National CO_2 lignite emission factors

Prof. Aleksandar Jovović, PhD
Asst. Prof. Dušan Todorović, PhD

24.04.2019.
Vrdnik

Project Purpose:

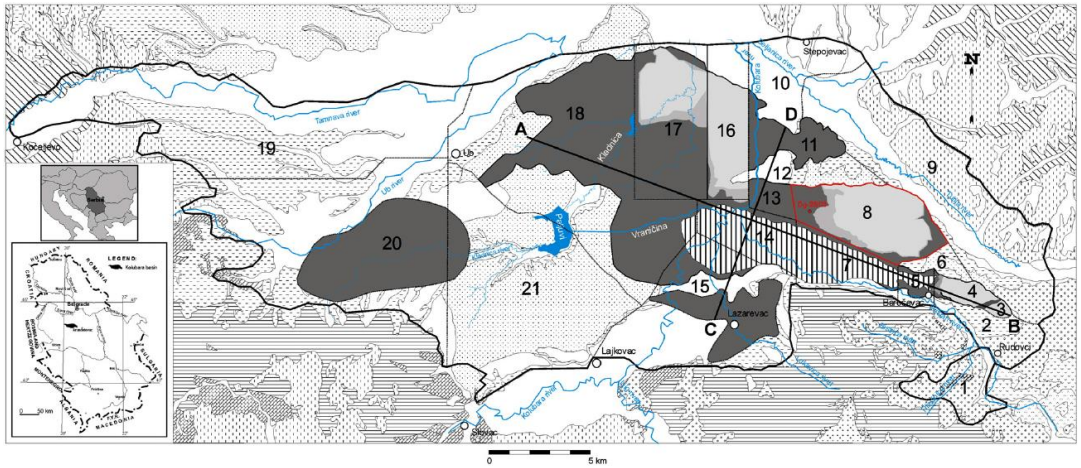
To assist UNDP and Serbian Environmental Protection Agency of the Ministry of Agriculture and Environmental Protection (SEPA) in identifying the national emission factors for domestic lignite and calculating national emissions from TPP for the reporting period 1990-2013.

Outputs:

- ✓ Report on net calorific value and emission factor of the raw lignite from pit-mine exploitation in Serbia
- ✓ Report on consumption of fuel in each individual combustion plant
- ✓ CalEF – tool with purpose to calculate coal CO_2 emission factor and net calorific value (NCV)

- **LIGNITE COMBUSTION**

General Considerations
Combustion Technology
Emissions (CO_2, N_2O, CH_4)

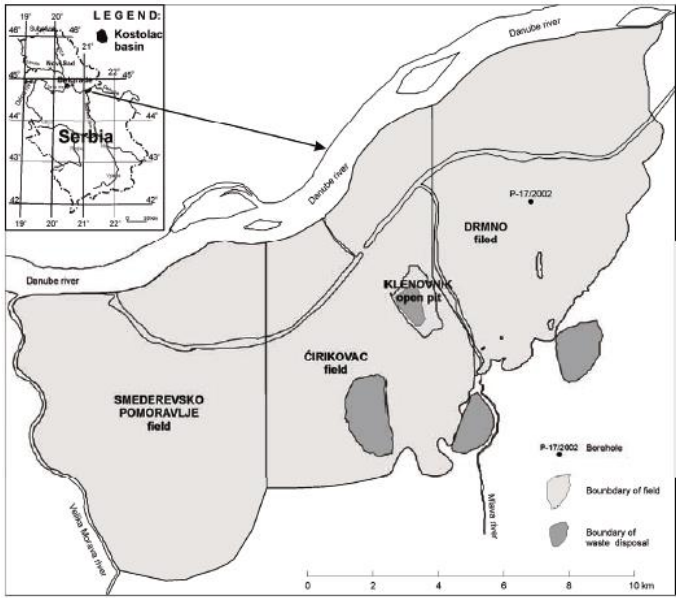


- **DESCRIPTION OF SERBIAN COALS**

Kolubara basin
Kostolac Basin

- **METHODS TO ESTIMATING EMISSIONS**

Overview of CO_2 emission factors from coal combustion
Calculation of CO_2 emission factor



Methodology for calculation of CO_2 emission factor and net calorific value (NCV)

Coal contains five main fuel elements: C, H, S, N and O.

For calculation of accurate CO_2 emission factor it is necessary to obtain the high reliable composition of coal (mass fraction of mentioned main fuel elements) as well as mass fraction of ash (A) and moisture (W).

- Lower heating value (LHV) of coal:

$$H_d = 339 \times C + 1197 \times \left(H - \frac{O}{8}\right) + 105 \times S - 25 \times W, \quad \left[\frac{kJ}{kg}\right]$$

- CO_2 emission factor of coal:

$$EF_{CO_2} = \frac{r_{CO_2} \times V_{CO_2} \times 10^9}{H_d}, \quad \left[\frac{g_{CO_2}}{GJ}\right]$$

CO_2 emissions

- Total CO_2 emissions from stationary combustion of coal:

$$Emissions_{CO2} = Coal\ consumption \cdot EF_{CO2}$$

where:

$Emissions_{CO2}$	- emissions of CO_2
Coal consumption	- amount of fuel combusted, expressed in energy units
EF_{CO2}	- calculated emission factor

Report on net calorific value and emission factor of the raw lignite from pit-mine exploitation in Serbia

Due to very disaggregated data of lignite used in thermal power plants (TPP) that are in PE EPS system, it was possible to calculate a CO_2 emission factors and net calorific values (NCV) for each TPP. In some cases, it was even for each unit within the TPP.

