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TECHNICAL REPORT

Health Impacts of Coal Fired Power Stations in the Western Balkans

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Summary

This report provides an assessment of the health impacts associated with air pollutant emissions from coal and lignite combustion at power stations in Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro and Serbia.

The methods used here reflect those used for pan-European assessments for the EU Commission and European Environment Agency (EEA). A health impact assessment follows the recommendations of the World Health Organization in Europe (WHO-Europe).

The Balkans region is home to a large number of coal and lignite-fired units and there are plans in place to develop significantly more. The readily available amount of solid fuel in each country is seen to offer some degree of energy independence. However, this needs to be set against the negative effects of a reliance on coal and lignite in the interests of efficient policy making. This will assist in making a fair comparison across all possible approaches for meeting desired levels of energy service. The term 'energy service' rather than 'energy provision' is used here to highlight the role that energy efficiency can play in meeting societal demand. Energy efficiency measures, including basic insulation and proper maintenance of boilers and other equipment, can pay back costs and reap profits within a few months of installation. These benefits will be most significant for those in fuel poverty.

Existing power stations in the region generally operate to low environmental standards and generate high emissions, which are in turn associated with large impacts to health. It is anticipated that some of these facilities will close whilst others are upgraded in order to meet new legislative requirements.

Analysis demonstrates that the newer power stations will operate to much tighter standards than existing plants currently do - standards defined through the EU's Industrial Emissions Directive (IED). However, analysis also shows that cleaner plants will still cause damage to health across and beyond the region.

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1. INTRODUCTION

1.1 BACKGROUND

This report describes the health impacts of emissions of air pollutants from power stations in Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro and Serbia. The stations concerned comprise of 59 units spread across 30 sites, and range from existing plants operating with minimal emission controls to proposed facilities (not yet in operation) that would operate to the standards required under the EU's Industrial Emissions Directive (IED). A further four units, believed to be closed, are excluded from the analysis. Previous analysis (see reference: CEE (2013) Health Impacts of Coal Fired Power Generation in Tuzla) highlighted the high health impacts associated with the reliance on coal power generation in specific parts of the region. This report goes further to consider all plants.

1.2 OBJECTIVES OF THIS REPORT

The analysis quantifies health impacts and associated economic costs of air pollutant emissions from each plant. Results are expressed in terms of both physical indicators of impact (premature deaths, though results permit other impacts to also be quantified) and their economic equivalent accounting for healthcare costs, lost productivity and amenity losses. The general approach used for quantification is similar to that used in an earlier study of thermal power plants around Tuzla (CEE, 2013) and analysis by the European Environment Agency (EEA, 2014). It is based on World Health Organization (WHO) recommendations (WHO, 2013 a, b) for a health impact assessment. The valuation is based on methods used by the EU Commission (2013) and the Organisation for Economic Co-operation and Development (OECD, 2012).

It is intended that the results will contribute to the debate about energy provision in the region. The health impacts of coal are of course only one factor to consider: also relevant are other impacts, particularly climate change and the increasing competitiveness of renewable technologies for power generation (Bloomberg New Energy Finance BNEF, 2015).

1.3 AIR POLLUTION AND HEALTH

Air pollution is increasingly recognised as a significant threat to public health. Review work by WHO-Europe through the REVIHAAP and HRAPIE studies (WHO, 2013a, b) demonstrates that the health impacts of air pollutants include respiratory and cardiac mortality, bronchitis, hospital admissions, and various other effects.

The WHO's International Agency for Research on Cancer (IARC) has classified outdoor air pollution as carcinogenic to humans (Group 1), in relation to lung cancer (IARC, 2013). The Group 1 classification is used where it is considered that the evidence of causality between an agent and an effect is clear. They also noted a positive association with an increased risk of bladder cancer. Particulate matter (PM), a major component of outdoor air pollution, was evaluated separately and was also classified as carcinogenic to humans (also Group 1).

Table 1 provides further information on the health risks of the pollutants with which this report is mainly concerned, sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter (PM). It includes reference to WHO guidelines and EU air quality limit values for the three pollutants, expressed in µg.m-3 (microgrammes, 10-6 g, per cubic metre of ambient air). Information is based on both WHO recommendations (see Krzyzanowski and Cohen, 2008) and EU Directives. The table highlights life-long impacts of air pollution on health, as highlighted by the Royal College of Physicians, London (RCP, 2016).

The impacts of SO_2 and NO_x are linked not only to exposure to the pollutants in the form in which they are emitted, but also to their reaction products. Both SO_2 and NO_x react with other pollutants in the atmosphere to form aerosols (especially ammonium sulphate and ammonium nitrate) that contribute to the total particulate loading of the air. NO_x also reacts with volatile organic compounds in the presence of sunlight to generate increased levels of ozone, another pollutant recognised as a threat to health.

Differences are apparent in the WHO Guidelines and EU limit values for the concentration of pollutants in ambient air. These differences reflect a view on the feasibility of achieving the WHO Guidelines in the EU on specific timescales. It is important to recognise that neither guideline nor limit values reflect thresholds for effects on health; it is widely agreed that impacts will still occur amongst sensitive individuals at lower concentrations, following various studies such as Crouse (2012) that found no evidence of a threshold even in remote areas with very low particle concentrations.

Table 1. Health risks from various pollutants, pollutant guideline values for ambient air and limit values

POLLUTANT	RELATED HEALTH RISKS (WHO)	AIR QUALITY GUIDELINES AND LIMIT VALUES
Sulphur dioxide (SO_2)	Lung functions, aggravation of asthma and chronic bronchitis, infections of the respiratory tract; irritation of eyes; cardiac disease; ischaemic stroke.	*WHO Guidelines.* 20 $\mu g/m_3$ (day) 500$\mu g/m_3$ (10min) EU Directive 2008/50/EC: 125 $\mu g/m_3$ (24 hours), not to be exceeded > 3 times/year 350 $\mu g/m_3$ (1 hour), not to be exceeded > 24 times/year
Nitrogen dioxide (NO_2)	Asthma development (suspected), asthma exacerbation, chronic obstructive pulmonary disease, stunted lung development; cardiac arrhythmias, ischemic stroke. Reacts with volatile organic compounds (VOCs) in sunlight to form ground- level ozone which is also harmful to health.	*WHO Air Quality Guidelines and EU Directive 2008/50/EC:* NO_2: 40 $\mu g/m^3$ (annual) NO_2: 200 $\mu g/m_3$(1 hour)
Particulate matter (PM): Coarse particulates (PM_{10}) Fine particulates ($PM_{2.5}$)	Asthma development (suspected), asthma exacerbation, chronic obstructive pulmonary disease, stunted lung development ($PM_{2.5}$); lung cancer Cardiac arrhythmias, acute myocardial infarction, congestive heart failure ($PM_{2.5}$) Ischaemic stroke.	*WHO Guidelines*: $PM_{2.5}$: 10 $\mu g/m_3$ (year) PM_{10}: 20 $\mu g/m_3$ (year) EU Directive 2008/50/EC: $PM_{2.5:}$ 25 $\mu g/m_3$ target (year) PM_{10}: 40 $\mu g/m_3$ (year) limit PM_{10}: 50 $\mu g/m_3$ (day) limit, not to be exceeded on > 35 days

