ANALYSIS

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BREF COMPLIANCE FOR GREEK LIGNITE PLANTS

A Cost Benefit Analysis

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Introduction

In April 2017, the EU has agreed to approve the new Best Reference Document for Large Combustion Plants (LCP BREF) which contains the new emission limit values for the pollutants emitted by these plants as well as the best available abatement technologies which can be implemented in order to achieve compliance with the new BREF limits. The decision was published in the official Journal of the European Union on August 17 2017[1]. According to Article 15 of the Industrial Emissions Directive (IED) (2010/75/EE), all plants must comply with the new limits four years from that date, i.e. August 17 2021.

Clearly this also applies to Greek lignite plants (see Table 1). However, the environmental permits of 5 existing lignite plants that have recently been issued do not comply with the new BREF limits. Instead, the corresponding environmental permits state that after the expiration of the Greek Transitional National Plan (June 2020) in which they are all included, the emission limit values with which the plants will comply are the less strict limits included in the IED. Moreover Greek officials have discussed the possibility of evoking a derogation of the IED (derogation of article 15(4)) in order for plants to avoid compliance with the new BREF limits should the costs for complying exceed the corresponding environmental benefits.

It therefore becomes important to quantitatively compare the environmental benefits with the abatement costs to achieve full compliance with the new BREF.

Table 1*: Emission Limit Values (IED and new BREF) as they apply to Greek lignite plants*

Pollutant	**Emission Limit Values (mg/Nm^3)**			
	Industrial Emissions Directive		**New LCP BREF**	
	Existing Plants	New Plants	Existing Plants	New Plants
Sulfur dioxide (SO_2)	200	150	130	75
Nitric Oxides (NO_x)	200	200	175	85
Dust (PM)	20	10	8-12	5

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017D1442&from=EL

Current state

According to the definition of a plant in the IED, there exist eleven lignite plants in Greece currently. Nine of these are located in the region of Western Macedonia and two in the regional unit of Arkadia in the region of Peloponnese. Their overall gross nominal and net capacities are 4.375 MW and 3.912 MW, respectively. The three oldest plants in the Greek lignite fleet are 43 years old, whereas the newest, has started its operation 15 years ago. Table 2 shows their capacities (gross, net and thermal), their commissioning date and their status with respect to the Industrial Emissions Directive (2010/75/EE).

***Table 2**: Basic characteristics of Greek lignite plants*

Plant	Gross Capacity (MW)	Net Capacity (MW)	Thermal Capacity (MW_{th})	Commissioning Date	IED status
Kardia I	300	275	762	1975	LLD[2]
Kardia II	300	275	762	1975	LLD
Kardia III	325	280	812	1980	LLD
Kardia IV	325	280	812	1981	LLD
Ag. Dimitrios I-II	600	548	1.524	1984	TNP[3]
Ag. Dimitrios III-IV	620	566	1.574	1985-86	TNP
Ag. Dimitrios V	375	342	892	1997	TNP
Amyntaio I-II	600	546	1.525	1987	LLD
Meliti I	330	289	796	2003	TNP
Megalopoli A	300	255	839	1975	TNP
Megalopoli B	300	256	822	1991	TNP
Total	4.375	3.912	11.120		

These plants constitute a major source of environmental pollution and some of them are amongst the most polluting plants in Europe burning coal or lignite. Using the official data of the Ministry of Environment and Energy, which we have been collecting through access to information requests, the average concentrations of the three major pollutants for the five-year period 2012-2016 were calculated.

Figure 1 presents the average in time concentration of sulfur dioxide (SO_2) emitted by each plant as well as the corresponding upper emission limit value of the new BREF.

[2] LLD: The plant has a Limited Lifetime Derogation according to article 33(1) of the Industrial Emissions Directive. The plant may operate up to 17.500 hours in the period 2016-2023

[3] TNP: The plant participates in Greece's Transitional National Plan. All plants participating in the TNP may emit limited masses of pollutants in total and should fully comply with IED's Emission Limit Values by 30/6/2020 at the lastest.

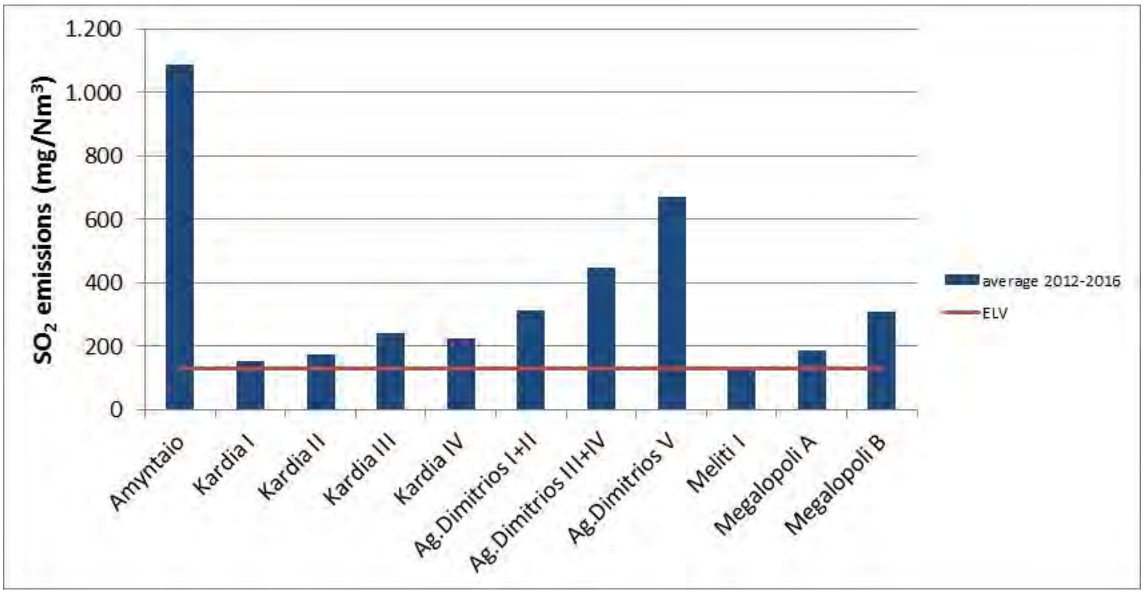

***Figure 1**: Average SO_2 concentration for each plant over the period 2012-2016 and Emission Limit Value in the new BREF for plants of this type (130 mg/Nm^3)*