As well, it is important to say that information of fields, within basins from which is used coal, was not available.

On the other hand beside this detailed data of combusted coal, there are some gaps in data within the observed period (1990-2013).

The period 2006-2013 is almost fully covered with all necessary data, while the previous period (1990-2005) completely missing. Nevertheless, based on analysis of emission factors calculated on available data and some periodic data for years from period earlier than 1990 (marked with red letters in tables), it is possible to use average values for specific facilities to fulfill the data gaps (for same facilities minor differences between calculated values for different years could be observed, less than 5%).

In this Report are presented emission factors of CO_2 and net calorific values of lignite combusted in next facilities:

TPP Nikola Tesla A (TENT A),
TPP Nikola Tesla B (TENT B),
TPP Kolubara,
HP Vreoci,
TPP Morava,
TPP Kostolac A,
TPP Kostolac B.

As well based on those results it was possible to give the same parameters for both lignite basins in Serbia:

Kolubara basin and
Kostolac basin.

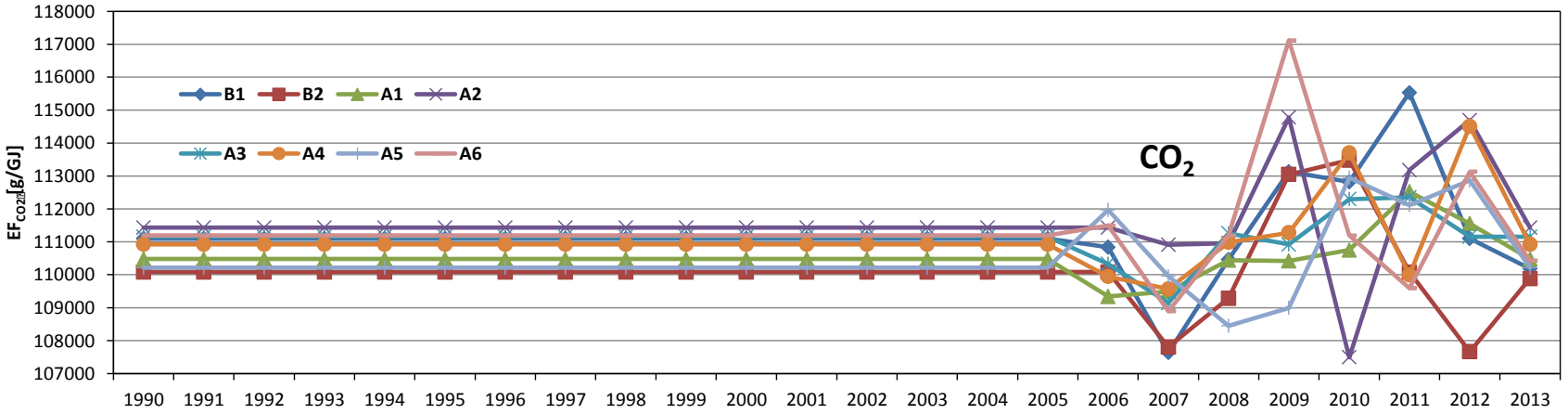
CO_2 emission factors and net calorific values of lignite combusted in TENT A and B

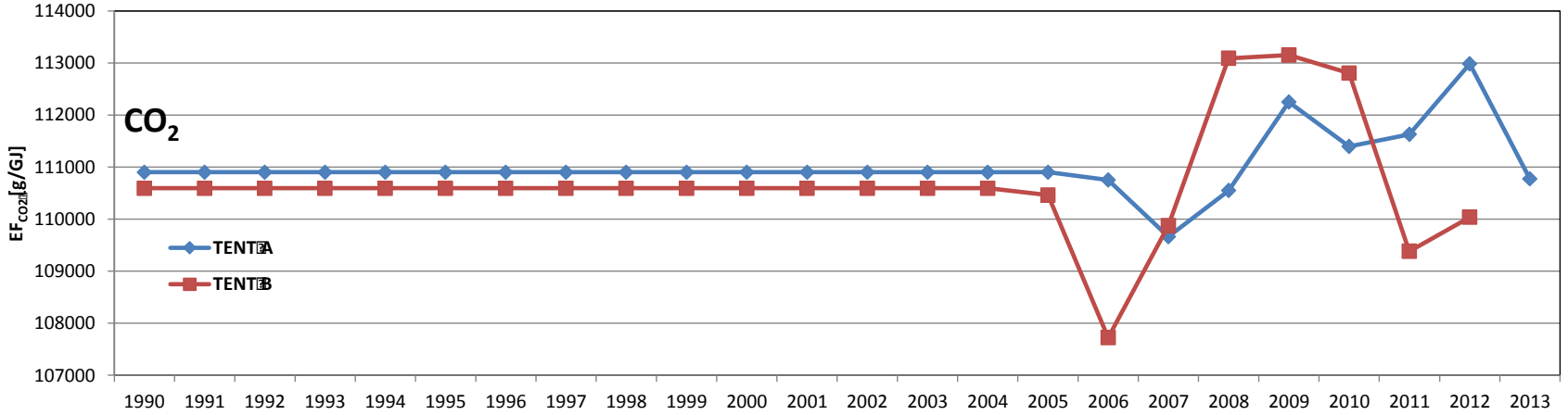
Table 1. CO_2 emission factors and net calorific values of lignite combusted in six units (A1-A6) of TENT A