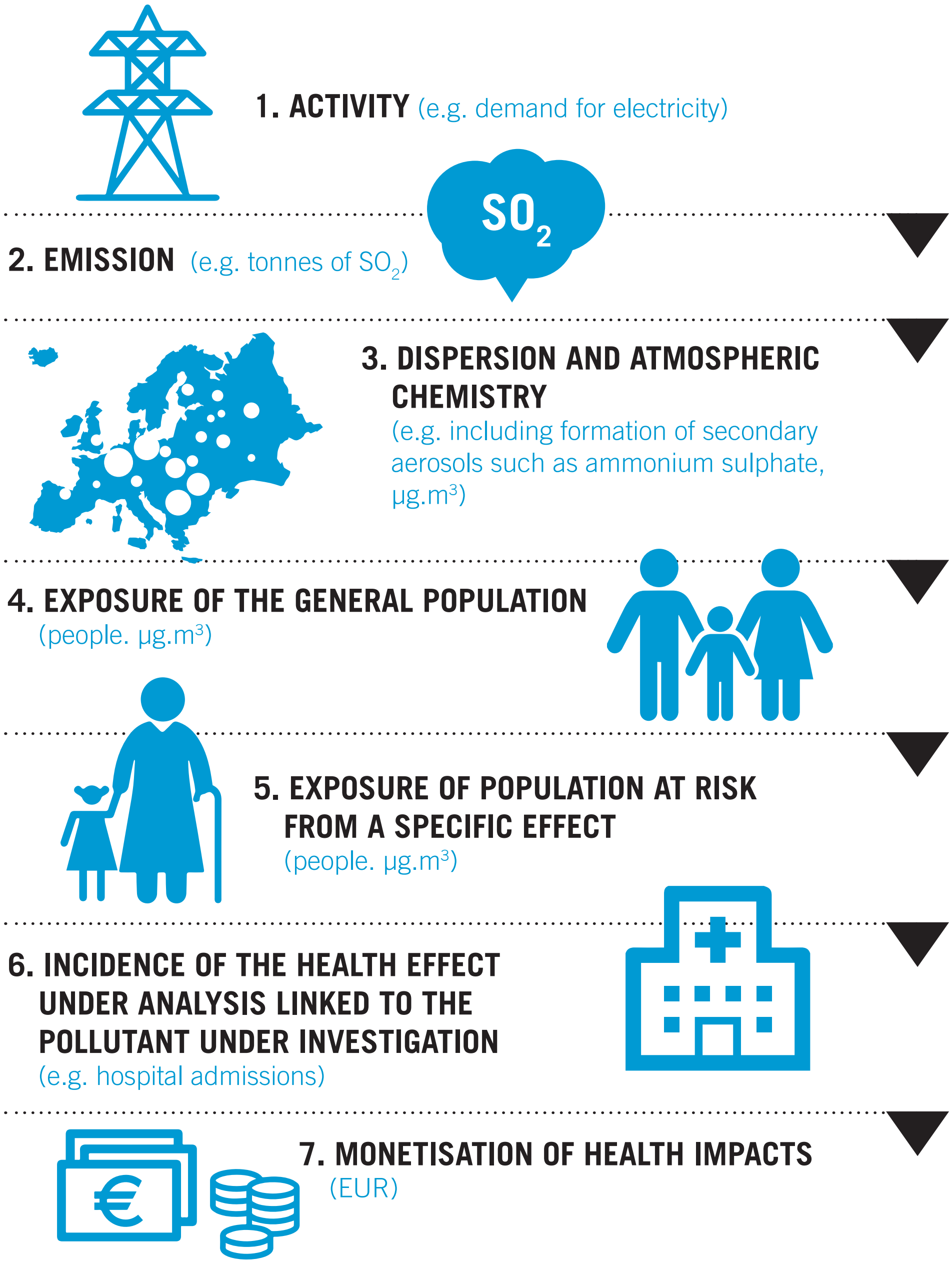
2. METHODS

This section summarises the approach taken for quantification of effects and subsequent valuation.

2.1 THE IMPACT PATHWAY APPROACH

Analysis follows the Impact Pathway Approach (IPA) developed in the ExternE Project funded by the EU in the 1990s. The IPA describes a logical pathway from emission through exposure of the population to pollution to impact assessment and finally monetisation.

Figure 1. The impact pathway approach (ExternE, 1995; 1998; 2005)



The example shown on the previous page deals with an assessment of the impacts of sulphur dioxide (SO_2) emissions on health, mediated through the formation of 'secondary' ammonium sulphate aerosols in the atmosphere. 'Primary' particles, in contrast, are those emitted directly from combustion sources and numerous other activities. The same general approach works for any air pollutant.

It is necessary to understand that the analysis performed here differs to that used in typical Environmental Impact Assessments (EIAs) for specific installations prior to their construction. EIAs consider risks in the area immediately surrounding a facility, typically extending to a distance of a few kilometres. Within this zone, it is expected that the highest ground level concentrations of pollutants emitted from the facility under examination will occur. EIAs are thus focused on describing the maximum risk to individuals living close to a plant, and whether this risk can be considered significant. A common misunderstanding relates to air quality limit values that are designed to protect the population: they do not reflect 'no effect' levels for some important air pollutants, particularly fine particles ($PM_{2.5}$: see WHO, 2013a, b). This has been reinforced by the publication of Canadian research that found no evidence for a threshold of effect even in areas where concentrations of particles were very low indeed (<5 µg.m-3, certainly below the concentrations reported for the countries considered here) (Crouse et al, 2012). The demonstration through an EIA that an area is in compliance with air quality standards does not therefore mean that people living there are completely protected from the effects of air pollutants from a specific source, and provides no information at all on impacts further away. The 'significance' of exposure as estimated through an EIA is thus a subjective position and does not indicate an absence of effect.

A number of studies on the health effects of air pollutants have found that risks are not restricted to a small area around a power plant or other combustion facility, but extend over considerable distances, in the order of several hundred kilometres. This is precisely the logic behind the development of extensive legislation within Europe through both the EU under the IED, National Emission Ceilings Directive (NECD) and various other Directives, and the United Nations Economic Commission for Europe (UN/ECE) through the Convention on Long-Range Transboundary Air Pollution (CLRTAP). It is not possible to control the health effects of air pollution only by controlling local sources. For this reason, the health impact assessment of power plants and other industrial facilities need to be assessed over the long range. This position is adopted in the present analysis.

2.2 THE STAGES OF THE IMPACT PATHWAY APPROACH

This section describes the way that the IPA is implemented.

2.2.1 Quantifying activity and emissions

The quantification of pollutant emissions, can be performed in two ways. For the current operation of an existing plant, emissions are typically measured and reported by the plant operator. Annual pollutant emissions for plants that have yet to enter service can be estimated by multiplying the permitted emissions (expressed as mg/m3 of flue gas) by the quantity of flue gas (expressed as m3) passing through the power station.

2.2.2 Pollutant dispersion and population exposure

Pollutant dispersion is based on consideration of long-range dispersion of air pollutants, using results from the Unified European Monitoring and Evaulation Programme (EMEP) model, which is the dispersion and atmospheric chemistry model that underpins most European air quality analysis. The EMEP is a scientifically based and policy driven programme under the CLRTAP for international co-operation to solve transboundary air pollution problems (http://emep.int/mscw/index_mscw.html). The EMEP Model has been used to generate a transfer matrix from a large number of model runs. Each run describes the effects of releasing a quantity of a specific pollutant (ammonia

[NH3], NO_x, $PM_{2.5}$, SO_2 and volatile organic compounds [VOCs]) from one country on the pollution climate of Europe as a whole. Changes in pollution levels are overlaid with a map of the European population, to describe the exposure of the population.

2.2.3 Health impact assessment

The core reference for the health impact assessment is the Health Response to Air Pollutants In Europe Project (HRAPIE) coordinated by WHO-Europe for the EU Commission, and bringing together a large number of senior experts on the health effects of air pollution from Europe and North America (WHO-Europe, 2013b; and Holland, 2013, for a description of the practical implementation of the recommended response functions). This is the most recent and complete review of the science available. For analysis for the EU Commission it supersedes the earlier work of Hurley et al (2005) developed under the Clean Air For Europe (CAFE) Programme.

HRAPIE provides response functions for exposure to three pollutants, fine particles ($PM_{2.5}$ or PM_{10}), NO_2 and ozone. However, there is currently a debate as to how to apply the NO_2 recommendations, and reliable analysis of impacts for this pollutant is not yet possible. No account was taken by HRAPIE of effects of SO_2 specifically, largely on the grounds that concentrations of SO_2 in EU cities are now very low (this does not apply in parts of the region considered here). The omission of direct effects of emitted NO_2 and SO_2 (rather than indirect effects from the generation of sulphate and nitrate aerosols in the atmosphere, which are included in the assessment of damage related to exposure to $PM_{2.5}$) may well lead to underestimation of health impacts in this report. The following health outcomes are considered in the analysis on the next page:

Table 2. Summary of information from HRAPIE showing endpoints for health impact assessment

EFFECT	POLLUTANT	EXPOSURE PERIOD	RELATIVE RISK FROM A $10\mu g.m^{-3}$ CHANGE IN EXPOSURE
All cause mortality, age 30+	PM	*Long*	1.062
All cause mortality	O_3	*Short*	1.0029
Post -neonatal infant mortality	PM	*Long*	1.04
Respiratory hospital admissions	PM	Short	1.019
Respiratory hospital admissions	O_3	Short	1.0044
Cardiovascular disease (CVD) hospital admissions	PM	Short	1.0091
Cardiovascular disease (CVD) hospital admissions	O_3	Short	1.0089
Prevalence of bronchitis in children	PM	Long	1.08
Incidence of chronic bronchitis in adults	PM	Long	1.117
Restricted activity days	PM	Short	1.047
Work loss days	PM	Short	1.046
Asthma symptoms in asthmatic children	PM	Short	1.028
Minor restricted activity days	O_3	Short	1.0154

The response functions shown are not fully additive. This applies especially to effects of long-term exposure to PM and ozone on mortality, and to effects of PM on restricted activity days (RADs), work loss days and childhood asthma. For effects of long-term exposure on mortality, at the present time it is recommended only to perform the quantification for PM. For the effects of PM on RADs (etc.) it is necessary to subtract results for work loss days and childhood asthma from the result for RADs to avoid double counting. These adjustments have been applied to the results that follow.

The HRAPIE recommendations do not propose use of a threshold for quantification of impacts, except (effectively) in the case of ozone. For ozone, only exposure above a level of 35 parts per billion is factored into the analysis. This is stated to be an analytical 'cut point', above which the quantification of impacts can be done with greater confidence than below although the HRAPIE authors are quite clear that this is not a threshold.

With respect to mortality assessment, two indicators are available. The first, not surprisingly, is the number of premature deaths linked to air pollution exposure. The second is the loss of life expectancy. For an assessment of long-term impacts the second indicator is considered more robust. This then leads to a question that at first sounds strange: When, in effect, does the loss of life expectancy occur? Does it simply curtail the final days or months of life, when quality of life may be very low, or does it reduce one's healthy life expectancy? There is general agreement amongst health experts that it is the latter, a reduction in healthy life expectancy.

To the extent possible, national data on the baseline incidence of health impacts (mortality rates, hospital admissions, etc.) have been used. For some effects (restricted activity days, prevalence of bronchitis) it is necessary to use data from the original epidemiological studies as national data are not available.