It is clear that with the exception of Meliti I, which is barely below the new ELV (129,2 mg/Nm^3), all other Greek lignite plants do not comply with the new BREF limits for SO_2. Amyntaio in particular with 1087 mg/Nm^{3}emits on average 8,4 times than what the new European environmental legislation allows. The second worse is Ag. Dimitrios V with 668 mg/Nm^3, more than 5 times above the new ELV, whereas the two other Ag. Dimitrios plants emit on average 313 mg/Nm^3 and 445 mg/Nm^3, 2,4 and 3,4 times above the ELV, respectively. Despite the fact that both Megalopoli A and B have installed wet flue gas desulfurization units to reduce their SO_2 emissions, they still emit significantly above the new ELV (187 mg/Nm^3 for Megalopoli A and 307 mg/Nm^3 for Megalopoli B).

Figure 2 shows the average in time concentration of nitric oxides (NO_x) emitted by each plant as well as the corresponding upper emission limit value of the new BREF.

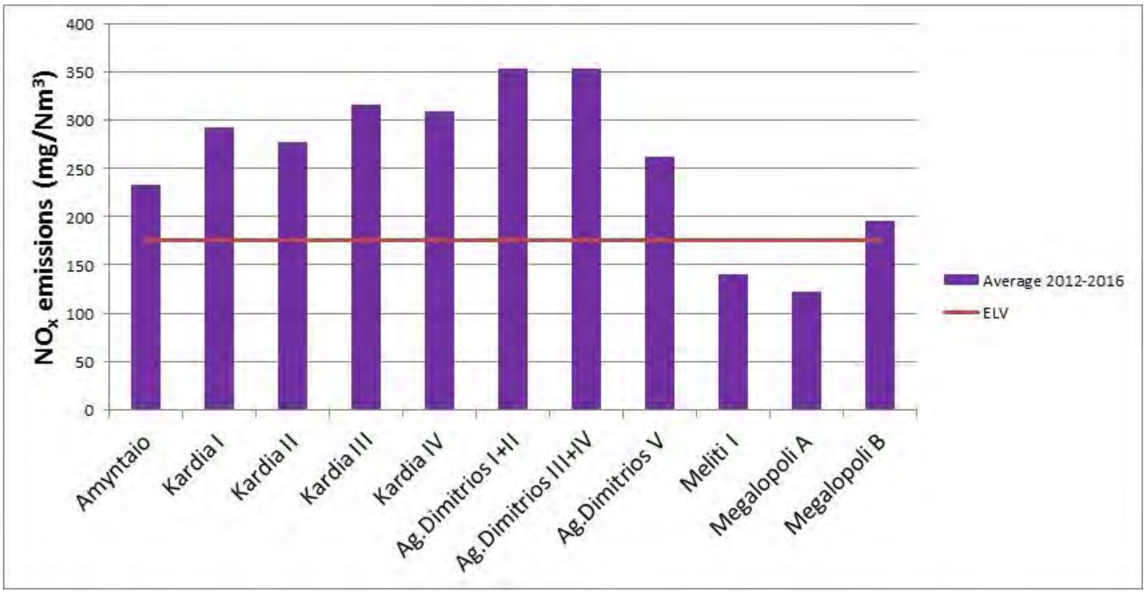

***Figure 2**: Average NO_x concentration for each plant over the period 2012-2016 and Emission Limit Value in the new BREF for plants of this type (175 mg/Nm^3)*

Only Meliti I and Megalopoli A comply with the new BREF, whereas the two older Ag. Dimitrios plants (I-II and III-IV) emit on average two times above the new limit with 353 mg/Nm^3 and 354 mg/Nm^3, respectively. All four Kardia plants and Amyntaio also emit significantly above the new limit value, with average concentrations ranging from 233 mg/Nm^3 (Amyntaio) to 316 mg/Nm^3 (Kardia III).

Finally, figure 3 shows the average during the period 2012-2016 concentration of dust emitted by each plant as well as the corresponding upper emission limit values (ELV) of the new BREF. Note that for the two Ag. Dimitrios plants (I-II and III-IV) the emission limit value of 8 mg/Nm^3 applies since both plants are above the 1000MW$_{th}$ threshold, whereas for the rest of the plants the corresponding limit is 12 mg/Nm^3.