Year	A1		A2		A3		A4		A5		A6	
	EF_{CO_2} g/GJ	NCV kJ/kg	EF_{CO_2} g/GJ	NCV kJ/kg	EF_{CO_2} g/GJ	NCV kJ/kg	EF_{CO_2} g/GJ	NCV kJ/kg	EF_{CO_2} g/GJ	NCV kJ/kg	EF_{CO_2} g/GJ	NCV kJ/kg
1970	107820	7403	-	-	-	-	-	-	-	-	-	-
1972	110994	7792	110818	7292	-	-	-	-	-	-	-	-
1975	-	-	108612	6427	-	-	-	-	-	-	-	-
1977	-	-	-	-	111219	7099	-	-	-	-	-	-
1979	-	-	-	-	-	-	107261	8445	-	-	-	-
1980	-	-	-	-	-	-	-	-	107934	8665	-	-
1982	-	-	-	-	-	-	-	-	-	-	107701	8120
1989	111442	7007	-	-	111702	7688	111088	7185	106725	8339	-	-
1990	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
1991	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
1992	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
1993	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
1994	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
1995	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
1996	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
1997	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
1998	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
1999	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
2000	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
2001	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
2002	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
2003	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
2004	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
2005	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	111191	7976
2006	109342	7929	111432	7361	110328	8397	109946	8275	111967	7872	111491	7859
2007	109493	8235	110914	8138	109145	9230	109570	8203	109957	8845	108890	8818
2008	110444	8278	110960	7875	111260	7821	110985	8089	108448	7975	111191	7976
2009	110418	7782	114781	7230	110920	7704	111275	7858	108992	8504	117113	7270
2010	110751	6629	107496	7772	112295	5957	113696	7729	112946	6232	111191	7976
2011	112524	7407	113180	7076	112355	6444	109993	7844	112111	6825	109591	7755
2012	111555	6927	114693	7076	111153	7543	114507	6830	112865	7370	113125	7934
2013	110478	7539	111432	7361	111153	7543	110925	7829	110216	7847	110424	8074

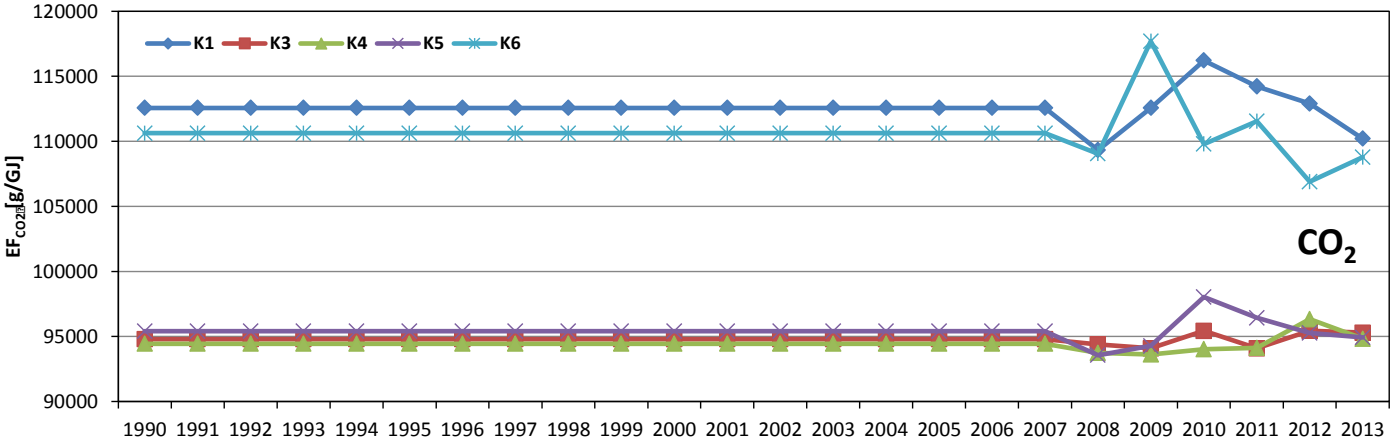
Table 2. CO_2 and net calorific values of lignite combusted in two units (B1-B2) of TENT B.