2.2.4 Monetisation of impacts

The monetisation of health impacts accounts for several factors:

- Additional health care costs arising from hospital admissions, increased levels of medication, etc;
- Lost productivity from workers taking time off for their own sickness or to look after their dependents, and;
- The loss of what is termed 'utility' or 'welfare' in the economic literature through pain, suffering, and reduced life expectancy.

The first two elements can be quantified directly from healthcare expenditures and information from employers. The third element (the loss of utility) is described using results of economic surveys where individuals are asked for their 'willingness to pay' to maintain good health. This data can be corroborated with further evidence, for example from wage-risk analysis, where willingness to accept higher risks can be equated against increased wage levels.

Each of these elements has been investigated for the list of impacts given in cost-benefit analysis for the EU Commission (Holland, 2014). Those valuations form the basis for the monetisation of health impacts applied here, subject to some adjustment as described on the next page.

2.3 DAMAGE COST APPROACH

A complete implementation of the IPA is beyond the scope of the present analysis. However, simplification is possible, using estimates of average damage per tonne of emission from most countries in Europe that have been generated previously for the European Environment Agency (EEA, 2014).

2.3.1 Baseline values

The EMEP transfer matrix was used to quantify the exposure of the European population to emissions from each country, averaged across all sources. These data were then combined with response functions, etc. recommended by WHO's HRAPIE study, and valuations used in cost-benefit analysis for the EU Commission (Holland, 2014) to provide estimates of health impact and economic damage per tonne of emission (EEA, 2011; 2013). Effects were quantified against exposure to primary $PM_{2.5}$, secondary $PM_{2.5}$ linked to emissions of SO_2 and NO_x and ozone formed as a consequence of NO_x emissions. Effects of SO_2 on damage to building materials, and of NO_x on crop production, via ozone formation were also quantified.

EEA (2014) provides estimates for Bosnia and Herzegovina and Macedonia, but not for the other countries considered here (Kosovo, Montenegro and Serbia). However, the underlying analysis for the EEA included estimates for the three countries grouped together. Economic results, reflecting average economic conditions in the EU, for Bosnia and Herzegovina, Macedonia and surrounding countries were as follows:

Table 3. Damage per tonne estimates for air pollutant emissions from countries in or close to the Balkans

	SO_2		NO_x		$PM_{2.5}$	
	Lower estimate (VOLY)	Upper estimate (VSL)	Lower estimate (VOLY)	Upper estimate (VSL)	Lower estimate (VOLY)	Upper estimate (VSL)
Bosnia & Herzegovina	7,453	21,792	5,106	13,626	20,720	58,677
Macedonia	6,130	16,795	3,080	7,980	19,978	52,814
Albania	8,734	19,981	3,713	7,939	26,582	55,439
Bulgaria	6,068	19,526	4,207	12,200	24,186	80,806
Croatia	10,200	31,200	6,397	18,028	21,353	65,336
Greece	3,808	11,479	1,021	2,773	18,669	56,883
Hungary	11,682	35,340	7,074	19,926	38,433	118,336
Romania	10,515	31,286	7,102	19,956	35,666	105,101
Average	8,074	23,425	4,713	12,804	25,698	74,174
Kosovo	7,652	19,221	3,735	8,901	23,404	55,104
Montenegro	8,093	20,887	4,410	10,783	23,651	57,058
Serbia	8,800	24,904	5,218	13,920	26,749	74,482
Serbia, Kosovo, Montenegro (grouped)	**8,894**	**26,127**	**5,634**	**15,464**	**29,458**	**86,361**

To provide values for Kosovo, Montenegro and Serbia, averages are adopted from data for surrounding countries. Hence for Montenegro, the average is taken of results for Bosnia and Herzegovina and Albania. For Kosovo, the average was then taken for results from Albania, Macedonia and Montenegro. For Serbia, the average was taken of results for Bosnia and Herzegovina, Bulgaria, Croatia, Hungary, Kosovo, Macedonia, Montenegro and Romania. Comparison of the results so calculated for the three countries, with the unpublished estimate from the EEA work that covers all three as a group, showed that estimates for each country were broadly comparable with, but lower than the group estimate. This indicates some error in the extrapolation (ideally the figures would average out to the overall estimate when weighted by emissions in each country, but this clearly is impossible if all estimates are lower than the group estimate). Given that Serbia has the largest population and emissions of the three countries, the figure for Serbia, Kosovo and Montenegro combined was adopted for Serbia in the analysis. For Kosovo and Montenegro the analysis adopts the average against surrounding countries as shown in the table. Whilst there is clearly some uncertainty in this process, results are sufficiently similar that they are not considered likely to add major additional uncertainty.

The ranges provided are associated with alternative approaches to the valuation of mortality. The lower bound applies the 'value of a life year' (VOLY) to the estimated loss of life expectancy across the population. The upper bound applies the 'value of a statistical life' (VSL) to the estimated number of deaths. The values used represent average 'willingness to pay' across the EU for the year 2005.

Application of these damage costs for use with a particular sector at the national level requires some adjustment to take account of:

- Factors that make emissions from the sector more or less damaging than the national average per unit mass of emission;
- Conversion of reported or calculated 'dust' emissions to the finer $PM_{2.5}$ fraction of 'dust' that is most associated with health impacts, and;
- Differences between the economic situation of Bosnia and Herzegovina and the average for the EU.

2.3.2 Adjusting for source sector

The analysis for the EEA (2014) recognises that emissions from tall stacks, as used at the power stations considered in this report, will reduce exposure to the emitted pollutants and their atmospheric reaction products, relative to the average for all emissions. The following correction factors were calculated for the public power sector using data from the Eurodelta II study, as an average for the four countries for which analysis was performed:

- SO_2: 0.87
- NO_x: 0.78
- $PM_{2.5}$: 0.50

2.3.3 Converting 'dust' to $PM_{2.5}$

The second adjustment factor concerns conversion of emissions of 'dust' (often referred to as 'total suspended particulates', or TSP) to $PM_{2.5}$, the fraction of 'dust' that is less than 2.5 micrometers in diameter. This conversion is necessary as the coarser fractions tend to deposit in the upper airways and do not penetrate deep into the lung. In making such estimates it is necessary to note that the fractionation of TSP is dependent on the fuel, the way that the fuel is processed, the abatement technologies in place and so on. A further problem is that some sources provide conversion between TSP and PM_{10} or PM_{10} and $PM_{2.5}$, rather than TSP and $PM_{2.5}$. The following estimates have been obtained (Table 4). Preference is given to the US Environmental Protection Agency (USEPA) sources at the top of the table, as although old, they provide a breakdown of emissions for different abatement technologies. It is also understood that they have been kept under review since they were originally published. Other sources are listed for comparison, though in none of these cases is it clear what abatement technology underpins the estimates.

Table 4. Fractionation of Total Suspended Particulate Matter to $PM_{2.5}$ and PM_{10} (for grey shaded cells see text)

SOURCE	ABATEMENT	PM2.5:TSP	PM10:TSP	PM2.5:PM10	EMISSION[1]
USEPA, 1998 sub-bituminous coal	Uncontrolled	6%	23%	26%	10A
	Multiple cyclones	3%	29%	10%	2A
	Scrubber	51%	71%	72%	0.6A
	Electrostatic precipitator (ESP)	29%	67%	43%	0.08A
	Baghouse	53%	92%	58%	0.02A
USEPA, 1998 anthracite coal	Uncontrolled	6%	23%	26%	10A
	Multiple cyclones	24%	55%	44%	2A
	Baghouse	32%	67%	48%	0.02A
USEPA, 1998 lignite	Uncontrolled	10%	35%	29%	6.6A
	Multiple cyclones	27%	67%	40%	1.3A
Huang et al, 2014 coal	Not stated	10%	26%	38%	
Huang et al, 2014 lignite		10%	35%	29%	
SCAQMB, 2006 coal		15%	40%	37.5%	
UK NAEI, 2015 coal				44%	

Notes: 1: Emissions are shown relative to percentage Ash Content (A) of fuel. Hence where emission is shown as '10A' and A=3.4 percent, 34 percent of the ash would be emitted as particulate matter.

The emission data in the final column are provided to demonstrate the effectiveness of the different abatement technologies (where present).

The question then arises of which estimates to adopt. The information available does not provide definitive guidance as some gaps are present and there will inevitably be variation between sites, so some approximation is necessary. The cells shaded grey in Table 4 are most relevant to the current analysis. Given the similarity between 29 percent for ESPs and 32 percent for baghouse filters, a single estimate of 30 percent is applied below to convert from dust to $PM_{2.5}$. Using a similar rationale, an estimate of 45 percent is taken from the table to convert from PM_{10} to $PM_{2.5}$. These factors have been applied in this study directly to the emission estimates.

2.3.4 Adjusting monetary values for local conditions

Monetisation of impacts is useful in the context of cost-benefit analysis, to test the extent to which society is willing to pay for improvement in air quality. Monetary valuation reflects the 'willingness to pay' (WTP) of the population for reduced health risk. WTP will vary from country to country, reflecting differences in income and other factors (collectively defined in terms of attitude to risk). This variation in health values does not signify that one set of people is any more valuable than any other: it simply reflects the fact that in a world where resources and money are not evenly distributed, preference for expenditure will vary. Analysis for the EU Commission uses estimates of average willingness to pay for the EU as a whole in 2005, irrespective of the location of impact. 2005 is used as the base year in air pollution work for the EU Commission for consistency between different models, for example to permit comparison of costs and benefits. For the present case, however, we are considering the situation from the perspective of Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro and Serbia, and so should seek to adopt an estimate of WTP to avoid risks to health that is in line with the views of people within these countries at the present time.

