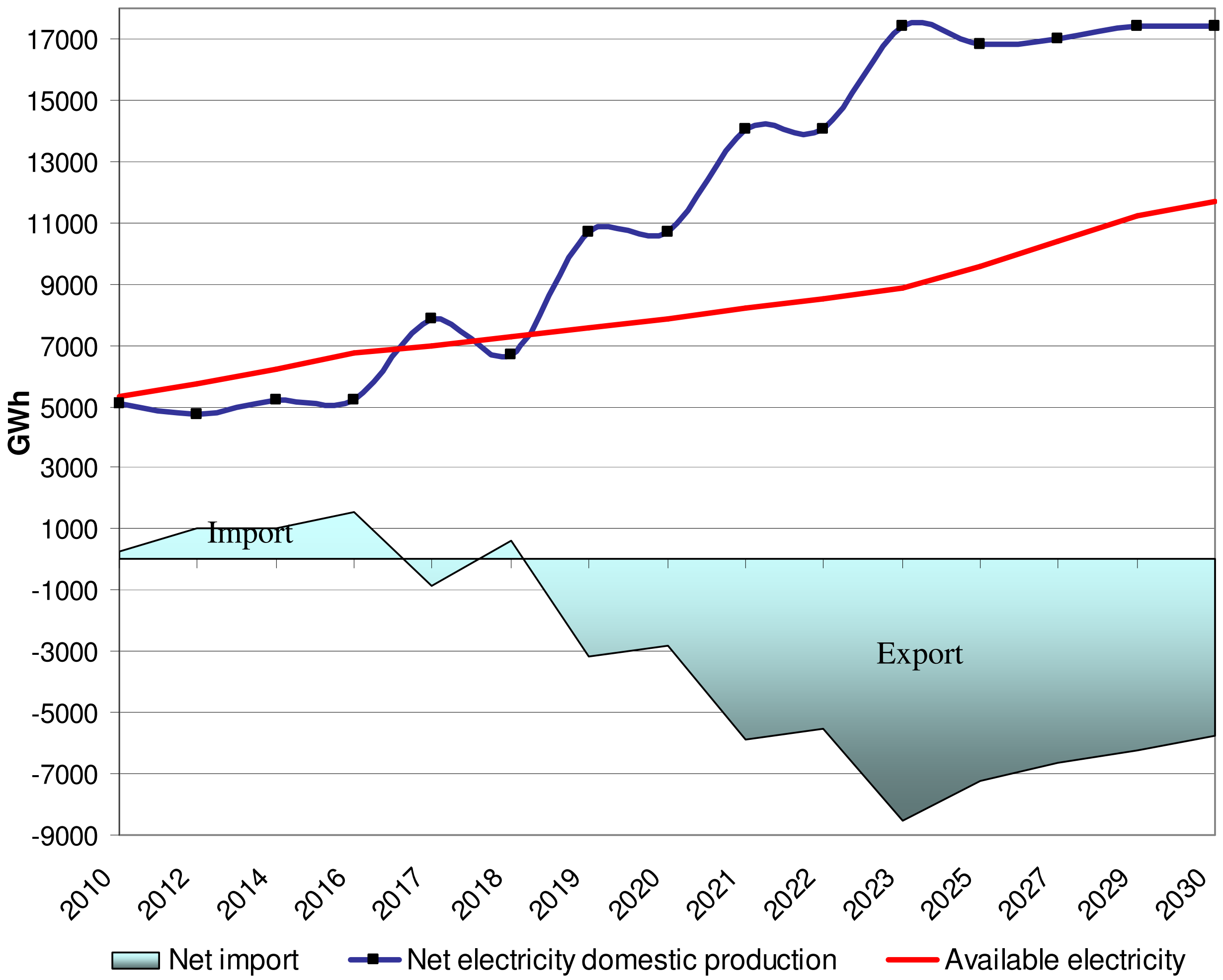
Figure. 5.3. Electricity production and gross demand for Scenario 3



Available electricity = domestic production + import - export

The scenario 4 shows rapid growth of electricity generations, and precondition for Kosova to become one of the key players in the region for exporting of the electricity. The construction of 4 units with power capacity 500MW each, and new HPP Zhur, will triple the production of electricity compared to the year 2010 (see Figure 5.4).