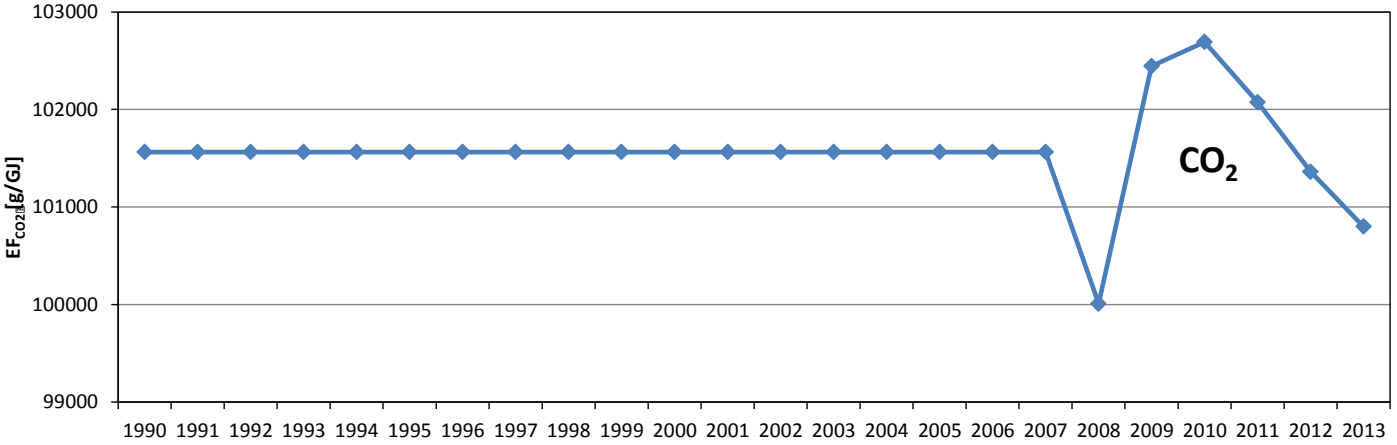
Year	B1		B2	
	EF_{CO_2} g/GJ	NCV kJ/kg	EF_{CO_2} g/GJ	NCV kJ/kg
1984	108187	8394	-	-
1986	-	-	109417	8695
1990	111099	7869	110083	8006
1991	111099	7869	110083	8006
1992	111099	7869	110083	8006
1993	111099	7869	110083	8006
1994	111099	7869	110083	8006
1995	111099	7869	110083	8006
1996	111099	7869	110083	8006
1997	111099	7869	110083	8006
1998	111099	7869	110083	8006
1999	111099	7869	110083	8006
2000	111099	7869	110083	8006
2001	111099	7869	110083	8006
2002	111099	7869	110083	8006
2003	111099	7869	110083	8006
2004	111099	7869	110083	8006
2005	111099	7869	110083	8006
2006	110839	8633	110083	8006
2007	107636	9425	107809	8941
2008	110466	8526	109281	8813
2009	113129	7170	113045	7098
2010	112821	6792	113482	7232
2011	115529	6318	110083	8006
2012	111099	7869	107662	7334
2013	110184	7691	109886	7929


118000
117000
116000
115000
114000
113000
112000
111000
110000
109000
108000
107000
B1
B2
A1
A2
A3
A4
A5
A6
CO2
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

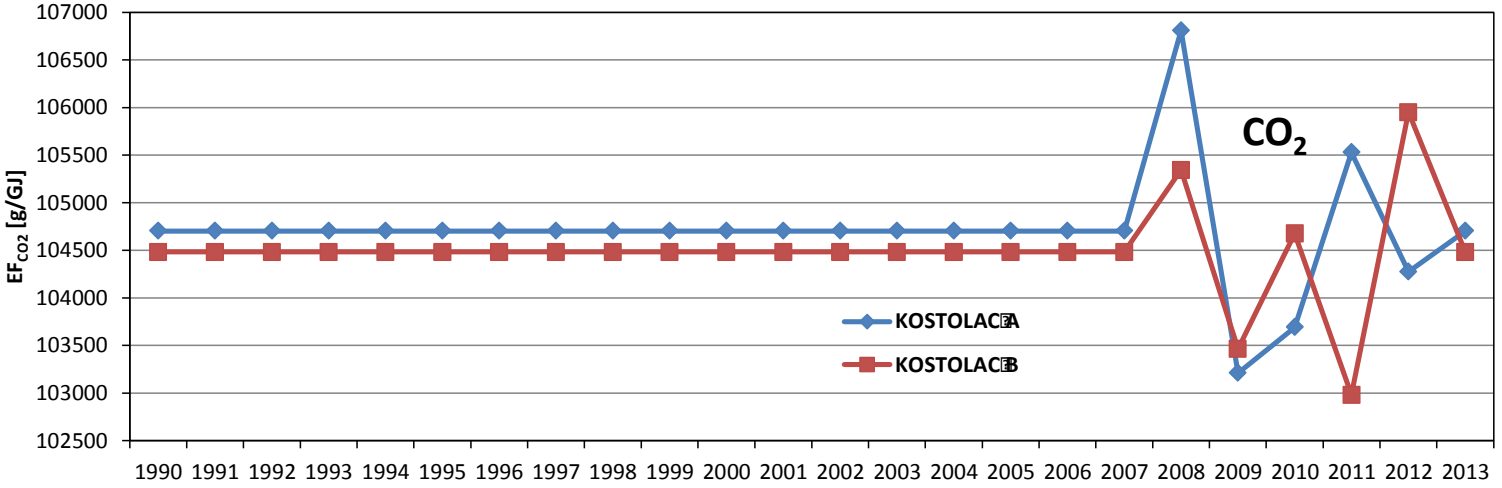

114000
113000
112000
111000
110000
109000
108000
107000
CO2
TENTE A
TENTE B
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