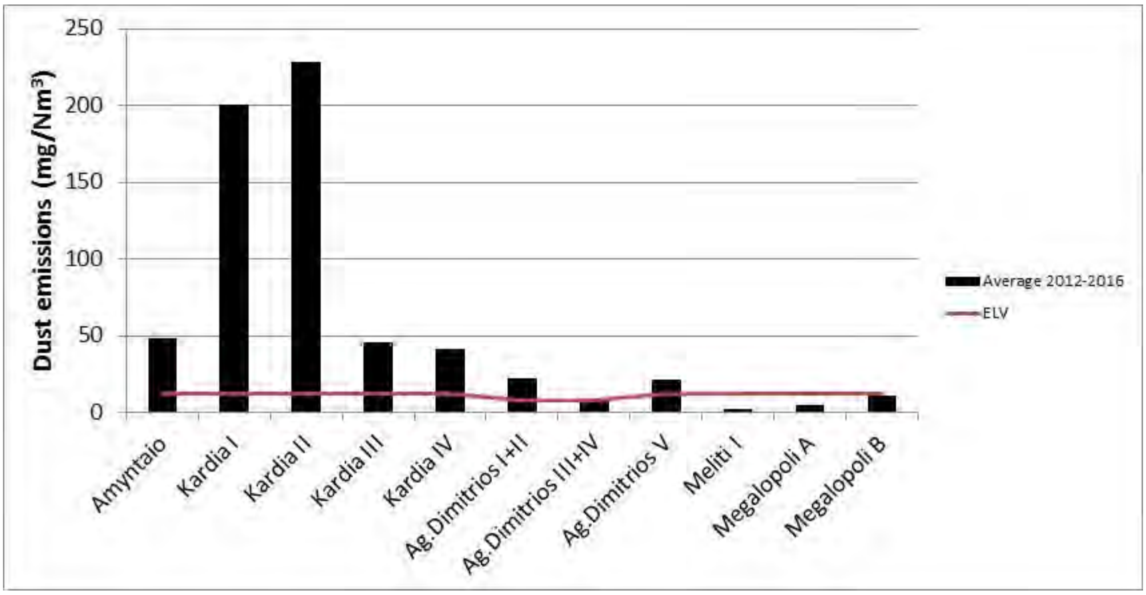

Figure 3*: Average dust concentration for each plant over the period 2012-2016 and Emission Limit Values in the new BREF for plants of this type (12 mg/Nm^3, and 8 mg/Nm^3 for Ag. Dimitrios I-II and III-IV)*

Four out of eleven lignite plants comply with the new BREF (Meliti I, Megalopoli A, Megalopoli B, Ag. Dimitrios III+IV), whereas the other seven do not. Notice that the two older Kardia plants emit 17 (Kardia I) and 19 (Kardia II) times above the new limit value. However, this has not prevented the Greek government to request extended hours of operation for all four Kardia plants during the period 2016-2023, without any intention to install new electrostatic filters in order to reduce this gross violation of environmental legislation. The European Commission has rejected the request

From these three figures it becomes apparent that only Meliti I is compliant with new BREF with respect to the emissions of the three major pollutants, whereas the rest of the Greek lignite plants are above the emission limit values with respect to all or some of the pollutants, and by huge factors in some cases. Amyntaio is the biggest outlier in terms of SO_2 emissions, Ag. Dimitrios I-II and III-IV with respect to NO_x emissions, and Kardia I and II in terms of dust emissions.

Despite Meliti I's compliance with the new BREF, the plant was included in Greece's TNP, which aims at rendering all plants included, compliant with the less strict limits of the IED by June of 2020. This choice was therefore clearly wrong, and can be interpreted as an effort to offer more room for pollution for the other plants included in Greece's TNP, namely Ag. Dimitrios I-II, III-IV and V, and Megalopoli A and B. The same error was also made with the inclusion of Megalopoli A, Megalopoli B and Ag. Dimitrios III-IV regarding dust emissions, and Megalopoli A regarding NO_x emissions.

Environmental costs from lack of compliance with the BREF

A. The EEA method

In this section we will estimate the environmental cost from the lack of compliance with the new stricter emission limit values contained in the new BREF, or else, the benefits for the environment and public health from the application of appropriate abatement technologies which will lead to full compliance with the new BREF regarding the emissions of the three main pollutants. Meliti I will be excluded from the analysis since it is already compliant with the new BREF, as shown in the previous section.

The analysis will be performed using the method applied by the European Environment Agency (EEA) to quantify the damage associated with individual power stations and other industrial facilities[4]. The method is based on estimates of marginal damage costs as €/tonne of emissions above a certain threshold. These marginal damage costs have been derived using a full impact pathway approach (IPA) and are provided by the EEA as national averages (see Table 3 for marginal costs for Greece). The full IPA approach takes a very detailed sequential pathway from emission, to exposure, to impact quantification and monetization. Emissions are tracked over extended distances (the whole of the EU and bordering countries) and account is taken of the formation of secondary pollutants, especially nitrate and sulphate aerosols, and ozone. Since the marginal costs in the EEA method are derived from a full IPA approach, the former constitutes a reliable simplification of the latter, which also takes into account transboundary effects of environmental pollution. According to Holland (2017)[5], the assessment of the damage costs using this method is considered conservative since it is not possible to include all pollution impacts, and the values adopted for mortality, in particular, are low compared to those recommended elsewhere (e.g. by OECD and USEPA). These biases need to be considered in evaluating any application for a derogation.

***Table 3**: Marginal costs for Greece in €/tonne*

	SO_2		NO_x		PM_{10}		$PM_{2.5}$	
	Low VOLY	High VSL	Low VOLY	High VSL	low VOLY	High VSL	low VOLY	high VSL
Marginal cost	4000	11671	1390	3142	12123	36937	18669	56883

The EEA method consists of computing the difference in tonnes emitted annually by each plant, from an initial to a final state and for all three pollutants. For example, if one wants to estimate the damage for the environment and public health caused by the fact that most Greek lignite plants currently emit significantly above the emission limit values of the new BREF, then the current emission levels of Greek lignite plants should be used as the "initial" state, whereas the emission levels corresponding to the new BREF emission limit values should be taken as the "final" state. Then, by multiplying these differences with the Greece-specific estimates of the marginal damage costs per tonne from the EEA study, and making all the necessary adjustments (inflation, sectoral corrections, discount rates, GDP uplift etc),

[4] https://www.eea.europa.eu/publications/costs-of-air-pollution-2008-2012

[5] http://env-health.org/IMG/pdf/20180129_guidance_on_cba_for_ied_derogations_mholland.pdf

one can estimate the cost for the environment and public health from remaining at the initial state, or else, the benefits from achieving the desired state through the application of appropriate abatement technologies.