Figure. 5.4. Electricity production and gross demand for Scenario 4

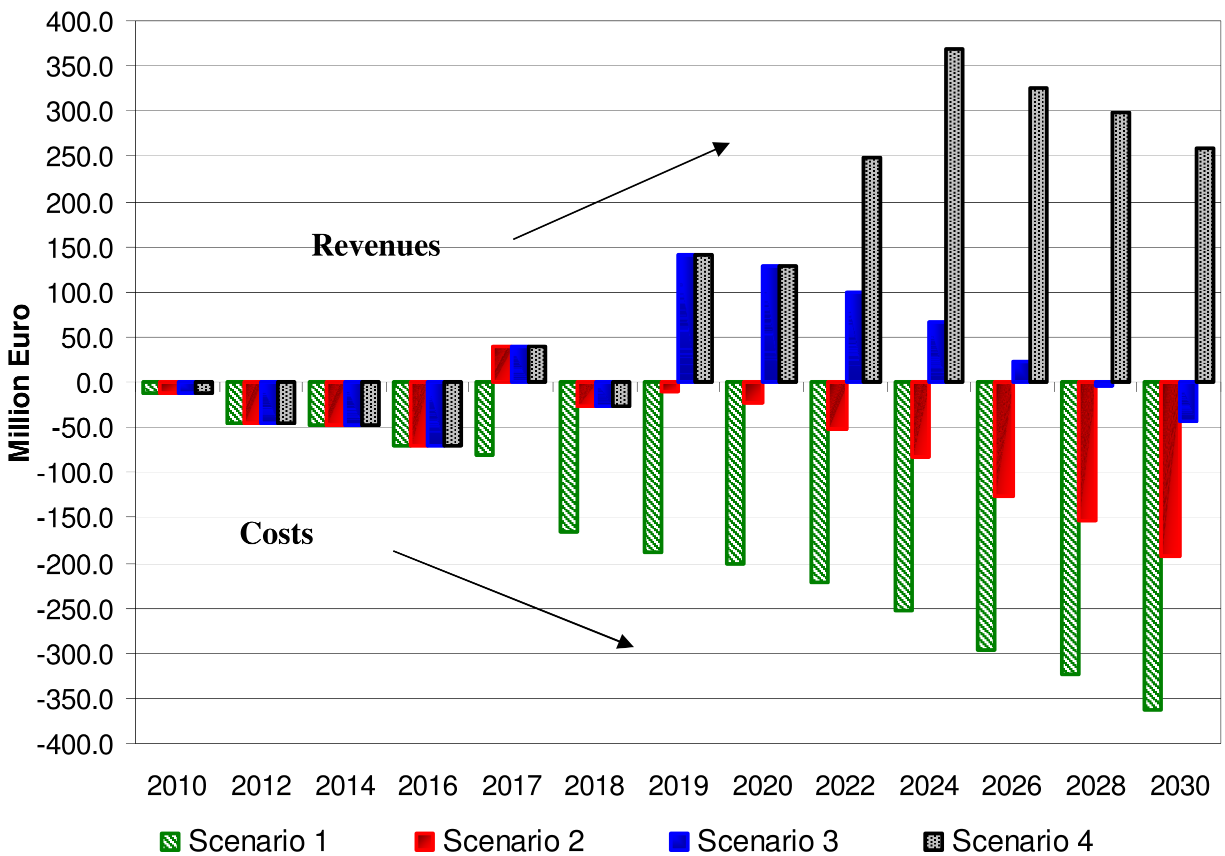


Available electricity = domestic production + import - export

The costs or revenues for electricity import or export are difficult to be foreseen for the wide period having in mind that the prices are not the same for export compared to prices for import of electricity. Another factor that causes differences on prices is that Kosova's electricity system is based more on thermal generation what causes that the main surplus of electricity will be during peak off hours (the period form 24:00 h till 06:00 h and 13:00 till 17:00h). The export for these periods of the day have lower prices compared the period of peak hours (from 18:00h till 23:00h).

The prices for importing of electricity during the previous years were not stabile. They were from 40Euro per MWh up to 100Euro per MWh depending of the type of import. Sometimes the price for import of emergency power and electricity was very high (more than 120Euro per MWh). In this Capstone the price for import and export of electricity for the whole period are foreseen to be in average 45Euro/MWh. In the table B.1 (see appendix B) it has been simulated the net import of electricity expressed in monetary values. This was taken to show how will different scenarios generate revenues or costs (see Figure 5.5).

Figure. 5.5. Costs or revenues from net import or net export of electricity for all scenarios



In Scenario 1 and 2 during all period of analysis, imports of electricity are present; therefore a considerable amount of money will be spent to cover the demand. The scenario 3 and 4 are favorable for generation of revenues due to preconditions for exports of electricity. These two scenarios can foster the economic development.

5.2. CO_2 emission forecast for all scenarios

CO_2 emissions from existing units of Kosova A and B power plant for the Scenario 1 are presented in figure 5.6. The contribution of TPP B for CO_2 total emission is higher then in TPP A because of higher consumption of coal.

For the second scenario the emissions of CO_2 starting from 2017 are higher than in the first scenario but afterwards they are as much as the same as the period 2009 till 2016 but also this configuration of power plants nearly meets the demand for electricity.

Figure. 5.6. CO_2 Emissions for Scenario 1

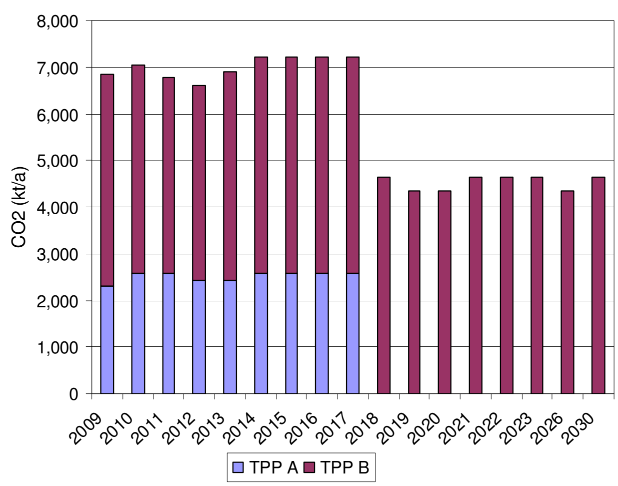


Figure. 5.7. CO_2 Emissions for Scenario 2

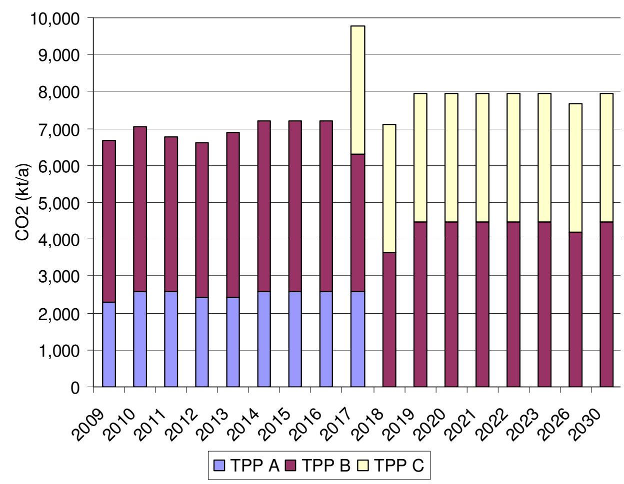


Figure. 5.8. CO_2 Emissions for Scenario 3

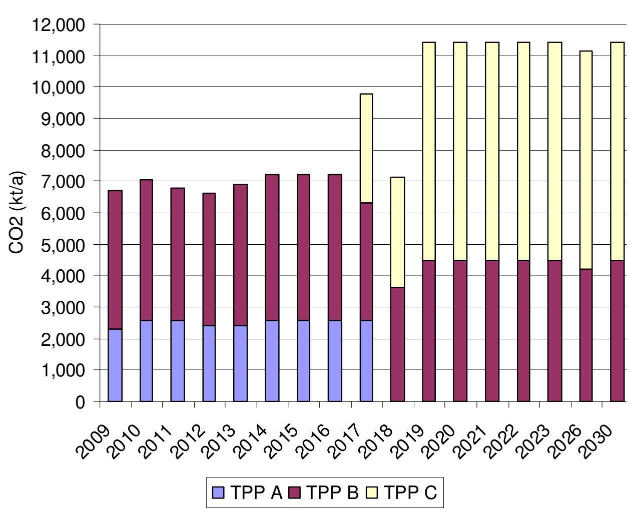
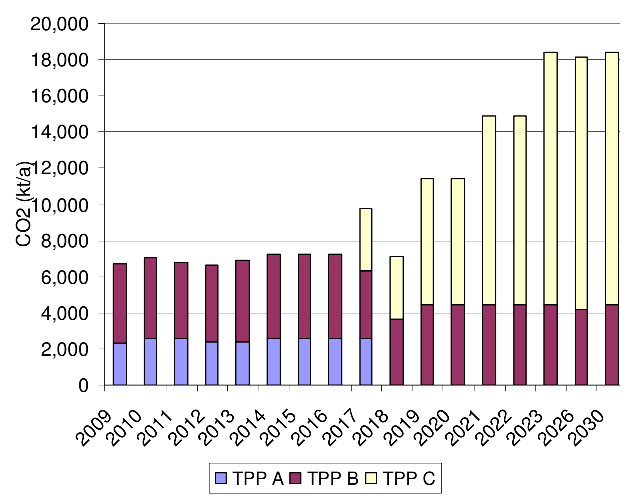