The following data are applied:

- EU GDP/capita in 2005, adjusted for purchasing power parity (PPP): 28,100 int$ (World Bank)
- Population weighted GDP/capita in Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro and Serbia in 2014, adjusted for PPP: 12,108 int$ (World Bank)
- An elasticity of 0.8, to account for variation in willingness to pay as incomes change (OECD, 2012)
- This generates an adjustment factor of (12,108/28,100)0.8 = 0.51.

2.3.5 Adopted values

Following adjustment for the factors just described, values in terms of damage per tonne emission of pollutant are summarised in Table 5. Variation in values between countries is largely a consequence of differences in population exposure.

Table 5. Monetised estimates of health damage per tonne of pollutant emission, (EUR/tonne)

	NO_x		SO_2		$PM_{2.5}$	
	Lower estimate (VOLY)	Upper estimate (VSL)	Lower estimate (VOLY)	Upper estimate (VSL)	Lower estimate (VOLY)	Upper estimate (VSL)
Bosnia & Herzegovina	2,031	5,420	3,307	9,669	5,284	14,963
Kosovo	1,486	3,541	3,395	8,528	5,968	14,052
Macedonia	1,225	3,174	2,720	7,452	5,095	13,468
Montenegro	1,754	4,289	3,591	9,267	6,031	14,550
Serbia	2,241	6,151	3,946	11,592	7,512	22,022

The following table illustrates values disaggregated to their component health impacts per tonne emission for Bosnia and Herzegovina.

Table 6. Health impacts per tonne emission of NO_x, SO_2 and $PM_{2.5}$ for Bosnia and Herzegovina, adjusted for the power sector

BOSNIA	NO_x	SO_2	$PM_{2.5}$
Acute Mortality (All ages) life years lost*	0.0026	-0.00015	0
Acute Mortality (All ages) deaths*	0.0026	-0.00015	0
Respiratory hospital admissions (>64)	0.0014	-0.00008	0
Cardiovascular hospital admissions (>64)	0.00858	-0.00050	0
Minor Restricted Activity Days (all ages)	11	-0.62	0
Chronic Mortality (All ages) Life years lost*	0.044	0.087	0.14
Chronic Mortality (30yr +) deaths*	0.0040	0.0078	0.012
Infant Mortality (0-1yr)	0.0000094	0.000018	0.0000295
Chronic Bronchitis (27yr +)	0.0029	0.0057	0.0090
Bronchitis in children aged 6 to 12	0.010	0.020	0.032
Respiratory Hospital Admissions (All ages)	0.0018	0.0035	0.0055
Cardiac Hospital Admissions (>18 years)	0.0012	0.0025	0.0040
Restricted Activity Days (all ages)	4.2	8.4	14
Asthma symptom days (children 5-19yr)	0.086	0.17	0.26
Lost working days (15-64 years)	1.1	2.2	3.4
Bronchitis in children (5 to 14)	0.00078	-0.000066	0
Acute Mortality (All ages) life years lost*	0.00062	-0.000051	0
Acute Mortality (All ages) deaths*	0.00062	-0.000051	0
Respiratory Hospital Admissions (All ages)	0.0064	-0.00053	0

An indication of the extent to which impacts occur in the five countries considered in this analysis is shown in Table 7. These results are for average emissions from all sources in the countries considered: it is not possible to disaggregate specifically for the power sector, so they are subject to some additional uncertainty beyond that affecting the overall estimates of damage.

Table 7. Percentage of impacts for each pollutant occurring in the region covered by the five Balkan countries

	BOSNIA AND HERZEGOVINA		SERBIA, MONTENEGRO, KOSOVO		FYR MACEDONIA	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
NO_x	33%	30%	36%	35%	39%	37%
$PM_{2.5}$	59%	55%	65%	64%	63%	61%
SO_2	36%	33%	43%	42%	40%	38%

3. DATA ON THE POWER PLANTS

3.1 POWER PLANTS CONSIDERED

The power plants considered in this report are listed in Table 8, with additional information describing their status (whether operating already, under construction, permitted or simply announced by developers), capacity in MegaWatts of electricity (MWe), and start and end dates for operation. For power plants that are yet to enter operation, the start date is as announced although it is accepted that some of these plant will not materialise or that construction target dates may not be met.

3.2 EMISSIONS DATA

Emissions data for many power plants are available from operators, developers or national authorities. However, these may only be available at the site level, potentially covering several units. Disaggregation to unit is desirable given that different units have different life expectancies. This disaggregation of emissions from site to unit has been carried out by multiplying emissions for all plant on the site by the capacity of each unit as a fraction of total site capacity. This of course assumes that all units on a site are equally polluting per unit of power generation, which is unlikely to be the case as they may differ in generation efficiency or flue gas controls. However, the approximation is unlikely to cause errors that are too serious as it is only necessary for plants that are already in operation rather than a mix of old and new facilities.

For plants where data is unavailable the approach taken differs depending on whether the power station is already operating or is yet to be commissioned. For one existing plant (Gacko in Bosnia and Herzegovina) no data was available and so emissions were calculated as the product of capacity and average emission per unit capacity for other 'existing' plants in the database.

For new plants, annual emissions are calculated as:

$$Emission\ x = IED_{LV} \times Cap_{MW} \times V \times LF$$

Where:

IED_{LV} = IED emission limit value, mass/unit flue gas volume

Cap_{MW} = plant capacity in MegaWatts of electricity

V = hourly flue gas volume per unit of capacity

LF = Load factor in hours per year

Table 8. List of power plants considered in this report

COUNTRY	STATUS	NAME OF PLANT	MW_E	START OF OPERATION*
Bosnia & Herzegovina	existing	Gacko	300	1983
Bosnia & Herzegovina	existing	Kakanj Unit 5	110	1969
Bosnia & Herzegovina	existing	Kakanj Unit 6	110	1977
Bosnia & Herzegovina	existing	Kakanj Unit 7	230	1988
Bosnia & Herzegovina	existing	Tuzla G3	100	1966
Bosnia & Herzegovina	existing	Tuzla G4	200	1971
Bosnia & Herzegovina	existing	Tuzla G5	200	1974
Bosnia & Herzegovina	existing	Tuzla G6	215	1978
Bosnia & Herzegovina	existing	Ugljevik 1	300	1985
Bosnia & Herzegovina	new	Banovici	350	2020
Bosnia & Herzegovina	new	Bugojno Unit 1	300	2020
Bosnia & Herzegovina	new	Gacko Unit 2	300	2020
Bosnia & Herzegovina	new	Kakanj unit 8	300	2022
Bosnia & Herzegovina	new	Kakanj unit 9	300	2020
Bosnia & Herzegovina	new	Kongora unit 1	275	2020
Bosnia & Herzegovina	new	Kongora unit 2	275	2020
Bosnia & Herzegovina	new	Stanari	300	2016
Bosnia & Herzegovina	new	Tuzla unit 7	450	2019
Bosnia & Herzegovina	new	Tuzla unit 8	450	2027
Bosnia & Herzegovina	new	Ugljevik 3 unit 1	300	2020
Bosnia & Herzegovina	new	Ugljevik 3 unit 2	300	2020
Kosovo	existing	Kosovo A Unit 3	200	1970
Kosovo	existing	Kosovo A Unit 5	210	1975
Kosovo	existing	Kosovo B Unit 1	339	1983
Kosovo	existing	Kosovo B Unit 2	339	1984
Kosovo	new	Kosovo C Unit 1	300	2018
Kosovo	new	Kosovo C Unit 2	300	2018
Macedonia	existing	Bitola Unit 1	225	1982
Macedonia	existing	Bitola Unit 2	225	1984
Macedonia	existing	Bitola Unit 3	225	1988
Macedonia	existing	Oslomej	125	1989
Macedonia	new	Mariovo	300	2033
Montenegro	existing	Pljevlja I	210	1982
Montenegro	new	Berane	110	2030
Montenegro	new	Maoce	500	2030
Montenegro	new	Pljevlja II	220	2020
Serbia	existing	Kolubara 1	32	1956
Serbia	existing	Kolubara 2	32	1957
Serbia	existing	Kolubara 3	64	1961
Serbia	existing	Kolubara 5	110	1979
Serbia	existing	Kostolac A1	100	1967
Serbia	existing	Kostolac A2	210	1980
Serbia	existing	Kostolac B1	348	1987
Serbia	existing	Kostolac B2	348	1991
Serbia	existing	Morava	125	1969
Serbia	existing	Nikola Tesla A1	210	1970
Serbia	existing	Nikola Tesla A2	210	1970
Serbia	existing	Nikola Tesla A3	305	1976
Serbia	existing	Nikola Tesla A4	309	1978
Serbia	existing	Nikola Tesla A5	309	1979
Serbia	existing	Nikola Tesla A6	348	1979
Serbia	existing	Nikola Tesla B1	620	1983
Serbia	existing	Nikola Tesla B2	620	1985
Serbia	new	Kolubara B unit 1	375	2020
Serbia	new	Kolubara B unit 2	375	2020
Serbia	new	Kostolac	350	2020
Serbia	new	Nikola Tesla unit 3	375	2020
Serbia	new	Nikola Tesla unit 4	375	2020
Serbia	new	Štavalj	350	2020

Note: For new plants start date of operation is an estimate.

