Europe's Coal-Fired Power Plants: Rough Times Ahead

Analysis of the Impact of a New Round of Pollution Controls

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By Gerard Wynn, Energy Finance Consultant (gerard.f.wynn@gmail.com) and

and Paolo Coghe, President, Acousmatics (acousmatics@protonmail.com)

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Executive Summary

Overview

In Europe, as elsewhere, coal-fired power plants face growing regulatory pressures to lower greenhouse gas emissions and reduce air pollution tied to heart and lung diseases. Coal-fired power plants also face increasing market headwinds from growing renewable-power capacity and from cheaper natural gas, trends that are developing against a backdrop of stagnating demand.

This report focuses on the impact of a new round of controls on air pollution agreed to by a committee of European Union member states on April 28.

These limits will be the new reference for permitting large thermal power plants in Europe. They follow a "best available techniques reference document" for Large Combustion Plants, or LCP BREF, under the European Union's Industrial Emissions Directive (IED). The LCP BREF (henceforth termed "BREF") includes emissions limits for toxic pollutants including oxides of sulphur (SOX) and nitrogen (NOX), as well as mercury and particulate matter (PM). Large combustion plants will have until 2021 to comply with BREF, meaning that they will have to make investment decisions in the near term, where they have to retrofit pollution control technologies. The BREF limits succeed similar pollution limits agreed to in 2010 and implemented from January 2016.

This study is intended as a first take on the implications of BREF.

Our initial assessment here is of nearly 600 installations, comprising all of Europe's main power plants larger than 50 megawatts thermal capacity (MWth) that burn solid fuels, i.e. coal, lignite (a very low-quality form of coal intermediate between bituminous coal and peat) and biomass. We use 2014 data, from the European Environment Agency, for NOX and SOX emissions by power plant.

We then focus on the most polluting power plants, in terms of SOX and NOX emissions, which we term "low hanging fruit." These 108 installations are some of the largest polluters across the European Union, responsible for the majority of SOX and NOX emissions. They are all at least 300MWth in size, and at least 40% above the relevant BREF limits.

Our research suggests a major opening now for European policymakers and the European electricity-generation industry to embrace BREF as a catalyst for transitioning profitably from coal-fired to clean-energy business models. While the temptation no doubt remains for utilities and energy companies to resist change and defend the old order, the most profitable strategies will acknowledge that the electricity-generation economy across Europe is in transition and that old electricity-generation models are becoming increasingly unviable.

Main Findings

- The BREF emissions limits are expressed as wide ranges, between less and more strict standards. Coupled with various exceptions, these ranges make the new rules more complicated, and in some cases ambiguous. In particular, the IED allows national regulators to consider more lenient limits where they judge that local factors add "disproportionately higher costs compared to the environmental benefits." However, national regulators are permitted to set more lenient limits only following a compulsory public consultation, where any claim for disproportional costs may be disputed. And it should be remembered that BREF can require more stringent emission limits than the upper "backstop" emissions levels. Thus, countries can implement much stricter limits, and implement BREF sooner than 2021.
- BREF represents a material step-change in ambition, compared with the corresponding IED emissions limits currently being implemented. We find that most of our main sample of nearly 600 installations were non-compliant with BREF as of 2014 (the latest data available from the European Environment Agency). This was the case even for the less strict, very upper end of the ranges of allowed emissions. Some 69% of installations were non-compliant with the upper end of the NOX range (175 milligrams of NOX per normal cubic metre of flue gases). Some 43%-61% were non-compliant with the upper SOX range (180-320mg/Nm3).
- We find that our smaller sample of the 108 heaviest and largest (over 300MWth) polluters, those we place in the "low hanging fruit" category, were concentrated in eastern Europe. These totalled 108 installations in 10 countries (6 in eastern Europe and the Balkans, the remainder in the U.K., Spain, Italy and Germany). Poland alone accounted for 45% of the heaviest polluters. We note that there are many more heavy polluters below 300MWth, but our findings and EEA data both show that the largest power plants account for the vast majority of SOX and NOX emissions.
- Six operators accounted for more than half of the "low hanging fruit." They were PGE, Enel/ Endesa, EDF, Tauron, CEZ, Drax and PPC. We assume that this "low hanging fruit" was so far above the upper BREF emissions limits that operators will have to use best-in-class abatement to comply rather than trying to do so through a combination of cheaper, less effective or less tested technologies. Using a range of literature and assumptions, we calculate that best-in-class NOX abatement would add €2-4 per megawatt hour of electricity generation, and best-in-class SOX abatement would add €6-7/MWh. These estimates assumed a 15-year depreciation period, which is an upper estimate. Costs per MWh rise sharply over shorter depreciation periods. We conclude that in the case of older power plants particularly, these costs are prohibitive, and that it would be more rational to close the installations.
- We find that BREF is in line with, or less ambitious than, corresponding emissions limits in China and the United States. Coupled with a continuing, long-term trend of SOX and NOX emissions reductions in Europe, we conclude that BREF is only the latest round of pollution curbs, with more to come, reinforcing our finding that it is more rational for the older, heavier polluters to close now and cut their losses, rather than continue to retrofit.