B. From current state to BREF compliance

In order to compute the cost from maintaining the current average emission levels presented in figures 1-3 and not complying with the new BREF, the official data provided by the Greek Ministry of Environment and Energy were utilized to compute for each pollutant the mass (in tonnes) emitted annually by each plant as an average over the five-year period 2012-2016. We then estimated the average flue gas volume emitted annually from each plant (stack) by dividing the mass emitted with the corresponding pollutant concentration. By multiplying this average flue gas volume with the emission limit values of the new BREF, one obtains an estimate of the pollutant mass that each plant would emit if it were compliant with the BREF. Subtracting the average mass currently emitted from each plant for each pollutant with the estimate of the pollutant mass that would be emitted in the case of BREF compliance, yields the difference (in tonnes) which is necessary in order to apply the EEA method. This difference was then multiplied with the Greece-specific marginal damage costs per tonne from the EEA study (Table 3), to yield the damage costs from not complying with the BREF. Using the same assumption as the EEA (2014) for particulate matter, 65% of PM was assumed to exist in the form of $PM_{2.5}$, while the remaining 35% in the form of PM_{10} and hence the corresponding marginal damage costs per tonne in Table 3 were used in this analogy.

Given the fact that that the marginal costs from the EEA study (Table 3) correspond to 2005, the result was corrected for the inflation. Since the damage costs from the lack of compliance of Greek plants with the new BREF are not limited to Greece, the Greek inflation rates do not accurately reflect the corresponding effect. According to the recommendation of Holland (2017), the inflation data from the EU's Harmonised Index of Consumer Prices[6] presented in Table 4, were used instead. Thus, to correct from 2005 (year for the calculation of marginal costs in the EEA report) to 2018, the abovementioned result was multiplied by **1,219**.

Table 4*: Change in HICP, 2005 to 2018*

Year	HICP Inflation (%)	Index, base year 2005 (%)
2005	2,20	100,00
2006	2,21	102,21
2007	2,16	104,42
2008	3,35	107,92
2009	0,32	108,26
2010	1,61	110,00
2011	2,72	113,00
2012	2,50	115,82
2013	1,35	117,38
2014	0,43	117,89
2015	0,03	117,92

[6] http://www.inflation.eu/inflation-rates/europe/historic-inflation/hicp-inflation-europe.aspx

2016	0,24	118,21
2017	1,54	120,03
2018	1,57	121,91

In addition, the marginal damage costs per tonne presented by the EEA are national averages, accounting for all sources and sectors. Industrial sources tend to be less closely linked to population than some others (e.g. traffic) and hence it is anticipated that they will have lower damage costs per unit emission. According to the recommendation of Holland (2017) and in order to account for this discrepancy, the result of the calculation was then multiplied with the sectoral correction factors for public power, used by the EEA study (2014) -originally from Eurodelta II- specifically, **0,87 for SO_2, 0,78 for NO_x and 0,5 for PM**.

Figure 4 shows the application of the aforementioned methodology and calculation steps for all existing Greek plants to estimate the annual damage costs from maintaining the current average emission levels and not complying with the emission limit values in the new BREF.

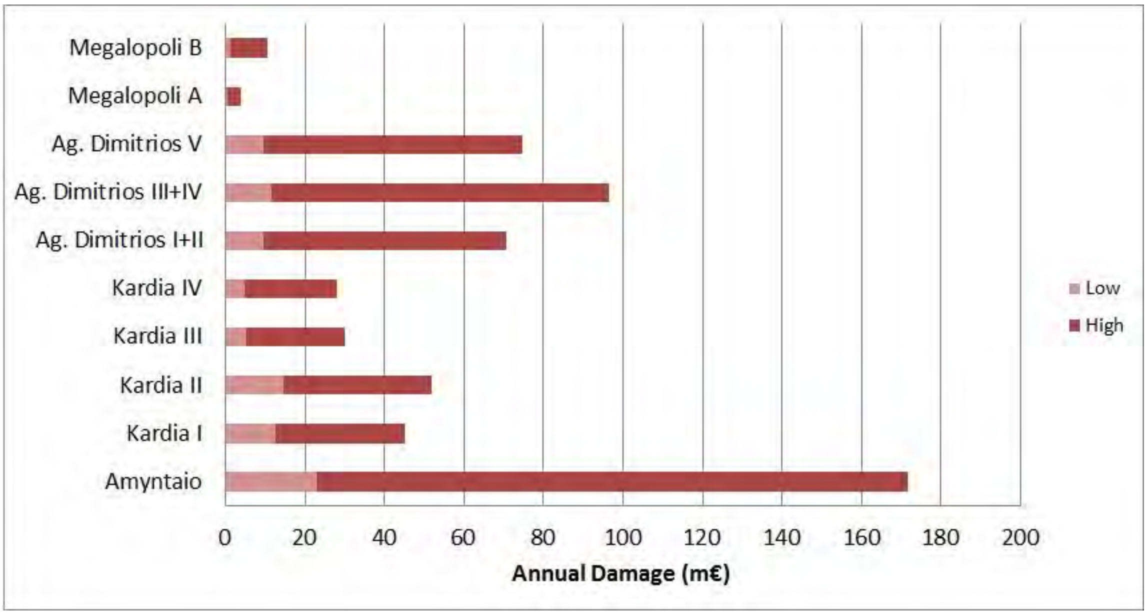

***Figure 4**: Low and high estimates of annual damage costs from maintaining the current average emission levels and not complying with the emission limit values in the new BREF*

The total annual damage cost is € 92-583 million. Ag. Dimitrios is the most costly lignite complex (3 IED plants) with ~€ 30-240 million, mainly due to the combined effect of its high SO_2 and NO_x emissions, whereas Amyntaio is the most costly single IED plant with annual damages of € 23-170 million, due to its huge SO_2 emissions. The Kardia complex (4 IED plants) is responsible for an annual damage cost of € 37-155 million resulting predominately from the huge exceedance of the BREF limits in dust from Kardia I and II plants.

C. From IED to BREF compliance

The environmental permits for the Megalopoli A, Megalopoli B and Ag. Dimitrios plants that have recently been issued do not comply with the new BREF limits, despite the fact that the first two were issued after the publication of the new BREF. Instead, all three environmental permits state that after the expiration of the Greek TNP (June 2020) in which they are all included, the emission limit values with which the plants will comply are the less strict limits included in the IED. Moreover, several Greek officials have discussed the possibility of Greek plants evoking the exception of article 15 of the IED, paragraph 4, according to which:

"By way of derogation from paragraph 3, and without prejudice to Article 18, the competent authority may, in specific cases, set less strict emission limit values. Such a derogation may apply only where ***an assessment shows that the achievement of emission levels associated with the best available techniques as described in BAT conclusions would lead to <u>disproportionately higher costs</u> compared to the environmental benefits*** *due to:*
(a) the geographical location or the local environmental conditions of the installation concerned; or
(b) the technical characteristics of the installation concerned.
The competent authority shall document in an annex to the permit conditions the reasons for the application of the first subparagraph including the result of the assessment and the justification for the conditions imposed."