TPP KOLUBARA

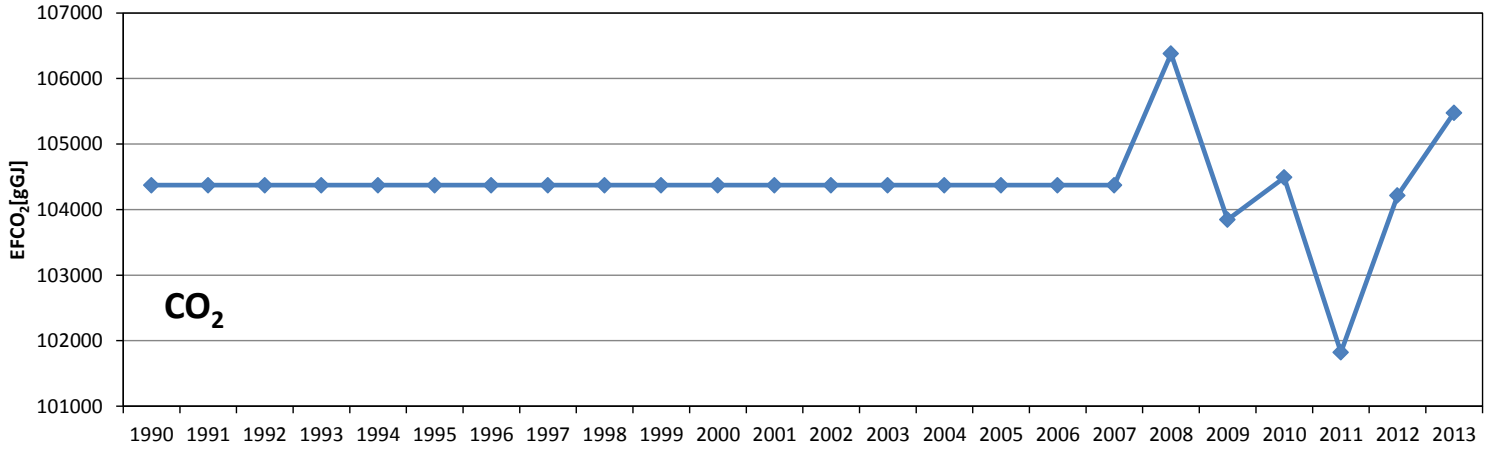




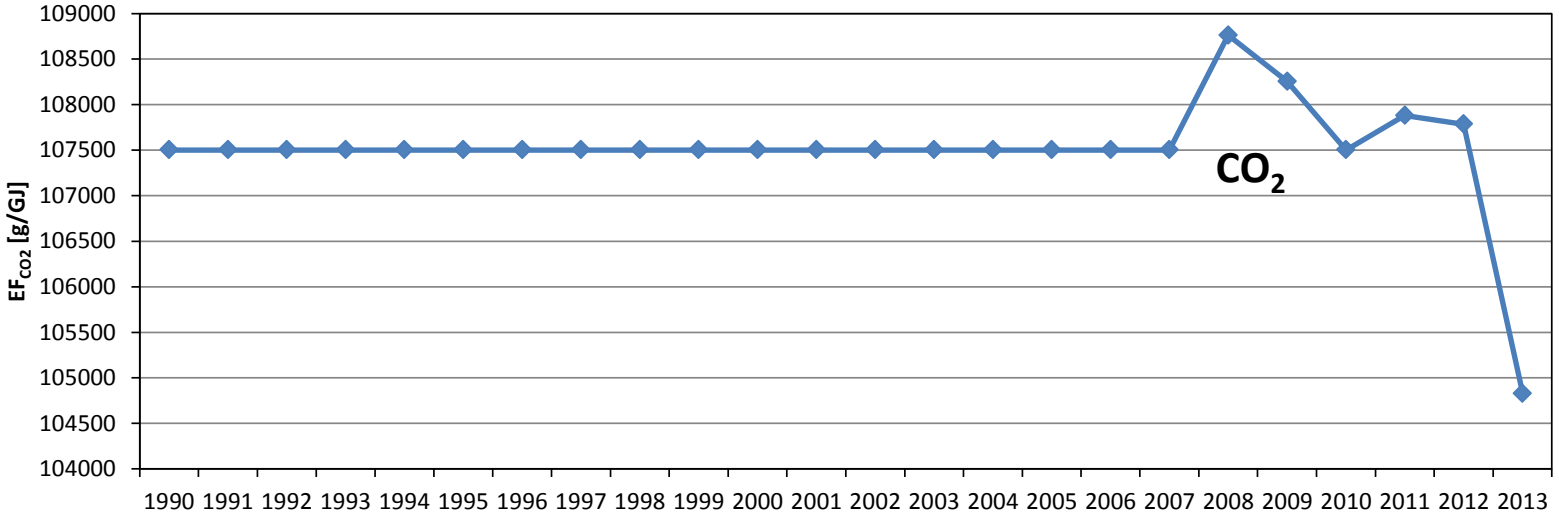
TPP KOSTOLAC A and B



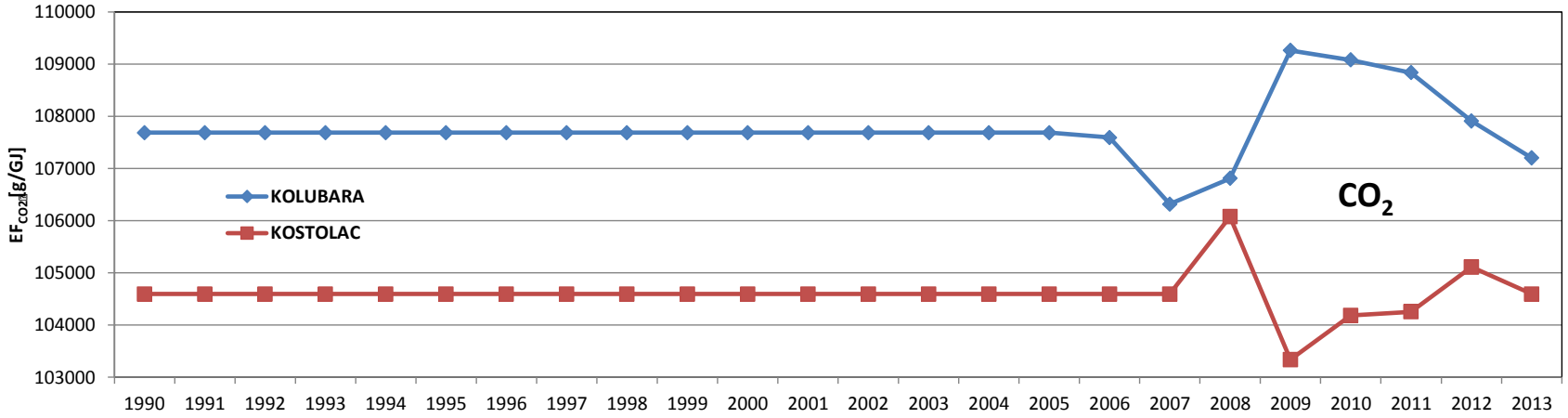
TPP Morava



HP Vreoci



KOLUBARA and KOSTOLAC basins



Average value of CO_2 emission factors for lignite from Kolubara basin, according data presented in this report, is 107685 g_{CO2}/GJ, while net calorific value is 7975 kJ/kg.

Raw lignite from Kostolac basin has CO_2 emission factors of 104592 g_{CO2}/GJ and net calorific value of 8454 kJ/kg.

It is important to underline that those mentioned values are the most aggregated data, and that this Report provides data disaggregated to the lowest level - unit level.

If compare aggregated results of CO_2 emission factors for Kolubara and Kostolac basin with IPCC default CO_2 emission factor for lignite (101000 g_{CO2}/GJ) it could be concluded that Serbian open-pit mined lignite has slightly higher value. But on the other hand if it is compared with CO_2 emission factors for each unit or plant it could be observed that factor is in wider borders (approximately from 94000 to 118000 g_{CO2}/GJ).

Report on consumption of fuel in each individual combustion plant and emission calculation

According the calculations provided from above mentioned Reports and data of fuel consumption provided by PE EPS, in this Report are presented results of CO_2 emissions calculations for next facilities:

TPP Nikola Tesla A (TENT A),
TPP Nikola Tesla B (TENT B),
TPP Kolubara,
HP Vreoci,
TPP Morava,
TPP Kostolac A (TEKO A),
TPP Kostolac B (TEKO B).

As well as aggregated CO_2 emissions from these sources are provided within this Report.

Available data on fuel consumption were for period 2008-2013, so based on that and CO_2 emissions were calculated and presented in this Report.

Fuel consumption

Table 1: Consumption of coal per units in TPPs TENT A and TENT B [10^3 t].

Year	TENT A							TENT B		
	A1	A2	A3	A4	A5	A6	Total TENT A	B1	B2	Total TENT B
2008	1872	1703	2844	3215	2928	1456	**14018**	6263	5373	**11636**
2009	1636	1846	2661	2992	2840	2880	**14855**	5859	4728	**10587**
2010	1778	1610	2503	2945	2898	1321	**13055**	5281	6480	**11761**
2011	1976	1967	3113	2616	3136	3708	**16516**	6350	4482	**10832**
2012	1880	1799	3078	3294	2045	3513	**15609**	3184	6425	**9609**
2013	1607	1622	2549	2895	3257	2991	**14921**	6154	6111	**12265**

Table 2: Consumption of coal per units in TPP KOLUBARA [10^3 t].

Year	TPP KOLUBARA					
	K1	K3	K4	K5	K6	Total
2008	347	220	146	293	1101	**2108**
2009	460	124	464	287	530	**1865**
2010	398	305	199	233	1162	**2297**
2011	373	261	100	180	1283	**2197**
2012	341	341	359	333	953	**2327**

Table 3: Consumption of coal in TPPs KOSTOLAC A (TEKO A) and KOSTOLAC B (TEKO B) [10^3 t].