LOCATION AND SIZE OF EXISTING AND NEW POWER PLANTS IN THE WESTERN BALKANS

	PLANT	CAPACITY (MWe)
1	Tuzla	715
2	Kakanj	450
3	Ugljevik	300
4	Gacko	300
5	Banovici	350
6	Bugojno	300
7	Gacko	300
8	Kakanj	600
9	Kongora	550
10	Stanari	300
11	Tuzla	900
12	Ugljevik	600
13	Kosovo A+B	988
14	Kosovo C	600

existing plant — new plant

	PLANT	CAPACITY (MWe)
15	Bitola	675
16	Oslomej	125
17	Mariovo	300
18	Pljevlja I	210
19	Berane	110
20	Maoce	500
21	Pljevlja II	220
22	Nikola Tesla A+B	1690
23	Kolubara	238
24	Morava	125
25	Kostolac A+B	310
26	Kolubara B	750
27	Kostolac	350
28	Nikola Tesla	750
29	Štavalj	350

Plant capacities are shown in Table 8 and IED limit values in Figure 2. The other data required concerns the flue gas flow rate and the plant load factor. The load factor is taken as 86 percent (7500 hours per year out of a total possible of 8760 hours) for new plants and 80 percent (7000 hours per year) for existing plants, a lower figure being used for the latter as they may be less reliable than new plants or require additional maintenance. Flue gas flow rates for a number of indicative plants are shown in Table 9. The top two rows are for the proposed Stanari and existing Ugljevik plant. The rows by country are taken from a series of case studies carried out under the ExternE study (1997) - those selected are considered by the present author most comparable to the present analysis. Few of the ExternE case studies dealt with lignite specifically.

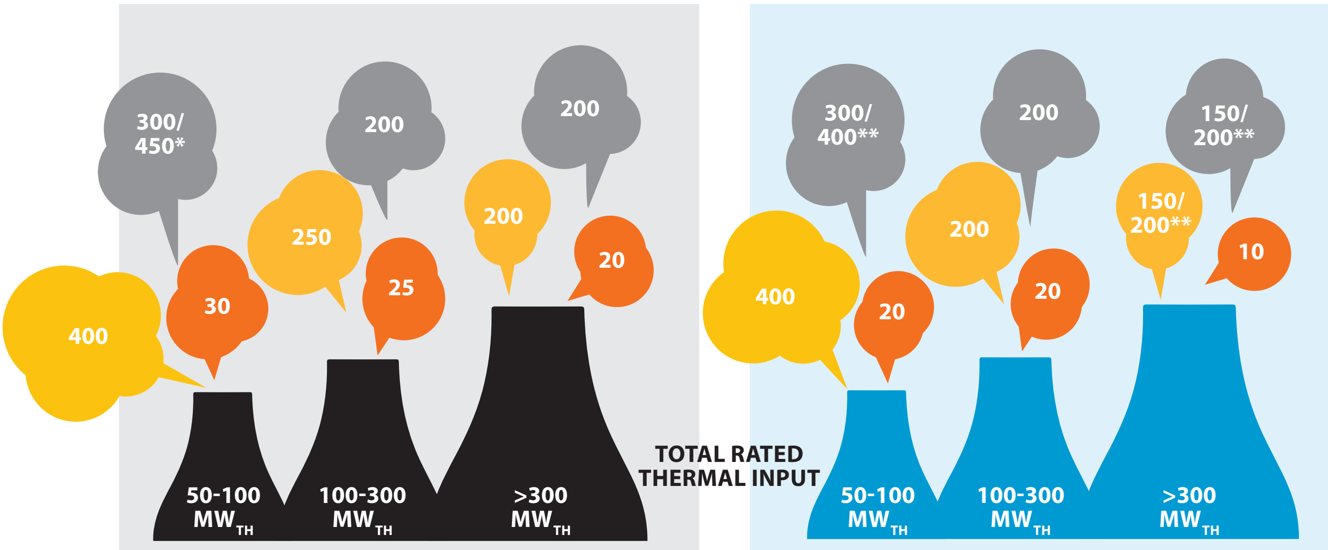
Table 9. Data on flue gas flow rate and capacity for power plants

	FUEL	Nm^3/h (normal cubic metre per hour)	MW
Stanari	Lignite	1,234,801	300
Ugljevik 1	Lignite	1,815,100	300
Belgium	Hard coal	1,017,770	300
Greece	Lignite	1,855,000	367
Ireland	Hard coal	3,300,000	915
Portugal	Hard coal	4,700,000	1,200

Hourly flow rate data are taken from the proposed Stanari power station (4,116 $Nm^3/h/MW$) for 'new' facilities as they seem broadly comparable to data from the ExternE series and the Stanari plant is likely to reflect current designs in the region. The estimate for the Ugljevik 1 power station (6,050 $Nm^3/h/MW$), however, seems high, 50 percent greater than for Stanari. A figure of 5,000 $Nm^3/h/MW$, broadly in line with the data from the Greek case in the ExternE project, is thus preferred for an existing plant. This approach of not applying data from an existing facility in the region on the grounds that the numbers appear high may be criticised as being overly conservative. However, given the variation that is clear in Table 9, the use of the lower figure for flue gas flow rate seems reasonable.

There are different limits for new, large plants than for older or smaller ones, as the following table shows. Existing plants under the IED are defined as those granted a permit before 7 January 2013 and entering operation before 7 January 2014.

Figure 2: Emission limits for existing and new plants burning coal, lignite and other solid fuels under the IED. Units in all cases: mg/Nm³. SO_2 NO_x **Dust**



** Higher figure in case of pulverised lignite combustion*
*** Higher figure in case of circulating or pressurised fluidised bed construction*
mg/Nm³: milligrams per (normal, standard) cubic metre
MWth: Megawatt thermal
SO_2: Sulphur dioxide
NO_x: Nitrogen oxides

The plant capacities in Table 8 are expressed per unit of electrical output, whilst those in Figure 2 are expressed per unit thermal input. The difference between the two reflects the efficiency with which plant convert energy inputs to electricity. Efficiency tends to be in the range 35 to 40 percent though higher and lower efficiencies are possible. On this basis, all plants greater than 105 – 120 MWe will fall into the >300MWth capacity band in Table 10. It can immediately be seen from Table 8 that most plants and units fall into this category.

Those units that do not are almost all part of a larger facility. The IED states that its emission limit values apply to the emissions of each common stack in relation to the total rated thermal input of the entire combustion plant. Assuming widespread use of common stacks, all units except one then come under the requirement for being treated as >300MWth. The one exception is the proposed Berane (Montenegro) plant, which is rated at 110 MWe. However, as this is in the 105 – 120 MWe range identified above, it is regarded as likely to need to meet the requirements of plant rated at 300 MWth.

The assumption that plants will precisely meet the requirements of the IED is a little pessimistic. Assuming that no plant exceeds the limit values it is logical to expect actual emissions to be below the limits to some degree. Partly with this in mind, the lower limits (150 mg/m³) for SO_2 and NO_x emissions from Figure 2 are adopted for existing plants. Where estimated emissions under IED are higher than documented emissions, the documented emissions have been adopted.

Emissions data are shown in Table 10 for current operation (existing plant) or planned operation (plant which have yet to enter operation, including some that are under construction and some that may never be built).

Table 10. Annual emissions data under current or planned (for new plants) operation

PLANT	CURRENT/PLANNED OPERATION		
	SO_2 (t)	NO_x (t)	$PM_{2.5}$ (t)
Gacko	27,880	4,405	748
Kakanj Unit 5	17,875	1,943	55
Kakanj Unit 6	17,875	1,943	55
Kakanj Unit 7	37,374	4,062	115
Tuzla G3	7,223	1,377	125
Tuzla G4	14,446	2,753	250
Tuzla G5	14,446	2,753	250
Tuzla G6	15,529	2,960	269
Ugljevik 1	154,385	4,078	373
Banovici	1,050	590	27
Bugojno Unit 1	1,389	1,389	28
Gacko Unit 2	1,389	1,389	28
Kakanj unit 8	1,389	1,389	28
Kakanj unit 9	1,389	1,389	28
Kongora unit 1	1,273	1,273	25
Kongora unit 2	1,273	1,273	25
Stanari	1,628	1,628	73
Tuzla unit 7	877	1,316	59
Tuzla unit 8	877	1,316	59
Ugljevik 3 unit 1	1,389	1,389	28
Ugljevik 3 unit 2	1,389	1,389	28
Kosovo A Unit 3	2,177	2,013	1,565
Kosovo A Unit 5	4,573	4,227	3,286
Kosovo B Unit 1	6,735	7,260	1,343
Kosovo B Unit 2	6,735	7,260	1,343
Kosovo C Unit 1	1,389	1,389	28
Kosovo C Unit 2	1,389	1,389	28
Bitola Unit 1	22,297	5,548	926
Bitola Unit 2	22,297	5,548	926
Bitola Unit 3	22,297	5,548	926
Oslomej	15,741	2,089	564
Mariovo	1,389	1,389	28
Pljevlja I	25,681	3,818	196
Berane	509	509	10
Maoce	2,315	2,315	46
Pljevlja II	1,019	1,019	20
Kolubara 1	2,366	274	147
Kolubara 2	2,366	274	147
Kolubara 3	4,733	549	294
Kolubara 5	8,134	943	505
Kostolac A1	16,677	1,029	195
Kostolac A2	35,023	2,161	408
Kostolac B1	44,550	3,835	837
Kostolac B2	44,550	3,835	837
Morava	11,400	1,500	860
Nikola Tesla A1	6,299	2,497	247
Nikola Tesla A2	6,299	2,497	247
Nikola Tesla A3	9,148	3,627	359
Nikola Tesla A4	9,253	3,668	363
Nikola Tesla A5	9,253	3,668	363
Nikola Tesla A6	10,449	4,142	410
Nikola Tesla B1	46,600	7,150	290
Nikola Tesla B2	46,600	7,150	290
Kolubara B unit 1	1,736	1,736	35
Kolubara B unit 2	1,736	1,736	35
Kostolac	1,621	1,621	32
Nikola Tesla unit 3	1,736	1,736	35
Nikola Tesla unit 4	1,736	1,736	35
Štavalj	1,621	1,621	32