Therefore, it becomes highly relevant to quantitatively compare the environmental benefits from full compliance with the BREF instead of remaining compliant with the less strict IED, with the abatement costs in order to achieve BREF compliance for all five lignite plants included in Greece's TNP. Amyntaio and Kardia are not relevant for such an analysis, since both plants are expected to retire in the imminent future since both of them have a Limited Lifetime Derogation (article 33 of the IED) and their 17.500 hours of operation are close to being exhausted.

The same EEA method was used in order to estimate the environmental benefits for the five plants. The pollutant masses in tonnes that would be emitted annually by each of plant if it complies with the new BREF were exactly those computed in the previous subsection. To estimate however the pollutant masses that would be emitted every year if the plants were only complying with the less strict IED limits, the 5 year average flue gas volume -previously computed as well- was multiplied with the IED ELV. As in the previous subsection, the differences between the two masses for each pollutant were then multiplied with the Greece-specific marginal costs to obtain the low and high estimates of the annual environmental benefits per plant from complying with the new BREF. The result was then also corrected for inflation and the fact that Greek power plants belong to the public power sector (sectoral correction). Finally, each result was then multiplied with the expected lifetime of these plants in order to compute the overall environmental benefits, which could then be directly compared with the abatement costs. According to several public statements and studies, it was assumed that all five plants will have retired by the end of 2030.

Moreover, in line with European Commission practice, future environmental benefits should be discounted at a rate of 4%. Although incomes per capita across the EU have been static in recent years, adjustment should also be made for future income growth, recognizing that this will increase willingness to pay for health protection. Using estimates of GDP/capita for each country out to 2050, weighted average growth rates for the EU based on OECD were calculated by Holland (2017). The average GDP uplift for the next decade -the time horizon of this analysis- was estimated to be 2,06%. Holland (2017) also recommends to subtract this from the 4% discount rate, thus yielding an adjusted discount rate of **1,94%**. Figure 5 shows the results of the computation in both the undiscounted and discounted forms.

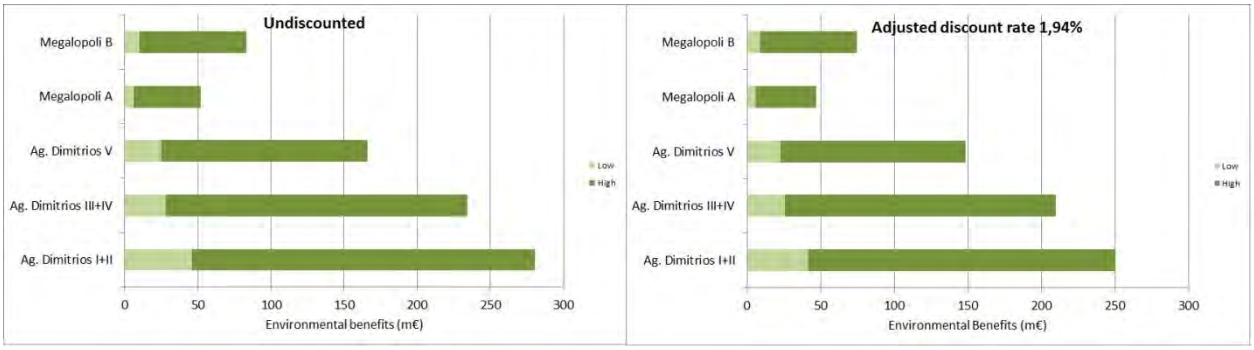

***Figure 5**: Low and high estimates of the environmental benefits until 2030 from complying with the emission limit values in the new BREF instead of the less strict IED limits. Left: undiscounted. Right: with an adjusted discount rate of 1,94%.*

The total benefits from transitioning from a hypothetical compliance with the IED emission limit values to full BREF compliance until 2030 are € 115-816 million (undiscounted), whereas compliance of the 3 Ag. Dimitrios plants results in the greatest benefits with € 99-680 million in total, with Ag. Dimitrios I-II having the most significant contribution. Discounting the benefits with an adjusted discount rate of 1,94% to reflect their net present value results in a reduction of the absolute value of the benefits (€103-729 million), without changing the relative comparison between the lignite plants.

Estimation of abatement costs

In order to assess the eligibility of Greek lignite plants for an article 15(4) derogation, the environmental benefits from full compliance with the new BREF should be compared with the abatement costs to achieve compliance. These consist of the installation costs of the appropriate abatement technology and the corresponding operating costs for the period until 2030. The analysis was performed for all plants in Greece's Transitional Plan with the exception of Meliti I, which already complies with the ELVs in the new BREF regarding SO_2, NO_X and dust emissions.

By taking into account the current average emission levels of each plant, the Best Available Technologies (BAT) according to the new BREF, the efficiency rates that each abatement technology needs to accomplish in order for the plant to comply with the new BREF, the appropriate abatement technologies were chosen for each plant and each pollutant and are shown in Table 5, together with the corresponding installation and operating costs for the period until 2030.