Year	TEKO A	TEKO B
2008	2878	4040
2009	2826	5530
2010	2866	4027
2011	2801	6035
2012	3346	4209
2013	2837	5783

Table 4: Consumption of coal in HPP VREOCI and TPP MORAVA [10^3 t].

Year	HPP VREOCI	TPP MORAVA
2008	199	803
2009	190	698
2010	208	779
2011	197	662
2012	206	870
2013	217	719

CO_2 emissions

$$Emissions_{CO2} = Coal\ consumption \cdot NCV \cdot EF_{CO2}$$

where:

$Emissions_{CO2}$	- emissions of CO_2
Coal consumption	- amount of fuel combusted, expressed in mass units
NCV	- net calorific value
EF_{CO2}	- calculated emission factor

Table 5: CO_2 emissions per units of TPPs TENT A and TENT B [Gg_{CO2}].

Year	TENT A							TENT B		
	A1	A2	A3	A4	A5	A6	Total TENT A	B1	B2	Total TENT B
2008	1711	1488	2475	2886	2532	1291	**12384**	5899	5175	**11073**
2009	1406	1532	2274	2616	2632	2452	**12912**	4752	3794	**8546**
2010	1305	1345	1674	2588	2040	1172	**10124**	4047	5318	**9365**
2011	1647	1575	2254	2257	2400	3151	**13284**	4635	3950	**8585**
2012	1453	1460	2581	2576	1701	3153	**12924**	2784	5073	**7857**
2013	1338	1330	2137	2514	2817	2667	**12804**	5215	5324	**10539**

Table 6: CO_2 emissions per units of TPP KOLUBARA [Gg_{CO2}].

Year	TPP KOLUBARA					
	K1	K3	K4	K5	K6	Total
2008	341	195	145	271	1033	**1985**
2009	376	107	390	231	410	**1514**
2010	289	245	164	168	1130	**1996**
2011	295	203	93	143	1081	**1814**
2012	268	274	299	278	812	**1930**

Table 7: CO_2 emissions of TPPs KOSTOLAC A (TEKO A) and KOSTOLAC B (TEKO B) [Gg_{CO2}].

Year	TEKO A	TEKO B
2008	2568	4007
2009	2616	5132
2010	2355	3664
2011	2279	5242
2012	2853	3520
2013	2444	5245

Table 8: CO_2 emissions of HPP VREOCI and TPP MORAVA [Gg_{CO2}].

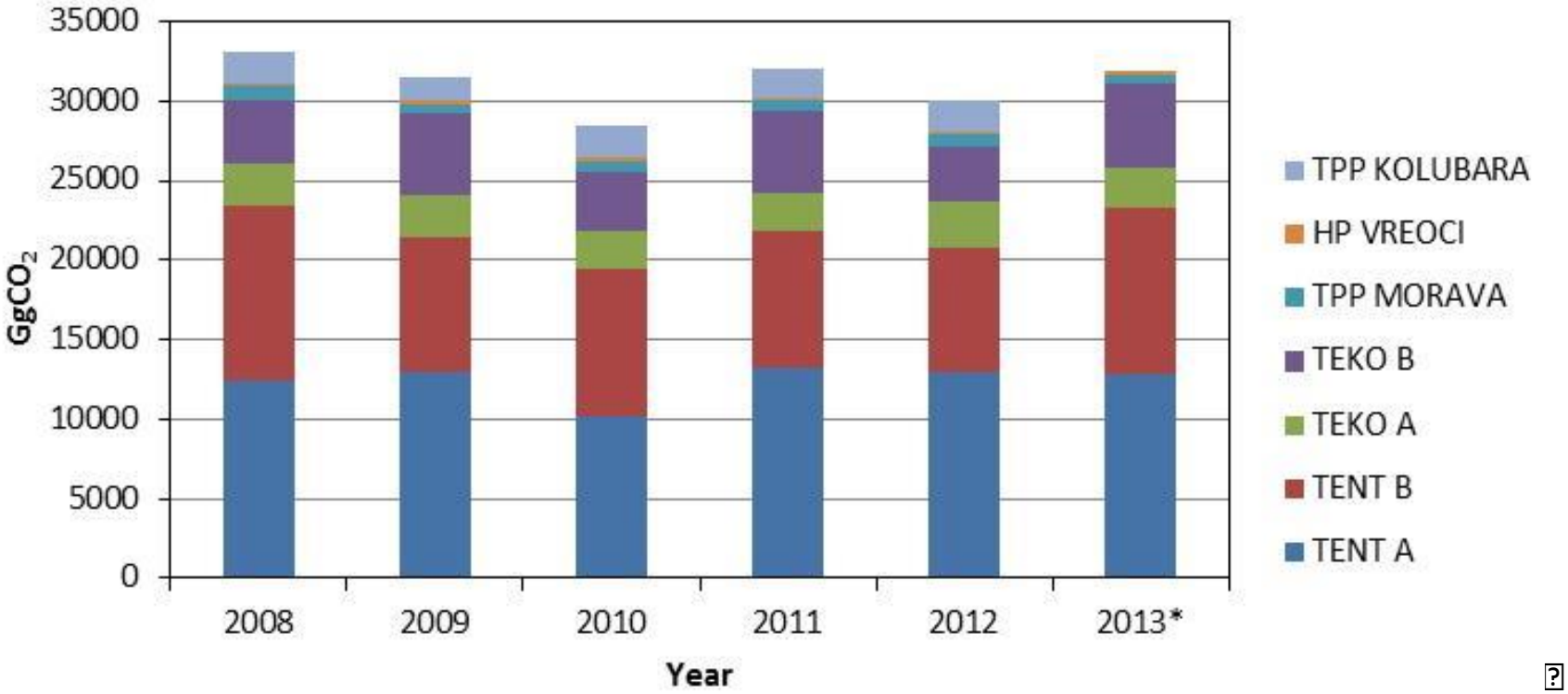
Year	HPP VREOCI	TPP MORAVA
2008	198	886
2009	198	629
2010	207	693
2011	187	595
2012	190	730
2013	232	617