Figure. 5.9. CO_2 Emissions for Scenario 4

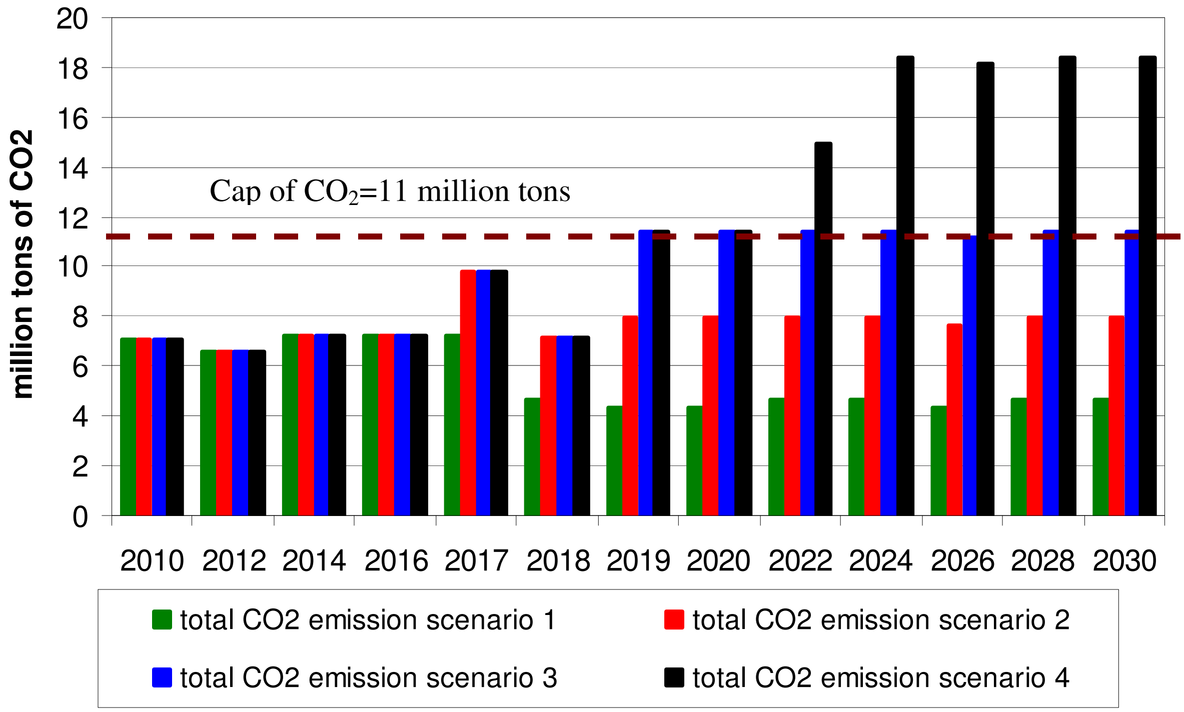


The Scenario 3 shows increasing of CO_2 production starting from the year 2019 by nearly one third of the year 2016. The reason for this increase is starting of operation of second new unit of TPP C.

For the Scenario 4 the CO_2 emissions by the end of time period considered in this Capstone is more than doubled compared to the existing emissions.

The summary of total CO_2 emissions for all scenarios is presented in the figure 5.10.

Figure 5.10. Summary of total CO_2 emissions

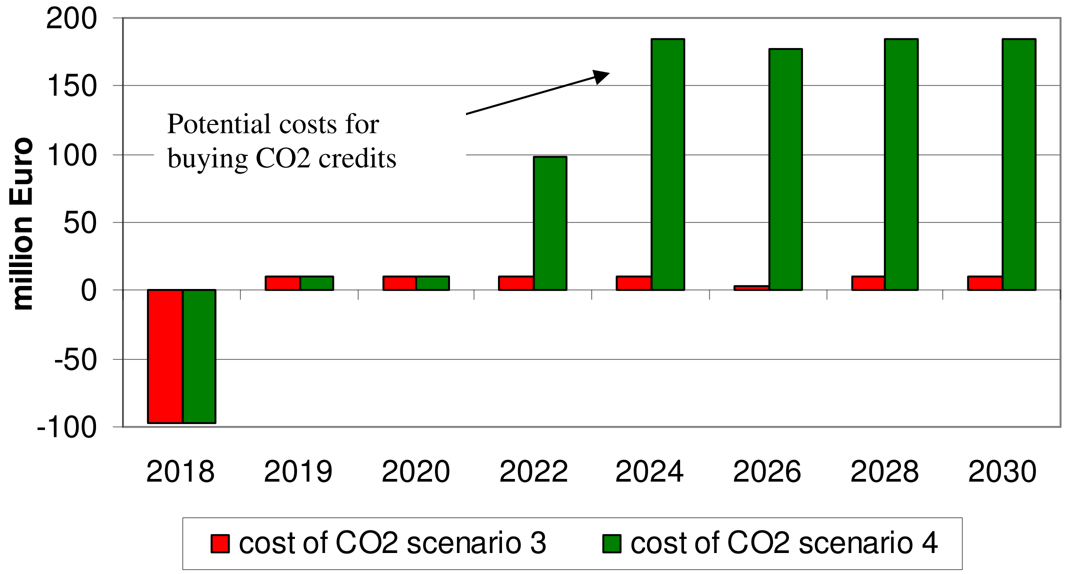


The costs of CO2 emissions (presented in table B.1, see appendix B) are simulated based on three assumptions:

1) Kosova will join the European Union by 2017 and will comply with environmental standards or regulations for CO_2
2) the cap of CO_2 emission will be 11 million tons (only of power generation)
3) the cost of CO_2 will be 25Euro/ton[21]

The result of this simulation is presented in the figure 5.11. In the figure are presented only scenario 3 and 4 as representative scenarios where the CO_2 emissions are higher than 11 million.

Figure 5.11. Cost of CO_2 allowances



For the scenario 4, TPP "New Kosova" will need to by credits in amount of more than 150 million to be allowed to emit CO_2 or will have to reduce the electricity generation down the limit. According to the Emissions Trading System [22] the prices for CO_2 credits, during 2007, were nearly 20Euros per ton emitted.

The prices of CO_2 credits should be set on that level that will increase the incentive for improvement of old technologies.

5.3. SO_2 emission forecast for all scenarios

The SO_2 emission for all scenarios is quite moderate and does not excide the existing level of total emission. This is due to modern technologies that are gong to be applied for new unit of poker plant “New Kosova”