In particular, according to the new BREF, as well as the old one (published in 2006), wet Flue Gas Desulphurisation (wFGD) is the technology to be used in large combustion plants with a thermal capacity above 300 MWth. In addition, the use of wFGD instead of dry scrubber technologies for reduction of SO_2 emissions has the added advantage of reducing emissions of heavy metals, in which the Ag. Dimitrios complex is amongst the leaders in the EU[7]. Because of that and the fact that all three Ag. Dimitrios plants are significantly larger than 300 MW_{th} (see Table 1), wFGD, was chosen for the compliance of these plants with the new SO_2 limits. The two Megalopolis plants already have wFGD systems installed. However, since both plants emit above the SO_2 ELV of the new BREF, an upgrade to these systems is necessary. As far as NO_x emissions are concerned, the method of Selective Non Catalytic Reduction (SNCR) was chosen for all plants in Greece's TNP with the exception of Megalopoli A, which already complies with the new 175 mg/Nm^3 emission limit value. SNCR was chosen because it is significantly cheaper than Selective Catalytic Reduction (SCR), the other secondary abatement technology capable of significant reductions in NO_x emission. However, since we wanted to assess the worst case scenario and many have argued that SNCR might not be a suitable abatement technology for achieving the new BREF limit of 175 mg/Nm^3, we also considered the possibility of implementing SCR systems. Finally, upgrades of the electrostatic filters are required for the Ag. Dimitrios I-II and V plants in order to reach the new 8 mg/Nm^3 and 12 mg/Nm^3 emission limit values for dust, respectively.

The installation cost for the new wFGD system for the Ag. Dimitrios III-IV plant was taken to be the same as in the corresponding tender[8] (€97 million). For the wFGD system of the Ag. Dimitrios V plant, a contract has been signed in June 2017 for €68 million[9]. Since Ag. Dimitrios I-II is of very similar capacity as Ag. Dimitrios III-IV, it was assumed that a new wFGD system for this plant would cost the same (€97 million). According to a recently

[7] http://www.tovima.gr/society/article/?aid=991347#.WyVuazK9THJ.facebook
[8] https://ted.europa.eu/TED/notice/udl?uri=TED:NOTICE:209615-2018:TEXT:EN:HTML&src=0
[9]http://www.jp-avax.gr/updocuments/J&P-%CE%91%CE%92%CE%91%CE%9E%20%CE%9F%CE%B9%CE%BA%CE%BF%CE%BD%CE%BF%CE%BC%CE%B9%CE%BA%CE%AE%20%CE%88%CE%BA%CE%B8%CE%B5%CF%83%CE%B7%2030.06.2017.pdf

published study on abatement technologies for the compliance of coal/lignite plants in the EU with the new BREF[10], the capital expenditure for technology upgrades for wFGD systems is approximately 10% of new build costs. Hence, taking into account the cost of the new wFGD system of the Ag. Dimitrios V plant and correcting for the smaller capacities of the Megalopolis A and B plants, the upgrade of the existing wFGD systems in the two Megalopolis plants is estimated to cost approximately €5,4 million each. According to the same study, the unitary installation cost for a new SNCR system (including primary measures) required for the reduction of NO_x emissions is 50 €/KWe, whereas the corresponding value for SCR is 120 €/KWe. Thus, taking into account the capacities of the plants requiring the implementation of this technology, an estimate of the corresponding installation costs is obtained. Finally, according to the study, the upgrade of ESP or fabric filters for the reduction of dust emissions may cost up to 20% of the capital expenditure of new ones, which are in turn estimated to cost approximately 75 €/KWe. Therefore, assuming that the unitary cost of a filter upgrade is 15 €/KWe and taking into account the capacity of the plant, the estimates of the corresponding costs are obtained.

The operating costs for the period until 2030 are the sum of fixed and variable operating costs. According to the aforementioned study on abatement technologies for BREF compliance of coal plants across the EU, the annual fixed costs are taken to be 3-4% of the corresponding installation costs, whereas the annual variable operating costs, which comprise mainly of the cost for the chemicals necessary for the implementation of each abatement technology, were calculated based on the study's estimate of 10 €/tonne for dust, 100-200 €/tonne for SO_2 and 200-400 €/tonne for NO_x. Since the assessment of the worst case scenario for the owners of the lignite plants was of primary interest, the most expensive estimates of the operating costs were considered in this analysis. The tonnes of the pollutant removed annually from the implementation of the abovementioned abatement technologies, which are necessary in order to computer the annual variable operating costs were calculated using the current average emission levels multiplied with the efficiency rate of removal for each abatement technology. According to the study, the removal efficiency for a wFGD system may reach up to 98%, for a SNCR system 60%, a SCR system 85%, whereas for electrostatic filters, 99,95%.

***Table 5**: Abatement technologies, CAPEX and OPEX to achieve BREF compliance*

Plant / Pollutant	**SO_2**			**NO_x**			**Dust**		
	Tech.	CapEx (m€)	OpEx (m€)	Tech.	CapEx (m€)	OpEx (m€)	Tech.	CapEx (m€)	OpEx (m€)
Ag. Dimitrios I-II	wFGD	97	60	SNCR/SCR	30/72	27,5/54,3	ESP-U	9	23,5
Ag. Dimitrios III-IV	wFGD	97	60,9	SNCR/SCR	31/74,4	28,9/56,8	-	-	-
Ag. Dimitrios V	wFGD	68	40,1	SNCR/SCR	18,8/45	15,6/31,7	ESP-U	5,6	4,7
Megalopoli A	wFGD–U	5,4	5	-	-	-	-	-	-
Megalopoli B	wFGD–U	5,4	5,4	SNCR/SCR	15/36	11,5/24	-	-	-
Totals		272,8	171,4		94,8/227	83,5/166,8		14,6	28,2

[10] https://europeanclimate.org/wp-content/uploads/2017/06/16-1213-rev2-DNV-GL-report-ECF-BREF-LCP2.pdf

The results indicate that compliance of the Greek TNP plants with the new SO_2 emission limit value is the most costly in terms of both the installation and operating costs, followed by compliance with the new NO_x ELV. Since thermal power station Kardia, the primary dust emitter in Greece, is not included in this analysis, and the exceedances of the new dust ELV by the Ag. Dimitrios I-II and Ag. Dimitrios V plants are relatively small (see figure 3), compliance with the new BREF can be accomplished at a relatively low expense. By summing up all the abatement costs for all pollutants and plants until 2030, one deduces that the overall cost of complying with the new BREF amounts to **€ 665 million** (undiscounted) in case SNCR is used for the reduction of NOx emissions and **€ 881 million** for the case of the SCR. Note that the use of a 1,94% adjusted discount rate until 2030 reduces the present value of operating costs, which in turn leads to reduced overall costs of € 635 million (€ 842 million in case SCR is chosen for the reduction of NOx emissions instead of SNCR). It must be noted that this is the maximum possible abatement costs since the starting point is the current state and not the hypothetical case where plants have achieved lower emissions (e.g. IED compliance) through some less efficient and less expensive abatement technologies.