Table 9: Total CO_2 emissions of facilities discussed in this Report

Year	2008	2009	2010	2011	2012	2013*
Total CO_2 emissions	33102	31548	28405	31986	30003	31881

*Without TPP KOLUBARA.

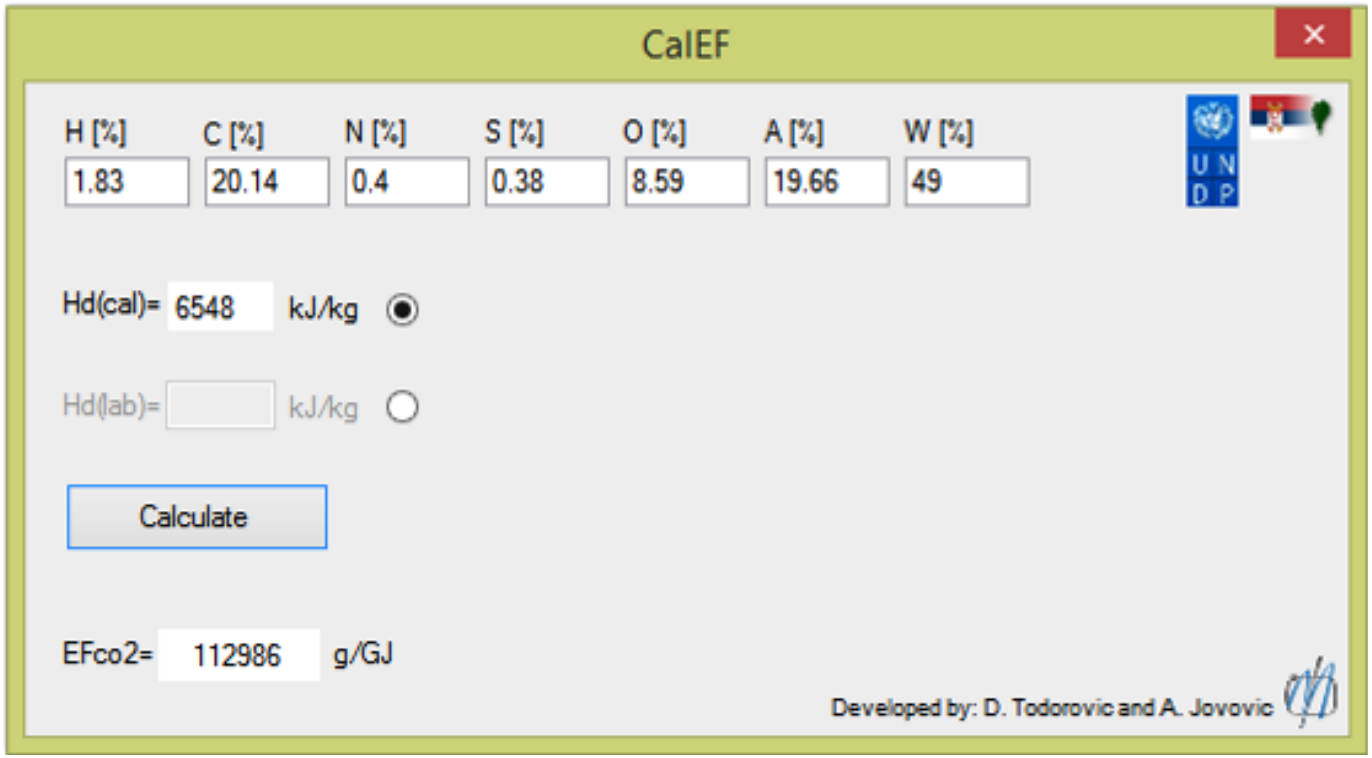
Contribution of each coal TPPs and HP, discussed within this Report, to the overall CO_2 emissions



Data that are using for mentioned calculations, have to be highly reliable and have to be provided from adequate institution, otherwise using inadequate data could resulted more incorrect results than using default emission factor.

CalEF

CalEF is tool with purpose to calculate coal CO_2 emission factors using the specific elements of proximate and ultimate analysis (H, C, N, S, O, A and W) as well as net calorific value of coal. Beside that in case if the net calorific value is missing CalEF is able to calculate it based on mentioned specific coal components.



ajovovic@mas.bg.ac.rs
dtodorovic@mas.bg.ac.rs