Figure. 5.12. SO_2 Emissions for Scenario 1

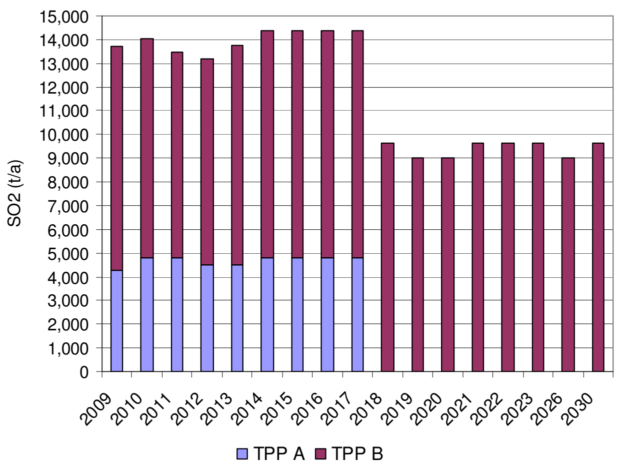


Figure. 5.13. SO_2 Emissions for Scenario 2

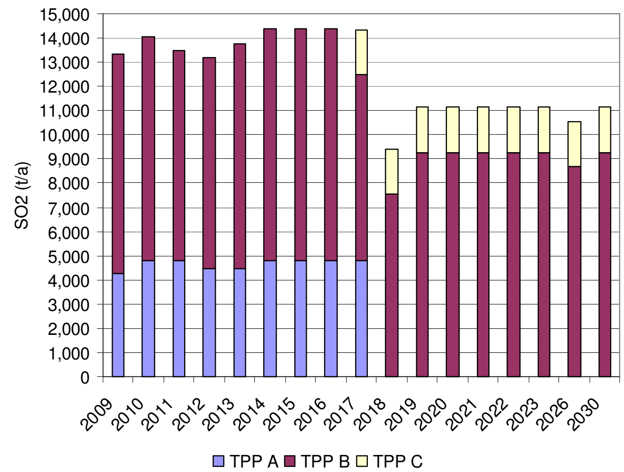


Figure. 5.14. SO_2 Emissions for Scenario 3

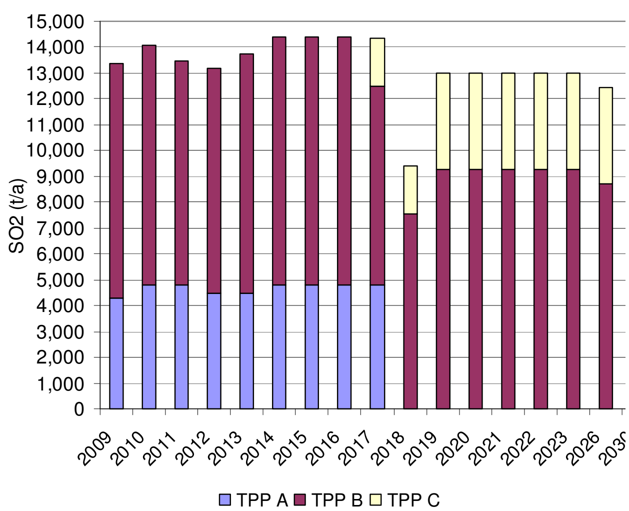
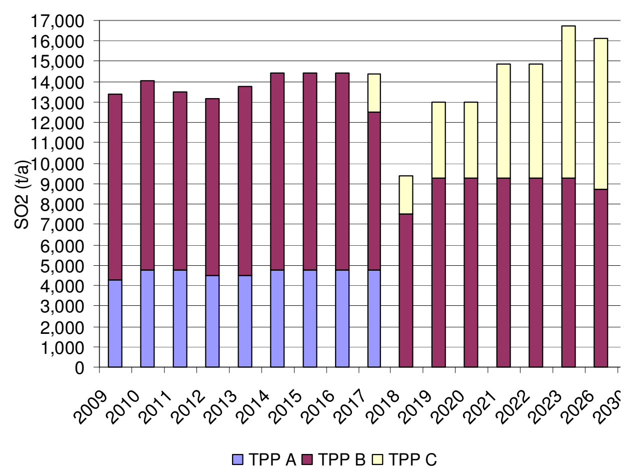


Figure. 5.15. SO_2 Emissions for Scenario 4



5.4. NOx emission forecast for all scenarios

The level of NOx emission for all scenarios is lower than emissions in 2009. Again this is due to modern technologies that are going to be applied in new units of "New Kosova". Regarding the NOx emissions scenario 2 and 3 are more favorable that scenario 4, where the emission level comes to the existing level.

Figure. 5.16. NOx Emissions for Scenario 1

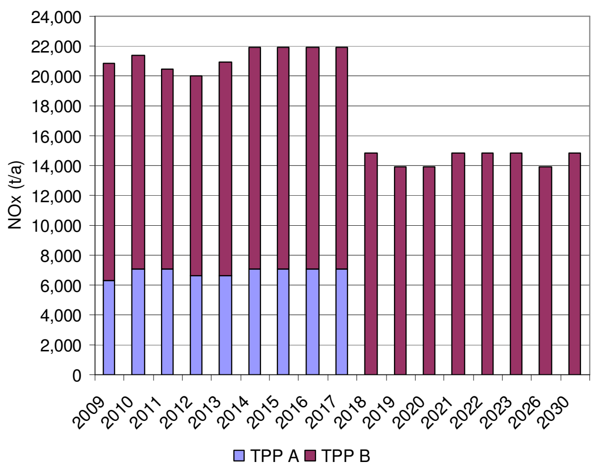


Figure. 5.17. NOx Emissions for Scenario 2

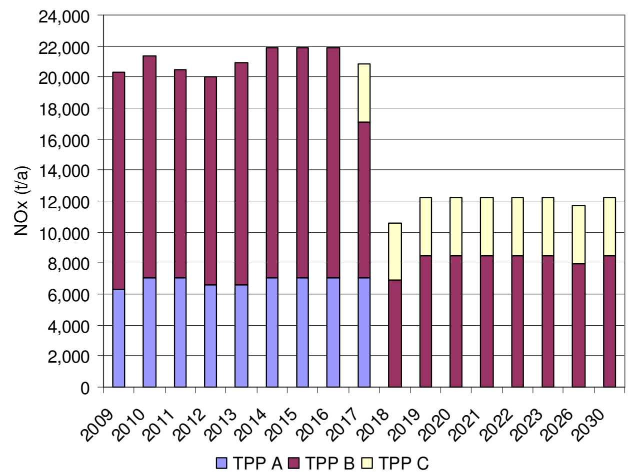


Figure. 5.18. NOx Emissions for Scenario 3

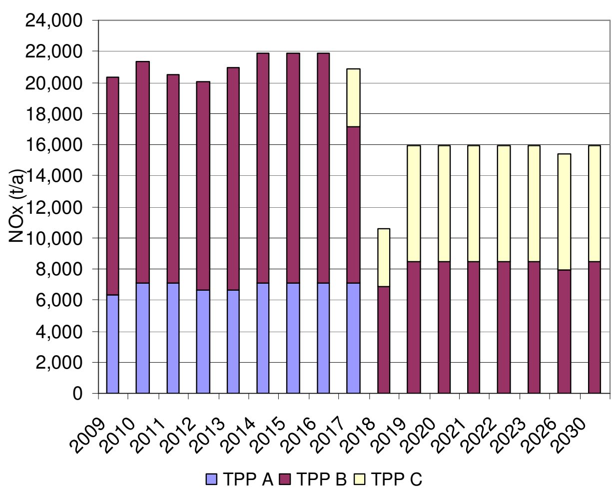
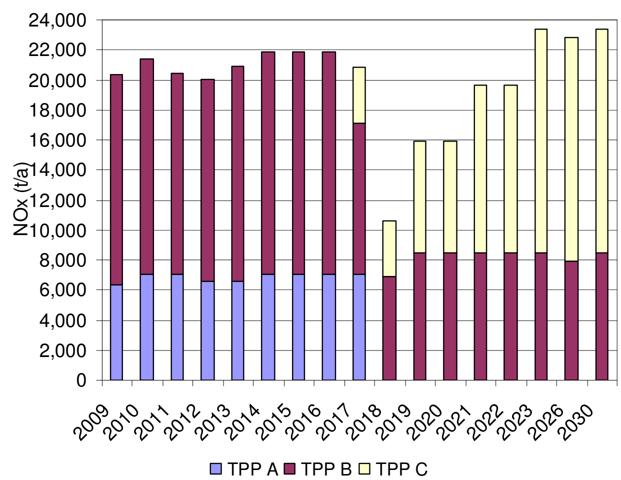


Figure. 5.19. NOx Emissions for Scenario 4



5.5. Dust emission forecast for all scenarios

The best effort in reducing air emission is shown with the dust emission. From the figure presented below it can be shown that the dust emission will be reduced more than six times compared to the existing situation. Regarding the dust emission scenarios 2, 3 and 4 are acceptable.