Environmental benefits vs abatement costs

Having estimated the environmental benefits of fully complying with the new BREF for the five lignite plants participating in the Greek TNP, as well as the abatement costs for achieving BREF compliance for each plant and for all three pollutants, it is possible to compare the two for each plant in order to assess eligibility of Greek lignite plants for the aforementioned derogation of article 15(4) of the IED.

For this purpose, the criterion presented by Holland (2017) will be used:

$$Abatement\ Costs > \frac{Environmental\ Benefits}{0{,}7} \tag{1}$$

In other words, if the abatements costs are greater than the environmental benefits divided by the factor 0,7, then the plant may be eligible for a derogation. According to Holland (2017) and in line with the precautionary principle, the factor of 0,7 attempts to quantify the omission by this cost benefit analysis using the EEA methodology, of several types of impact. Moreover, according to the same study, in deciding whether a derogation should be given to a lignite plant or not, the upper estimate of the environmental benefits from compliance with the new BREF should be used.

Figure 6 compares the abatement costs to achieve BREF compliance with the environmental benefits starting from the current state as well as from compliance with the IED with a time horizon until 2030. In both cases, the environmental benefits have been divided by the factor 0,7 according to Holland (2017). It is clear that the environmental benefits starting from the current state are much more significant than the abatement costs, even in the cases of Megalopoli A and B where the absolute values are much smaller compared to the Ag. Dimitrios plants. The same applies for the comparison with environmental benefits starting from compliance with the less strict IED emission limit values. It must be noted that the same is also true even if the factor 0,7 is not used. Specifically, the uncorrected environmental benefits until 2030 from the full compliance of all five plants with the new BREF starting from the IED are estimated at **€816 million** if no discount rate is used (**€729** million with a 1,94% adjusted discount rate), approximately 30% higher than the abatement costs, whereas those starting from the current state at **€3,33 billion** undiscounted (**€2,97 billion** if using a 1,94% discount rate).

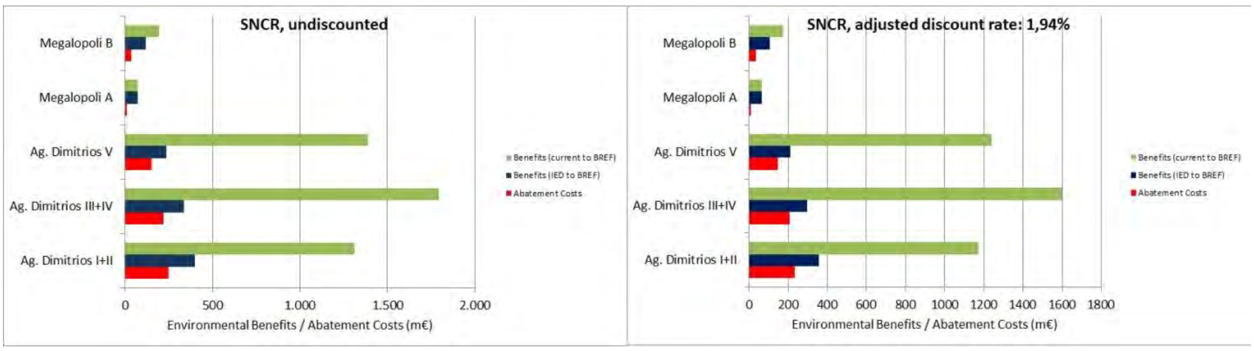

Figure 6*: SNCR is used for the reduction of NO_x emissions. Comparison between abatement costs to achieve full compliance with the BREF limits (red) and environmental*

benefits starting from the current state (green) as well as environmental benefits starting from compliance with the IED (blue).Left: undiscounted. Right: with an adjusted discount rate of 1.94%

The calculations were repeated to assess the effect of implementing SCR for the reduction of NOx emissions for all four plants which are above the new BREF limit (175 mg/Nm^3), instead of the far cheaper SNCR technology. Although the difference between the environmental benefits of achieving full BREF compliance starting from compliance with the IED (blue) and the abatement costs (red) is reduced compared to the case where SNCR is used for the reduction of NOx emissions, the former benefits remain greater than the abatement costs for all five plants.

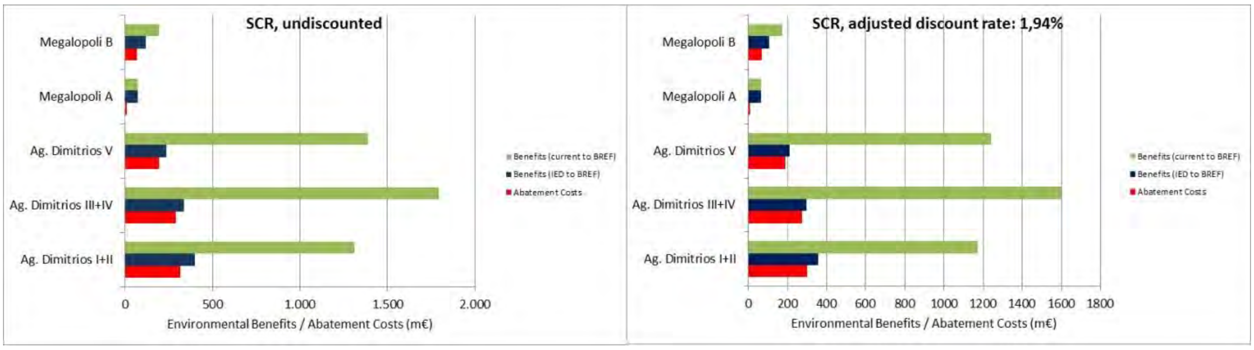

***Figure 7**: SCR is used for the reduction of NO_x emissions. Comparison between abatement costs to achieve full compliance with the BREF limits (red) and environmental benefits starting from the current state (green) as well as environmental benefits starting from compliance with the IED (blue). Left: undiscounted. Right: with an adjusted discount rate of 1.94%.*

It must be further noted that these comparisons presented in figures 6 and 7 would be even more in favor of fully implementing the appropriate abatement technologies if one could calculate the abatement costs starting from the hypothetical case where Greek plants were already compliant with the IED. However, this is not feasible since the abatement technologies which would have achieved IED compliance are unknown and, hence, it is not possible to assess the additional abatement technologies that need to be installed or the upgrade measures that need to be implemented in order to achieve compliance with the BREF.