Review of the data in Table 10 indicates widely varying performance amongst 'Existing' plants, particularly for emissions of SO_2. For one facility, Ugljevik 1 in Bosnia and Herzegovina, SO_2 emissions seem excessive for a 300MW plant, at 154kt, a figure three times higher than for any other plant (noting that this comparison includes some plant, such as Nikola Tesla B1/B2 in Serbia that are twice the size of Ugljevik 1). However, data have been checked with the reporting authority, the Republic Hydrometeorological Service in Banja Luca, and have been accepted for analysis here. One explanation for the very high emissions from this plant would be the use of coal/lignite with a very high sulphur content.

Table 11. Annual emission totals (tonnes) for each country for all the facilities

	CURRENT/PLANNED OPERATION		
	SO_2	NO_x	$PM_{2.5}$
EXISTING PLANT	**(t)**	**(t)**	**(t)**
Bosnia and Herzegovina	307,033	26,274	2,240
Kosovo	20,220	20,760	7,537
Macedonia	82,632	18,733	3,342
Montenegro	25,681	3,818	196
Serbia	313,700	48,799	6,799
Existing total	**749,266**	**118,384**	**20,114**
NEW, PLANNED PLANT			
Bosnia and Herzegovina	15,312	15,730	436
Kosovo	2,778	2,778	56
Macedonia	1,389	1,389	28
Montenegro	3,843	3,843	76
Serbia	10,186	10,186	204
New total	**33,508**	**33,926**	**800**
ALL PLANTS			
Bosnia and Herzegovina	322,345	42,004	2,676
Kosovo	22,998	23,538	7,593
Macedonia	84,021	20,122	3,370
Montenegro	29,524	7,661	272
Serbia	323,886	58,985	7,003
All total	**782,774**	**152,310**	**20,914**

Note: Direct comparison of emissions from 'Existing' and 'New' plants is not valid, given differences in capacity.

4. RESULTS

4.1 HEALTH IMPACTS

Due to limited space, a full breakdown of health impacts for each power plant is not presented in this report. However, estimates of the number of premature deaths associated with exposure to air pollutants from each plant, under current/planned operations are provided in Table 12. In each case it is assumed that plants are operating at full capacity subject to assumed load factors (7000 hours per year for an existing plant, 7500 hours per year for a new plant). Other health impacts (hospitalisations, cases of chronic bronchitis, lost working days, etc) can be calculated using the factors provided for each country.

It would be misleading to add results for all plants together to generate an annual estimate of premature deaths per year attributable to air pollutant emissions from the power sector of the Balkan countries. The plants listed will not all be available for operation simultaneously, and not all will operate at full capacity for the load hours on which estimates are based. Some units are likely to close down in the near future, some will not start operations for a number of years, and some currently proposed plants will not be constructed at all.

To interpret the information on impacts properly it is also necessary to consider the nature of the link between air pollution and (e.g.) the premature death of individuals. The Committee on the Medical Effects of Air Pollutants (COMEAP, 2010) notes that measures of impact are characteristics of the population as a whole and cannot be applied at an individual level. This is because air pollution acts in combination with many other causes to affect mortality, so we do not know how the changes in survival are distributed across individuals. Consequently, it is unrealistic to view air pollution as the sole cause of premature death in a number of cases equal to the population attributable deaths. However, the conclusion of a great number of epidemiological studies from around the world is the same - air pollution has a very significant impact on mortality.

Tables 12 and 13 show annual premature deaths across Europe attributable to each plant operating according to the assumptions described above. In this context, Europe includes EU28 member states plus Albania, Belarus, Moldova, Norway, the Western regions of Russia, Switzerland and Ukraine as well as the five Balkan countries of Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro and Serbia.

Tables 14 and 15 then present annual premature deaths attributable to each plant within the five Balkan countries. Data is presented by each plant and in the following table by country total for existing and new planned plants.

Note that the health costs given for the Western Balkans are part of the total health costs for Europe, and thus the amounts cannot be added up.

Table 12. Annual premature deaths across Europe attributable to each plant operating at capacity adjusted for load factor

	PREMATURE DEATH CASES ACROSS EU UNDER CURRENT/PLANNED CONDITIONS			
	SO_2	NO_x	$PM_{2.5}$	TOTAL
Gacko	213	32	9	254
Kakanj Unit 5	137	14	1	151
Kakanj Unit 6	137	14	1	151
Kakanj Unit 7	286	29	1	316
Tuzla G3	55	10	2	67
Tuzla G4	110	20	3	133
Tuzla G5	110	20	3	133
Tuzla G6	119	21	3	143
Ugljevik 1	1,181	29	4	1,215
Banovici	8	4	0	13
Bugojno Unit 1	11	10	0	21
Gacko Unit 2	11	10	0	21
Kakanj unit 8	11	10	0	21
Kakanj unit 9	11	10	0	21
Kongora unit 1	10	9	0	19
Kongora unit 2	10	9	0	19
Stanari	12	12	1	25
Tuzla unit 7	7	9	1	17
Tuzla unit 8	7	9	1	17
Ugljevik 3 unit 1	11	10	0	21
Ugljevik 3 unit 2	11	10	0	21
Kosovo A Unit 3	17	11	21	49
Kosovo A Unit 5	36	22	45	103
Kosovo B Unit 1	53	38	18	109
Kosovo B Unit 2	53	38	18	109
Kosovo C Unit 1	11	7	0	19
Kosovo C Unit 2	11	7	0	19
Bitola Unit 1	140	24	11	175
Bitola Unit 2	140	24	11	175
Bitola Unit 3	140	24	11	175
Oslomej	99	9	7	115
Mariovo	9	6	0	15
Pljevlja I	213	24	3	240
Berane	4	3	0	8
Maoce	19	14	1	34
Pljevlja II	8	6	0	15
Kolubara 1	22	2	3	26
Kolubara 2	22	2	3	26
Kolubara 3	43	4	5	53
Kolubara 5	74	7	9	90
Kostolac A1	152	8	3	164
Kostolac A2	320	17	7	344
Kostolac B1	407	30	14	451
Kostolac B2	407	30	14	451
Morava	104	12	15	131
Nikola Tesla A1	57	20	4	82
Nikola Tesla A2	57	20	4	82
Nikola Tesla A3	83	29	6	118
Nikola Tesla A4	84	29	6	120
Nikola Tesla A5	84	29	6	120
Nikola Tesla A6	95	33	7	135
Nikola Tesla B1	425	57	5	487
Nikola Tesla B2	425	57	5	487
Kolubara B unit 1	16	14	1	30
Kolubara B unit 2	16	14	1	30
Kostolac	15	13	1	28
Nikola Tesla unit 3	16	14	1	30
Nikola Tesla unit 4	16	14	1	30
Štavalj	15	13	1	28

Table 13. Annual premature deaths across Europe attributable to emissions from each country, with plant operating under current/planned conditions

	PREMATURE DEATH CASES ACROSS EU			
	SO_2	NO_x	$PM_{2.5}$	TOTAL
EXISTING PLANT				
Bosnia and Herzegovina	2349	189	27	2564
Kosovo	159	109	102	370
Macedonia	520	81	39	640
Montenegro	213	24	3	240
Serbia	2863	387	116	3366
Existing total	**6104**	**790**	**287**	**7181**
NEW PLANNED PLANT				
Bosnia and Herzegovina	117	113	5	235
Kosovo	22	15	1	37
Macedonia	9	6	0	15
Montenegro	32	24	1	57
Serbia	93	81	3	177
New total	**273**	**238**	**11**	**522**
ALL PLANT				
Bosnia and Herzegovina	2466	302	32	2800
Kosovo	181	124	103	407
Macedonia	529	87	39	655
Montenegro	245	48	4	297
Serbia	2956	468	120	3544
Total	**6376**	**1028**	**298**	**7702**

Table 14. Annual premature deaths attributable to each plant operating at capacity adjusted for load factor within the five Western Balkan countries, with plant operating under current/planned conditions