Figure. 5.20. Dust Emissions for Scenario 1

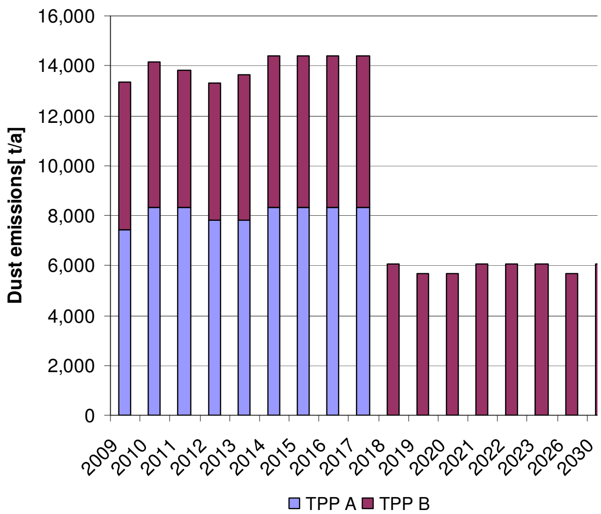


Figure. 5.21. Dust Emissions for Scenario 2

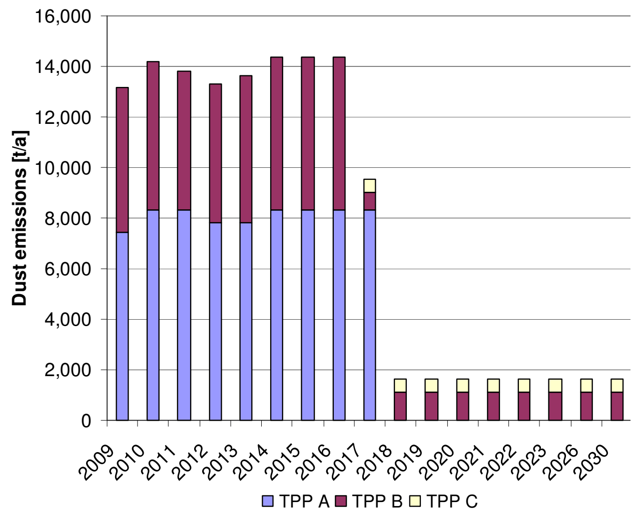


Figure. 5.22. Dust Emissions for Scenario 3

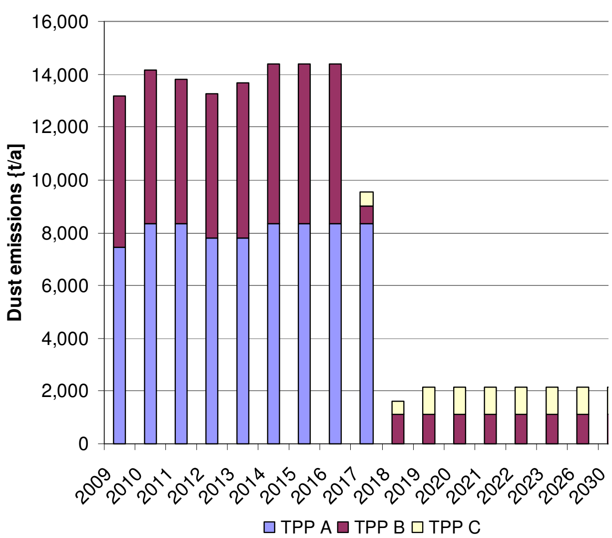
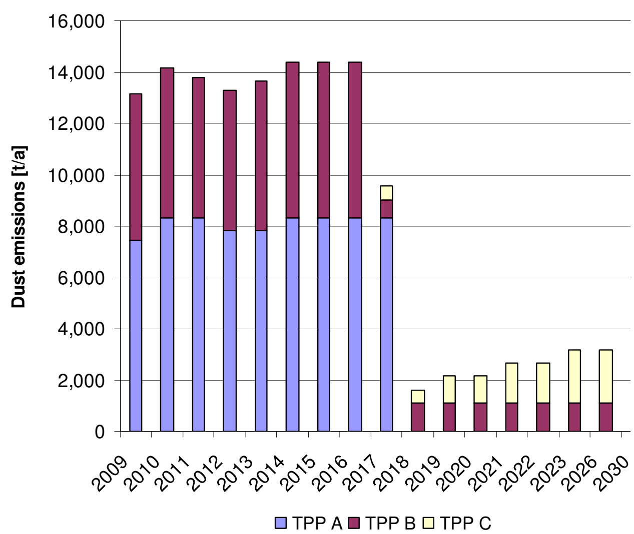


Figure.5.23. Dust Emissions for Scenario 4



CHAPTER 6

CONCLUSIONS

This capstone project has presented the current emissions from thermal power plants as well as from the other countries of EU. Even that total emissions of CO_2, dust and NOx in Kosova are small compared to EU countries, the specific emissions are considerable, and therefore the importance of reducing these emissions is essential especially after 2017.
In summary the conclusions from this Capstone are:

- The emission of CO_2 from the combustion process of lignite is considerably high in TPP Kosova A due to lower efficiency, which is 20 - 27%. In units of TPP Kosova B the CO_2 emissions are much lower because the efficiency is higher, nearly 36%. The planned power plant "New Kosova" represent the one of largest contributors of CO_2 in the country, but havening in mind that specific emission are 75% lower than TPP Kosova A or 39% lower than TPP Kosova B, this power plant plays essential role in reduction of CO_2 looking globally. The modern technology also allows much more efficient coal combustion, which reduces emissions per unit of electricity.

  The scenarios elaborated in the capstone shows that increase of CO_2 depends on the installed power of TPP New Kosova. The scenario 1, considering the CO_2 presents cut down of emissions especially after 2017. The scenario 2 is moderate scenario; the emission will be increased by 20% more than are today. The scenario 3 will have 80% higher emissions compared to these years, while for the scenario 4 the emission of CO_2 will be three times more than today.