Summary and conclusions

In this report we have first presented the current state of Greek plants in terms of SO_2, NO_x and dust emissions. We then applied the EEA methodology to estimate the damages of not complying with the new BREF emission limit values which can also be viewed as the benefits for the environment and public health from achieving full compliance with the BREF. Two cases were considered. In the first case the benefits were estimated starting from the current state, which is fully known from the official emissions data obtained from the Ministry of Environment and Energy. In the second hypothetical case, it was assumed that all plants comply with the less strict IED limits. The benefits were then compared with the costs of installing and operating appropriate abatement technologies for the five lignite plants which are included in Greece's TNP. The comparison centered around the lignite plants included in Greece's TNP (Ag. Dimitrios I-II, Ag. Dimitrios III-IV, Ag. Dimitrios V, Megalopoli A and Megalopoli B) since the sixth plant included in the TNP (Meliti I) is already compliant with the new BREF regarding emissions from the three main pollutants, and the other existing lignite plants in Greece (Amyntaio I-II, Kardia I, Kardia II, Kardia III and Kardia IV) all have a limited lifetime derogation and are expected to retire in the in the imminent future due to the exhaustion of the 17.500 hours they are entitled according to article 33(1) of the IED.

It was found that the environmental benefits are greater than the abatement costs both for each plant separately as well as overall, even if the starting point is a significant improvement compared to the current state, i.e. compliance of all plants with the IED, and even if the correction factor of 0,7, proposed by Holland (2017) is not applied. In particular, the abatement costs for achieving full compliance with the BREF for the 5 lignite plants amount to €665 million (including the operating costs until 2030), whereas the environmental benefits starting from IED compliance, to €816 million. The benefits are almost 4 times greater (€3,33 billion) if the starting point is the current state, where almost all Greek plants emit far more than what the new BREF allows. These results remain qualitatively the same if one applies an adjusted discount rate of 1,94% (resulting from the subtraction of the estimate of 2,06% by Holland (2017) for the GDP uplift for the next decade from the discount rate of 4% proposed by the European Commission). Furthermore, the comparison between environmental benefits and abatement costs remains in favor of fully implementing the appropriate abatement technologies even if Selective Catalytic Reduction (SCR) is used for the reduction of NOx emissions instead of the less efficient and less expensive SNCR.

It must be further noted that the comparisons between abatement costs and environmental benefits would be even more in favor of fully implementing the appropriate abatement technologies, if one could calculate the abatement costs starting from the hypothetical case where Greek plants were already compliant with the IED, instead of starting from the current state. However, this is not feasible since the abatement technologies which would have achieved IED compliance are unknown and, hence, it is not possible to assess the additional abatement technologies that need to be installed or the upgrade measures that need to be implemented in order to achieve compliance with the BREF.

It becomes therefore clear that none of the five Greek lignite plants are eligible for a derogation of article 15(4) of the Industrial Emissions Directive.

100

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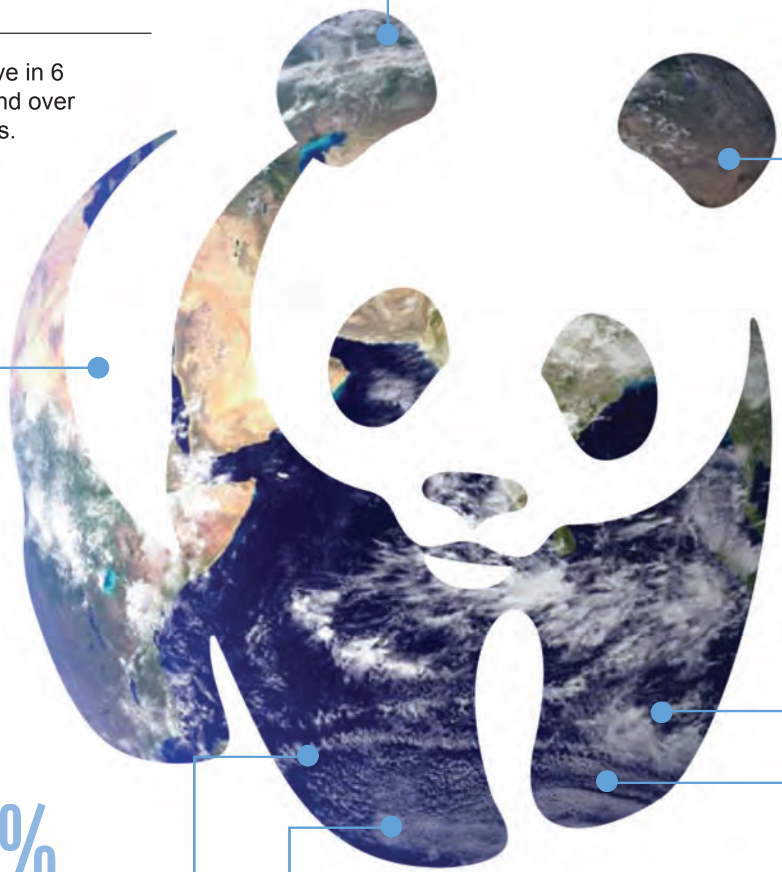

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