	PREMATURE DEATH CASES ACROSS EU			
	SO_2	NO_x	$PM_{2.5}$	TOTAL
Gacko	77	10	5	92
Kakanj Unit 5	49	5	0	54
Kakanj Unit 6	49	5	0	54
Kakanj Unit 7	103	9	1	113
Tuzla G3	20	3	1	24
Tuzla G4	40	6	2	48
Tuzla G5	40	6	2	48
Tuzla G6	43	7	2	52
Ugljevik 1	425	10	3	437
Banovici	3	1	0	4
Bugojno Unit 1	4	3	0	7
Gacko Unit 2	4	3	0	7
Kakanj unit 8	4	3	0	7
Kakanj unit 9	4	3	0	7
Kongora unit 1	4	3	0	7
Kongora unit 2	4	3	0	7
Stanari	4	4	1	9
Tuzla unit 7	2	3	0	6
Tuzla unit 8	2	3	0	6
Ugljevik 3 unit 1	4	3	0	7
Ugljevik 3 unit 2	4	3	0	7
Kosovo A Unit 3	7	4	14	25
Kosovo A Unit 5	15	8	29	52
Kosovo B Unit 1	23	14	12	48
Kosovo B Unit 2	23	14	12	48
Kosovo C Unit 1	5	3	0	8
Kosovo C Unit 2	5	3	0	8
Bitola Unit 1	56	9	7	72
Bitola Unit 2	56	9	7	72
Bitola Unit 3	56	9	7	72
Oslomej	39	3	4	47
Mariovo	3	2	0	6
Pljevlja I	91	9	2	101
Berane	2	1	0	3
Maoce	8	5	0	14
Pljevlja II	4	2	0	6
Kolubara 1	9	1	2	12
Kolubara 2	9	1	2	12
Kolubara 3	18	2	3	23
Kolubara 5	32	3	6	40
Kostolac A1	65	3	2	70
Kostolac A2	136	6	5	147
Kostolac B1	173	11	9	194
Kostolac B2	173	11	9	194
Morava	44	4	10	58
Nikola Tesla A1	25	7	3	34
Nikola Tesla A2	25	7	3	34
Nikola Tesla A3	36	10	4	50
Nikola Tesla A4	36	10	4	51
Nikola Tesla A5	36	10	4	51
Nikola Tesla A6	41	12	5	57
Nikola Tesla B1	181	20	3	205
Nikola Tesla B2	181	20	3	205
Kolubara B unit 1	7	5	0	12
Kolubara B unit 2	7	5	0	12
Kostolac	6	5	0	11
Nikola Tesla unit 3	7	5	0	12
Nikola Tesla unit 4	7	5	0	12
Štavalj	6	5	0	11

Table 15. Annual premature deaths in the five Western Balkan countries considered attributable to emissions from each country, with plant operating under current or planned conditions

	PREMATURE DEATH CASES WITHIN BALKAN			
	SO_2	NO_x	$PM_{2.5}$	TOTAL
EXISTING PLANT				
Bosnia and Herzegovina	845	61	16	922
Kosovo	68	39	67	174
Macedonia	207	31	24	263
Montenegro	91	9	2	101
Serbia	1221	139	76	1436
Existing total	**2431**	**280**	**184**	**2895**
NEW, PLANNED PLANT				
Bosnia and Herzegovina	42	37	3	82
Kosovo	9	5	0	15
Macedonia	3	2	0	6
Montenegro	14	9	1	23
Serbia	40	29	2	71
New total	**108**	**82**	**7**	**197**
ALL PLANTS				
Bosnia and Herzegovina	887	98	19	1004
Kosovo	77	45	67	189
Macedonia	210	34	25	269
Montenegro	105	17	2	124
Serbia	1261	168	78	1507
All total	**2539**	**362**	**191**	**3092**

4.2 MONETARY EQUIVALENT OF HEALTH IMPACTS

Monetised damage across Europe for each plant under current or planned operation conditions is shown in Table 16. Here and elsewhere, the results presented are for the lower bound VOLY (value of a life year) approach to mortality valuation and the upper bound VSL (value of a statistical life) to the estimated number of premature deaths. Table 18 summarises these results according to the country where emissions originate. Tables 19 and 20 provide similar results, but only for the damage within the five Balkan countries.

Table 16. Annual damage across Europe for each plant operating at capacity adjusted for load factor, EUR million/year

	ANNUAL DAMAGE, LOWER BOUND (VOLY), IN EUR MILLION/YEAR				ANNUAL DAMAGE, UPPER BOUND (VSL), IN EUR MILLION/YEAR			
	SO_2	NO_x	$PM_{2.5}$	TOTAL	SO_2	NO_x	$PM_{2.5}$	TOTAL
Gacko	92	9	4	105	270	24	11	305
Kakanj Unit 5	59	4	0	63	173	11	1	184
Kakanj Unit 6	59	4	0	63	173	11	1	184
Kakanj Unit 7	124	8	1	132	361	22	2	385
Tuzla G3	24	3	1	27	70	7	2	79
Tuzla G4	48	6	1	55	140	15	4	158
Tuzla G5	48	6	1	55	140	15	4	158
Tuzla G6	51	6	1	59	150	16	4	170
Ugljevik 1	511	8	2	521	1,493	22	6	1,520
Banovici	3	1	0	5	10	3	0	14
Bugojno Unit 1	5	3	0	8	13	8	0	21
Gacko Unit 2	5	3	0	8	13	8	0	21
Kakanj unit 8	5	3	0	8	13	8	0	21
Kakanj unit 9	5	3	0	8	13	8	0	21
Kongora unit 1	4	3	0	7	12	7	0	20
Kongora unit 2	4	3	0	7	12	7	0	20
Stanari	5	3	0	9	16	9	1	26
Tuzla unit 7	3	3	0	6	8	7	1	16
Tuzla unit 8	3	3	0	6	8	7	1	16
Ugljevik 3 unit 1	5	3	0	8	13	8	0	21
Ugljevik 3 unit 2	5	3	0	8	13	8	0	21
Kosovo A Unit 3	7	3	9	20	19	7	22	48
Kosovo A Unit 5	16	6	20	41	39	15	46	100
Kosovo B Unit 1	23	11	8	42	57	26	19	102
Kosovo B Unit 2	23	11	8	42	57	26	19	102
Kosovo C Unit 1	5	2	0	7	12	5	0	17
Kosovo C Unit 2	5	2	0	7	12	5	0	17
Bitola Unit 1	61	7	5	72	166	18	12	196
Bitola Unit 2	61	7	5	72	166	18	12	196
Bitola Unit 3	61	7	5	72	166	18	12	196
Oslomej	43	3	3	48	117	7	8	132
Mariovo	4	2	0	6	10	4	0	15
Pljevlja I	92	7	1	100	238	16	3	257
Berane	2	1	0	3	5	2	0	7
Maoce	8	4	0	13	21	10	1	32
Pljevlja II	4	2	0	6	9	4	0	14
Kolubara 1	9	1	1	11	27	2	3	32
Kolubara 2	9	1	1	11	27	2	3	32
Kolubara 3	19	1	2	22	55	3	6	65
Kolubara 5	32	2	4	38	94	6	11	111
Kostolac A1	66	2	1	70	193	6	4	204
Kostolac A2	138	5	3	146	406	13	9	428
Kostolac B1	176	9	6	191	516	24	18	558
Kostolac B2	176	9	6	191	516	24	18	558
Morava	45	3	6	55	132	9	19	160
Nikola Tesla A1	25	6	2	32	73	15	5	94
Nikola Tesla A2	25	6	2	32	73	15	5	94
Nikola Tesla A3	36	8	3	47	106	22	8	136
Nikola Tesla A4	37	8	3	47	107	23	8	138
Nikola Tesla A5	37	8	3	47	107	23	8	138
Nikola Tesla A6	41	9	3	54	121	25	9	156
Nikola Tesla B1	184	16	2	202	540	44	6	591
Nikola Tesla B2	184	16	2	202	540	44	6	591
Kolubara B unit 1	7	4	0	11	20	11	1	32
Kolubara B unit 2	7	4	0	11	20	11	1	32
Kostolac	6	4	0	10	19	10	1	29
Nikola Tesla unit 3	7	4	0	11	20	11	1	32
Nikola Tesla unit 4	7	4	0	11	20	11	1	32
Štavalj	6	4	0	10	19	10	1	29

Table 17. Annual damage across Europe from emissions from each country, with plant operating under current/planned conditions, EUR million/year

	ANNUAL DAMAGE, LOWER BOUND (VOLY), IN EUR MILLION/YEAR				ANNUAL DAMAGE, UPPER BOUND (VSL), IN EUR MILLION/YEAR			
	SO_2	NO_x	$PM_{2.5}$	TOTAL	SO_2	NO_x	$PM_{2.5}$	TOTAL
EXISTING PLANT								
Bosnia and Herzegovina	1015	53	12	1081	2969	142	34	3145
Kosovo	69	31	45	144	172	74	106	352
Macedonia	225	23	17	265	616	59	45	720
Montenegro	92	7	1	100	238	16	3	257
Serbia	1238	109	51	1398	3637	300	150	4086
Existing total	**2639**	**223**	**126**	**2988**	**7632**	**592**	**337**	**8561**
NEW, PLANNED PLANT								
Bosnia and Herzegovina	51	32	2	85	148	85	7	240
Kosovo	9	4	0	14	24	10	1	34
Macedonia	4	2	0	6	10	4	0	15
Montenegro	14	7	0	21	36	16	1	53
Serbia	40	23	2	65	118	63	4	185
New total	**118**	**67**	**5**	**190**	**336**	**179**	**13**	**528**
ALL PLANTS								
Bosnia and Herzegovina	1066	85	14	1165	3117	228	40	3385
Kosovo	78	35	45	158	196	83	107	386
Macedonia	229	25	17	270	626	64	45	735
Montenegro	106	13	2	121	274	33	4	310
Serbia	1278	132	53	1463	3755	363	154	4272
All total	**2757**	**291**	**131**	**3178**	**7967**	**771**	**350**	**9088**