  The simulation with the CO_2 trading allowance, even that the price of emission credits assumed to be 25€/t or the cap of CO_2 that is supposed to be 11 million tons might be biased, the importance of not exceeding the limits will be essential for every power plant to reduce their emissions in order to generate electricity in more reasonable prices. This will foster the need for introducing the future technologies for carbon capture and storage.

- The NOx emissions are generated in a combustion process mainly by two mechanisms. The "thermal NOx" is produced in the flame by oxidizing the nitrogen in combustion air in high temperature and creating NOx. The "fuel NOx" is generated by oxidizing the organic nitrogen in the fuel and creating NOx. The main measures to minimize the formation of NOx emissions are to decrease the combustion temperature and to decrease the excess air in primary flame. Having in consideration the temperatures in boilers of TPP Kosova B that are lower than 910^{o}C, the mechanism of thermal NOx have little effect on NOx formation.

NOx emissions are contributors to ozone depletion and their higher specific emissions from units of TPP Kosova B have to be taken in consideration in coming years. Installation of low NOx burners will reduce the NOx emissions. The "New Kosova" power plant have low specific NOx emission, 1 kg/MWh. Scenario 2 and 3 shows reduction by 40% respectively by 30% of total NOx emissions compared with current emission.

- The SO_2 emissions are more close to the requirements of EU Directive. The organic sulfur (portion of sulfur that is burned in boiler) content in the lignite is low. Also the content of calcium in the lignite contributes in the process of self-desulfurization. Due to the small percentage of deviation of existing emission to the required emission limit value there were not taken into the consideration any measures for SO_2 reduction for the existing units of TPP Kosova B.

  The construction of new thermal power pant will have to construct desulfurization equipments. The specific emissions of SO_2 are foreseen to be 0.5kg/MWh, respectively lower than 200mg/Nm^3.

- The dust emission from power plants depend on the boiler firing configuration, boiler operation, efficiency of equipments for emission controls and fuel ash content. The power plant Kosova A has low boiler efficiency, and the designed characteristics of equipments for dust collection – ESP doesn't meet the requirements of EU Directive for LCP. The Kosova B is in better situation compared to the Kosova A power plant, since the ESP has higher efficiency for collection of dust. Having in regard that units of Kosova B will be in operation for more than 20 years, the ESP will be refurbished to increase the efficiency and to meet the required emission limit value, $50mg/Nm^3$ which will be 5 times lower than existing design.

The new power plant regarding the dust emission is very modern type with specific dust emission of 0.14kg/MWh. The total dust emission in scenario 2, 3 and scenario 4 are considerably low compared to the existing situation. The abetment measures in TPP Kosova B and modern technology that is planned for "New Kosova" improves the dust emissions. The decrease of emissions in all scenarios is by 6 or 7 times compared to the existing situation.

Electricity consumption and generation with existing power capacities is unstable. The generation doesn't meet the demand therefore import of electricity is always present as well as electricity reductions. In order to have reliable and sufficient supply of electricity to the all costumers and even to export electricity, the construction of new power plants is inevitable. Even that the electricity and demand is not direct problem that is assessed in this Capstone, the conclusions that can be drawn in this context are as follows:

- Demand increase by 4% every year is a moderate projection that requires either intensive import of electricity or construction of new power plants. In this consideration for the scenario 2, 3 and 4 are projected different patterns of new power capabilities. For the scenario 2 with new HPP Zhur, 293MW and one new unit of TPP "New Kosova" with 500MW power capacity, improvement of electricity supply is improved for two or three years than again starts the situation where the demand will need to by covered by import of electricity.

- The scenario 3 with introduction of higher scale of power capacity 1000MW (2 new units of TPP "New Kosova") and 293 MW from HPP Zhur, and existing capacity from TPP Kosova B will bring better situation for reliable and sufficient supply with electricity of Kosova and the condition for export of electricity for the period from 2017 till 2028.

- The most extensive scenario for export of electricity is scenario 4. It includes full scale of new TPP with 2000MW power capacity, HPP Zhur and existing TPP Kosova B. More than 40% of generated electricity can be exported. This can generate huge revenues.

- Form the scenarios assessed the most favorable combination is the phased construction of new power facilities. The first phase should include the construction of 2 new units with 500MW each by 2017 respectively 2019 and the second phase to start the operation of 2 other new units with 500MW each by 2030 and 2032. This is because that TPP Kosova B by this period has to get out of operation and the need for electricity after 2030 again starts to become a problem.

The assessment of technologies for new thermal power plant was based on their status, emission reduction criteria, and their investment, operation and maintenance costs. The new technology has to take into consideration the characteristics of lignite. The existing transmission grid limits the maximum size units to be 500MW.

- The subcritical and supercritical pulverized firing boilers are in operation worldwide the world and their status is in commercial stage. The size of units fits the requirements of the grid. The higher efficiency is for the supercritical boilers by 4 to 5% compared to the subcritical boilers, but in the other point of view the construction material for piping system is more costly. Also the investment costs and fixed operation and maintenance costs are higher compared to the subcritical boilers. With high efficiency both technologies represents reduction of emissions into the atmosphere.

- The CFB are in commercial status but the size of units cant be higher than 300MW. This technology is ore advanced regarding the lower emissions of SO_2 and NOx. But CO_2 emissions compared to the pulverized firing are not showing any improvements. The investment costs and fixed O%M costs are higher compared to the pulverized firing technology.

- The IGCC technology is commercially developed for the sizes of units up to 500MW. Regarding the emission control this technology is one of the bests, but the costs for construction and fixed costs for O&M are higher compared to the pulverized firing. Strategic importance of IGCC is that this design can be carbon capture ready plant.

:

RECOMMENDATIONS

Based on the findings and conclusions of this capstone project are provided the information and analysis to help the decision makers for future power capacities to evaluate and determinate the optimal size of new units and to identify the most favorable scenario for future emission projections. The main recommendations are:

- To implement the scenario 3 (the existing units of TPP Kosova A and Kosova B with abatement measures, upgraded ESP for TPP B, new HPP Zhur 293MW and new TPP "New Kosova" with capacity 2x500MW) as the best scenario regarding the reduction of emissions and fulfilling the demand of electricity and crating the condition to induce the electricity export for considerable period of time. The average earnings from electricity export with this scenario, for each year, are nearly 100million Euro for the period of eight years

- By the year 2017 respectively 2018 in units B1 and B2 of TPP Kosova B the investment for improvements of environmental emissions has to be implemented by replacing the lignite burners with low NOx burners and refurbishment of existing ESP to comply with EU standards. A detailed project for these measures needs to be prepared.

- The technology for the new power plant is recommended to be subcritical or supercritical boilers with regard to the characteristics of lignite. Thus, the technology has to fulfill the requirements for emission reduction and high efficiency more than 42%, and the size of units to be 500MW. The higher efficiency of units will reduce the specific consumption of lignite and this will directly influence in lower CO_2 emissions.

- The new units should have installed modern equipments for dust collection – efficient ESP, low NOx burners, and desulfurization equipments.

- The decommissioning of units in TPP Kosova A should take place after the new units of TPP "New Kosova" will start the operation, this is foreseen by 2017.