Table 18. Annual damage for each plant operating at capacity adjusted for load factor within the five Balkan countries, EUR million/year

	ANNUAL DAMAGE, LOWER BOUND (VOLY), IN EUR MILLION/YEAR				ANNUAL DAMAGE, UPPER BOUND (VSL), IN EUR MILLION/YEAR			
	SO_2	NO_x	$PM_{2.5}$	TOTAL	SO_2	NO_x	$PM_{2.5}$	TOTAL
Gacko	33	3	2	38	97	8	7	111
Kakanj Unit 5	21	1	0	23	62	3	0	66
Kakanj Unit 6	21	1	0	23	62	3	0	66
Kakanj Unit 7	44	3	0	47	130	7	1	138
Tuzla G3	9	1	0	10	25	2	1	29
Tuzla G4	17	2	1	20	50	5	2	57
Tuzla G5	17	2	1	20	50	5	2	57
Tuzla G6	18	2	1	21	54	5	2	62
Ugljevik 1	184	3	1	187	537	7	3	547
Banovici	1	0	0	2	4	1	0	5
Bugojno Unit 1	2	1	0	3	5	2	0	8
Gacko Unit 2	2	1	0	3	5	2	0	8
Kakanj unit 8	2	1	0	3	5	2	0	8
Kakanj unit 9	2	1	0	3	5	2	0	8
Kongora unit 1	2	1	0	2	4	2	0	7
Kongora unit 2	2	1	0	2	4	2	0	7
Stanari	2	1	0	3	6	3	1	9
Tuzla unit 7	1	1	0	2	3	2	1	6
Tuzla unit 8	1	1	0	2	3	2	1	6
Ugljevik 3 unit 1	2	1	0	3	5	2	0	8
Ugljevik 3 unit 2	2	1	0	3	5	2	0	8
Kosovo A Unit 3	3	1	6	10	8	3	14	25
Kosovo A Unit 5	7	2	13	22	17	5	30	52
Kosovo B Unit 1	10	4	5	19	24	9	12	46
Kosovo B Unit 2	10	4	5	19	24	9	12	46
Kosovo C Unit 1	2	1	0	3	5	2	0	7
Kosovo C Unit 2	2	1	0	3	5	2	0	7
Bitola Unit 1	24	3	3	30	66	7	8	81
Bitola Unit 2	24	3	3	30	66	7	8	81
Bitola Unit 3	24	3	3	30	66	7	8	81
Oslomej	17	1	2	20	47	3	5	54
Mariovo	2	1	0	2	4	2	0	6
Pljevlja I	39	2	1	43	101	6	2	109
Berane	1	0	0	1	2	1	0	3
Maoce	4	1	0	5	9	4	0	13
Pljevlja II	2	1	0	2	4	2	0	6
Kolubara 1	4	0	1	5	12	1	2	14
Kolubara 2	4	0	1	5	12	1	2	14
Kolubara 3	8	0	1	10	23	1	4	29
Kolubara 5	14	1	2	17	40	2	7	50
Kostolac A1	28	1	1	30	82	2	3	87
Kostolac A2	59	2	2	63	173	5	6	184
Kostolac B1	75	3	4	82	220	8	12	241
Kostolac B2	75	3	4	82	220	8	12	241
Morava	19	1	4	25	56	3	12	72
Nikola Tesla A1	11	2	1	14	31	6	4	40
Nikola Tesla A2	11	2	1	14	31	6	4	40
Nikola Tesla A3	15	3	2	20	45	8	5	58
Nikola Tesla A4	16	3	2	20	46	8	5	59
Nikola Tesla A5	16	3	2	20	46	8	5	59
Nikola Tesla A6	18	3	2	23	52	9	6	67
Nikola Tesla B1	78	6	1	86	230	16	4	250
Nikola Tesla B2	78	6	1	86	230	16	4	250
Kolubara B unit 1	3	1	0	4	9	4	0	13
Kolubara B unit 2	3	1	0	4	9	4	0	13
Kostolac	3	1	0	4	8	4	0	12
Nikola Tesla unit 3	3	1	0	4	9	4	0	13
Nikola Tesla unit 4	3	1	0	4	9	4	0	13
Štavalj	3	1	0	4	8	4	0	12

Table 19. Annual damage in the five Balkan countries considered from emissions from each country, with plant operating under current/planned conditions, EUR million/year

	ANNUAL DAMAGE, LOWER BOUND (VOLY), IN EUR MILLION/YEAR				ANNUAL DAMAGE, UPPER BOUND (VSL), IN EUR MILLION/YEAR			
	SO_2	NO_x	$PM_{2.5}$	TOTAL	SO_2	NO_x	$PM_{2.5}$	TOTAL
EXISTING PLANT								
Bosnia and Herzegovina	365	17	7	390	1068	46	20	1134
Kosovo	29	11	29	70	74	26	69	169
Macedonia	89	9	11	109	245	23	28	297
Montenegro	39	2	1	43	101	6	2	109
Serbia	528	39	33	600	1551	108	97	1756
Existing total	**1051**	**79**	**81**	**1211**	**3039**	**210**	**216**	**3464**
NEW, PLANNED PLANT								
Bosnia and Herzegovina	18	10	1	30	53	28	4	85
Kosovo	4	1	0	6	10	4	1	14
Macedonia	2	1	0	2	4	2	0	6
Montenegro	6	2	0	9	15	6	1	22
Serbia	17	8	1	26	50	23	3	76
New total	**47**	**23**	**3**	**73**	**133**	**61**	**8**	**203**
ALL PLANTS								
Bosnia and Herzegovina	383	28	8	419	1121	74	24	1219
Kosovo	33	13	29	75	84	30	69	183
Macedonia	91	10	11	111	249	25	29	303
Montenegro	45	5	1	51	117	12	3	131
Serbia	545	48	34	627	1601	131	100	1832
All total	**1098**	**102**	**84**	**1284**	**3172**	**271**	**224**	**3667**

Aggregation of results across all plants assumed to be operating at full capacity is not a meaningful indicator of burden for reasons given above. For example, not all plants will operate simultaneously. Table 20 shows the total capacity available in each country in 2015 alongside average damage per MWe of capacity (EUR/MWe). Average damage is reported for impacts across the whole of Europe and for the five Balkan countries.

Table 20. MW_e available in 2015 and average annual damage assessed over Europe and over the five Balkan countries per unit of capacity across all available plant

	MW available	Damage across EU, in EUR/MW		Damage within 5 Western Balkan countries, in EUR/MW	
		lower bound (VOLY)	upper bound (VSL)	lower bound (VOLY)	upper bound (VSL)
Bosnia and Herzegovina	1,765	612,194	1,781,724	220,685	642,411
Kosovo	1,088	132,793	323,401	63,973	155,149
Macedonia	800	330,893	900,290	136,361	370,669
Montenegro	210	476,660	1,224,851	202,385	520,126
Serbia	4,299	325,238	950,485	139,645	408,426
Total	**8,037**	**366,087**	**1,048,781**	**148,374**	**424,435**

5. DISCUSSION

The analysis presented demonstrates the negative effects to health of continued use of coal and lignite for power generation. The results, however, do not include a range of additional impacts associated with the extraction of coal, the release of greenhouse gases from combustion and other activities, and the disposal of wastes at the end of the fuel chain. They are thus a sub-total of the full burden of generating electricity from coal and lignite.

The methods used here have been agreed with the WHO and were used also in the development of the Clean Air Policy Package by the EU Commission in 2013. They therefore represent the state of the art for impact quantification.

There is inevitably some level of approximation involved in this analysis. The approach taken has sought to take a balanced view on inputs to the analysis, not deliberately over-or under-estimating impacts.

The results given, and further information presented in the appendices, will enable the analysis to be extended with further quantification. For example, for reasons of space, the tables showing health impacts report only the number of premature deaths attributable to emissions from the power stations of interest. Other health impacts (hospital admissions, lost working days, etc.) can also be quantified using data presented in the methodology.

It is clear that one of the reasons for selecting coal or lignite for new power generation n in the Balkans is that it is readily available in the region. However, it is equally clear from the analysis carried out here that there are very good reasons, through the magnitude of the health impacts, for investigating alternative options for power generation. One important option that needs to be factored into analysis is the more widespread adoption of energy efficiency measures, particularly those with short pay-back times. Such measures will not only reduce pollutant emissions but have further benefits, for example in terms of reducing energy poverty.

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About HEAL

The Health and Environment Alliance (HEAL) is a leading European not-for-profit organisation addressing how the environment affects health in the European Union (EU). With the support of more than 70 member organisations, HEAL brings independent expertise and evidence from the health community to different decision-making processes. Our broad alliance represents health professionals, not-for-profit health insurers, doctors, nurses, cancer and asthma groups, citizens, women's groups, youth groups, environmental NGOs, scientists and public health research institutes. Members include international and Europe-wide organisations as well as national and local groups.

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