- Installation of continuous measurement of air emissions NOx, SO_2 and dust on unit B1 and B2 of TPP Kosova B are required by the EU Directive for LCP. This monitoring system will allow to have a precise data for emissions and to determine the level of investments and technologies for emissions reduction.

- By conduction of HPP Zhur the share of electricity produced by renewable resources will increase by 3 to 4 % compared to existing situation.

List of Acronyms

CFB	Circulating Fluidized Bed Combustion
CO_2	Carbon dioxide
EPER	The European Pollutant Emission Register
ESP	Electrostatic precipitator
EU	European Union
EVL	Emission Value Limit
FGD	Flue Gas Desulfurization
GWh	Giga Watt hours
HPP	Hydro Power Plant
IGCC	Integrated Gasification Combined Cycle
KEK	Power Corporation of Kosova
kt	kilotons, 1kiloton=1000ton
LCP	Large Combustion Plant
LHV	Lower heat value
MEM	Ministry of Energy and Mining
MPa	Megapascal, 1MPa=10 bar
MW	Mega Watt
MW_e	Mega Watt electric
MW_{th}	Mega Watt thermal
NOx	Nitrogen oxides
O_2	Oxygen
PC	Pulverized combustion
SCPC	Supercritical Pulverized combustion
SCR	Selective Catalytic Reduction
SO_2	Sulfur dioxide
TPP	Thermal Power Plant

List of References

[1]. KEK-Statistical Data, Strategic Development Office

[2]. KEK – Working Manual for Boiler and Turbine, Kosovo B Power Plant, 1995

[3]. Energy Sector Technical Assistance Project, Module G – *Lignite Development Strategy*, World Bank, 2002

[4]. Government of Kosova, Ministry of Energy and Mining: (2008): *Strategic Environmental and Social Assessment*

[5]. Directive 2001/80EC of the European Parliament and the Council, Official Journal of the European Community, 2001

[6]. Entec, (2008), Evaluation of the Member States' emission inventories 2004-2006 for LCPs under the LCP Directive (2001/80/EC), Final Report, European Commission

[7]. http://eper.ec.europa.eu/eper/emissions_pollutants.asp?i

[8]. Power Station Emission Handbook- www.ccsd.biz/PSE_Handbook/index.cfm

[9]. Gjurgjeala. B,(2007) *Efficiency of TPP*, Prishtina

[10]. Travoulareas. S & Jozewicz. W, (2005): *Multipollutant Emission Control Technology Options for Coal fired Power Plants*, EPA, Washington DC.

[11]. www.babcock.com/products/boilers/images/swup.gif

[12]. http://www.babcock.com/products/boilers/circulating_fluidized_bed_specs.html

[13]. www.ccsd.biz/factsheets/images/igcc1.gif

[14]. http://www.power-technology.com/projects/rwe-neurath/

[15]. T. Hatakka, "Vattenfall Capital Markets Day 2009", Amsterdam 2009, Presentation (Reviewed online on February 2010 at http://www.vattenfall.com/en/file/tuomo-hatakka-business-group-_8459841.pdf)

[16]. Duke Energy, "Cliffside Steam Station Modernization - Project Overview": (Reviewed online January 2010) at http://www.duke-energy.com/about-us/cliffside-overview.asp)

[17]. http://www.miga.org/documents/Maritzabrief.pdf

[18]. http://www.energy.ca.gov/2007_energypolicy/documents/2007-05-29_workshop/presentations/Dalton_EPRI_Clean_Coal.pdf

[19]. http://www.power-technology.com/projects/comanche/

[20]. http://www.energyjustice.net/coal/igcc/factsheet.pdf

[21]. Course lectures “Energy Policy” – AUK, 2008

[22]. The Emission Trading System, http://www.youtube.com/watch?v=y7veRksc_Yk

[23]. ElectroWatt – Ekono, Jaakko Pöyry Group, (2006), *Pre-feasibility studies for the new lignite fired power plant and for pollution mitigation measures at Kosovo B power plant*, Lot 2. Prishtina, European Agency for Reconstruction

[24]. Carl Bro, (2003), *Environmental Impact Assessment and Action plan for Kosova A and B Power Plants and Coal Mines*, European Agency for Reconstruction

[25]. Energy Community Treaty: http://www.stabilitypact.org/energy/Treaty.en05.pdf

Appendix A

A.1 Directives and Regulations

A.1.1. Directive 2001/80/EC on Large Combustion Plants

The Directive aims to set the limitations of emissions into the air from large combustion plants with the rated thermal input equal or greater than $50MW_{th}$, for the certain pollutants like: NOx, SO_2 and dust. The large combustion plants are divided into three groups;

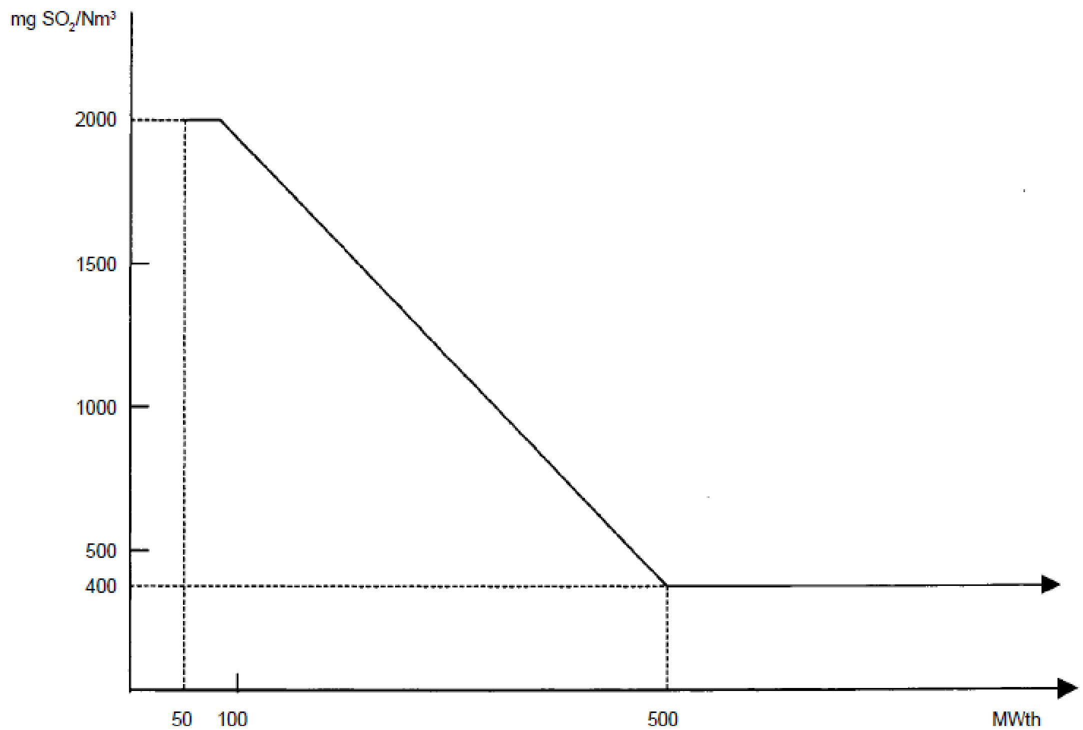
- old LCP (existing plant) – are combustion plants that are constructed or their operation license was granted before 1 July 1987;
- new plants - are combustion plants that are constructed or their operation license was granted after 1 July 1987
- new "new" plants – are combustion plant that are constructed or put in operation after 27 November 2003

According to this Directive there are set Emission Limit Values for two groups of large combustion plants in two timing period. According to the directive:

> *"the Emission Limit Value means the permissible quantity of a substance contained in the waste gases from the combustion plant which may be discharged into the air during a given period and it is expressed in mg/Nm3 assuming that oxygen content by volume in the waste gas is 6%."*

The ELV for SO2 for solid fuels for old plants and new plants are given in the figure A.1.

Figure. A.1. Diagram of ELV for SO_2 for solid fuels for old plants and new plants



For new "new" plants the EVL for SO_2 expressed in mg/Nm^3 (for O2 content 6%) are given in the following table (values are presented only for solid fuels and this would be related to the units of new power plant that might be constructed in Kosova)

Table A.1. SO_2 emission limit value for solid fuels for new "new" plants

Type of fuel	50 to 100MW_{th}	100 to 300MW_{th}	>300MW_{th}
Solid fuel (except biomass)	850	200	200

For old and new plants the NOx ELV expressed in mg/Nm^3 (with 6% of O_2 content) for solid fuels are presented in the following table.

Table A.2. NOx ELV for solid fuels (with 6% content of O_2)

Type of fuel:	Limit value (mg/Nm^3)
50 to 500 MW_{th}	600
>500 MW_{th}	500
From 1 January 2016	

50 to 500 MW_{th}	600
>500 MW_{th}	200

For new "new" plants NOx emission limit values expressed in mg/Nm^3 for solid fuels (with 6% of O_2 content) are presented in the following table

Table A.3. NOx ELV for solid fuels (with 6% content of O_2) for new "new"plants

Type of fuel	50 to 100MWth	100 to 300MWth	>300MWth
Solid fuel (except biomass)	400	200	200

Emission limit values for dust expressed in mg/Nm^3 (with 6% O_2 content) are presented in following table.

Table A.4. Dust (particulate) ELV for solid fuels (with 6% content of O_2) for new plants

Rated thermal input	Emission limit value (mg/Nm^3)
≥ 500MW_{th}	50
< 500 MW_{th}	100

For new "new" plants the dust emission limit value for solid fuels are presented in following table.

Table A.5. Dust (particulate) ELV for solid fuels (with 6% content of O_2) for new "new" plants

Rated thermal input	Emission limit value (mg/Nm^3)
50 to 100MW_{th}	50
>100 MW_{th}	30

A.2. Energy Community Treaty – Athens Treaty

Kosovo as a party of Athens Treaty [18] (signed at that time by Special Representative of UNMIK) – among the other duties like: creation of a stable regulatory and market framework of attracting the investments in gas network, power generation, transmission and distribution networks, creation of regulatory space for energy trade, they have accepted also the actions to improve the environmental situation in relation to Network Energy (electricity and gas sector).

Regarding the scope of this Capstone Project, one of the requirements for complying with the treaty is the implementation of EU Directive 2001/80/EC by end of 2017.

Appendix B

Table. B.1. Calculation for costs or revenues for net import or export of electricity and costs for CO_2 emissions

		2010	2012	2014	2016	2017	2018	2020	2022	2024	2026	2028	2030
total CO2 emission scenario 1	kiloton	7054	6613	7219	7219	7219	4634	4344	4634	4634	4344	4634	4634
total CO2 emission scenario 2	kiloton	7054	6613	7219	7219	9780	7111	7949	7949	7949	7670	7949	7949
total CO2 emission scenario 3	kiloton	7054	6613	7219	7219	9780	7111	11430	11430	11430	11151	11430	11430
total CO2 emission scenario 4	kiloton	7054	6613	7219	7219	9780	7111	11430	14911	18392	18113	18392	18392
net import/export scenario 1	GWh	260	1,006	1,038	1,546	1,816	3,673	4,488	4,910	5,605	6,578	7,171	8,051
net import/export scenario 2	GWh	260	1,006	1,038	1,546	- 873	584	516	1,159	1,855	2,828	3,420	4,300
net import/export scenario 3	GWh	260	1,006	1,038	1,546	- 873	584	- 2,834	- 2,191	- 1,496	- 523	70	950
net import/export scenario 4	GWh	260	1,006	1,038	1,546	- 873	584	- 2,834	- 5,542	- 8,197	- 7,224	- 6,632	- 5,752
Cost or revenues - Scenario 1	million €	-11.7	-45.3	-46.7	-69.6	-81.7	-165.3	-202.0	-221.0	-252.2	-296.0	-322.7	-362.3
Cost or revenues - Scenario 2	million €	-11.7	-45.3	-46.7	-69.6	39.3	-26.3	-23.2	-52.2	-83.5	-127.2	-153.9	-193.5
Cost or revenues - Scenario 3	million €	-11.7	-45.3	-46.7	-69.6	39.3	-26.3	127.5	98.6	67.3	23.5	-3.1	-42.7
Cost or revenues - Scenario 4	million €	-11.7	-45.3	-46.7	-69.6	39.3	-26.3	127.5	249.4	368.9	325.1	298.4	258.8
cap of CO2 (if set by EU)	kiloton						11000	11000	11000	11000	11000	11000	11000
Difference of total CO2 from cap of CO2													
scenario 1	kiloton						-6366	-6656	-6366	-6366	-6656	-6366	-6366
scenario 2	kiloton						-3889	-3051	-3051	-3051	-3330	-3051	-3051
scenario 3	kiloton						-3889	430	430	430	151	430	430
scenario 4	kiloton						-3889	430	3911	7392	7113	7392	7392
cost of CO2 - scenario 1	million €						-159	-166	-159	-159	-166	-159	-159
cost of CO2 - scenario 2	million €						-97	-76	-76	-76	-83	-76	-76
cost of CO2 - scenario 3	million €						-97	11	11	11	4	11	11
cost of CO2 - scenario 4	million €						-97	11	98	185	178	185	185
difference of cost for electricity to cost of CO2 scenario 1	million €						-6.1	-35.6	-61.8	-93.1	-129.6	-163.5	-203.1
difference of cost for electricity to cost of CO2 scenario 2	million €						70.9	53.0	24.1	-7.2	-44.0	-77.6	-117.2
difference of cost for electricity to cost of CO2 scenario 3	million €						70.9	116.8	87.9	56.6	19.8	-13.9	-53.5
difference of cost for electricity to cost of CO2 scenario 4	million €						70.9	116.8	151.6	184.1	147.3	113.6	74.0

The assumptions for calculation in table B.1 are:

- The cost of electricity for import or export 45€/MWh
- The cost for emitting CO_2 above the cap is 25€/t of CO_2
- The cap of CO_2 is foreseen to be 11 million tons.
- The period 2010 till 2017 is not considered in the costs for CO_2.