Implications, by Example, and Recommendations

BREF represents a significant new source of additional financial stress for much of Europe's coal power fleet, which is already under pressure and struggling to remain profitable. BREF will require utilities either to make potentially significant investment and technical changes to much of their coal fleet over a short timeframe—four year—or decide to close plants or significantly restrict their running. The implementation of BREF is therefore of major interest to investors as they consider whether utilities should invest instead in new and emerging opportunities in the European market rather than investing in and defending their increasingly exposed coal assets.

Based on our analysis of the costs to comply, we conclude that, BREF should force a decision to shut down older plants among the "low hanging fruit." In some cases, even though owners of these polluting plants have already invested billions of euros to keep them online, operators should realize they simply cannot catch up with forward-moving regulation. The sooner these plants close, the better.

We apply our findings to four regions and asset owners in particular: **utilities in general in Eastern Europe and the Western Balkans**; **EPH in Germany**; **Enel and Endesa in Spain and Italy**; and **RWE and Uniper in the U.K**.

For each of these four we include brief recommendations on how best to go forward.

- **Utilities in general in eastern Europe and the western Balkans**

  The larger, heaviest polluters are highly concentrated in the eastern half of Europe. Extraordinary examples include Bulgaria's "Bobov dol", which we calculate emits SOX at a rate of 3,671 mg/Nm3, or more than 10 times the limit sanctioned by BREF; Poland's Bełchatów plant, not only Europe's biggest power plant by size, but also one of the biggest emitters, with extremely high levels of SOX emissions (in 2014), which we calculate at a rate of 537 mg/Nm3, or about 70% above the very upper limit sanctioned by BREF; and Greece's Dimitrios ST I-II, with NOX emissions more than 150% above BREF. We acknowledge concerns around the cost of abatement in these countries, some of which have also above-European average electricity demand growth, and the short-term economic implications raised by the retirement of especially large power plants.

  We recommend encouraging better public-health policy, in particular through better support for cleaner technologies in this country. Such an approach would also aid diversification where recent European clean energy investment has been hugely concentrated in western Europe, and especially Britain and Germany.

- **EPH in Germany**

  Energetický a Průmyslový Holding (EPH) is a privately-owned, Czech company that has recently embarked on a strategy of purchasing out-of-favour, fossil fuel assets at distressed prices. Last year, it acquired the Jänschwalde power plant and multiple other German lignite assets from the Swedish utility Vattenfall. While EPH acquired these assets at a knock-down price, we note that BREF may now crystallise the risk in EPH's strategy by increasing the company's exposure to environmental liabilities as governments, investors and individual consumers respond to the problems of air pollution and climate change. Given the age of the six Jänschwalde units (average 32 years), and their level of NOX emissions (19% to 33% above the BREF limit), we conclude that Jänschwalde probably has no economic future post-2021. We therefore question the wisdom of the German state to agree to pay EPH to decommission two of the units in 2022 and 2023 under a standby capacity reserve agreement.

We recommend ending policies that reward ageing and highly polluting power plants, under schemes that subsidize their operators to shut them down.

- **Enel and Endesa in Spain and Italy**

  Enel has repeatedly stated that it intends to transition away from coal, that it will never build another coal plant, and that it will be carbon neutral by 2050. However, behind these bold aims, we find that Enel and its subsidiary Endesa own a large portfolio of highly polluting assets, and in this respect, is second only to Poland's PGE. These Enel and Endesa assets are in Italy and Spain, respectively. In all, the two utilities own some 8% of our "low hanging fruit," or a total thermal capacity of some 15.2 GWth. Standout examples include Enel power plants in Italy, Produzione E Camino 2, and Produzione W Camino 1, which respectively are 60% and 46% above BREF SOX limits. In Spain, Endesa's massive Teruel power plant was 917% above the SOX limit, by our calculations, and 176% above the NOX limit, in 2014.

  We recommend that Enel and Endesa recognize BREF as an ideal opportunity to back up their commitment to a low-carbon transition and to affirm a commitment to close these power plants by 2021.

- **RWE and Uniper in the U.K.**

  The examples of RWE and Uniper in the U.K. show how BREF will cut across the existing strategies of thermal power operators. In Britain, as elsewhere in Europe, utilities with large fleets of coal and lignite power plants are looking to regulated payments—in capacity markets, for instance—to boost their flagging incomes and revive broken balance sheets after years of massive impairments. We note that Uniper's Ratcliffe failed to secure contracts for all its units in the U.K.'s latest capacity auction, underlining the additional headwinds facing coal, besides the cost of pollution control, which include their age, poor flexibility compared with more modern gas, falling gas prices, and coal's higher carbon emissions. Cracks are starting to appear in the strategy of investing in old polluting plant to keep it alive and benefit from government-backed regulatory schemes. Those cracks are driven by economic and technological trends, as well as by targeted policies such as BREF. Increasingly, old coal plants are performing all sorts of acrobatics to keep running, when the demise is approaching, regardless.

  We recommend that utilities stop painting themselves into corners confined by low operating hours and reliance on capacity market auctions and that these companies consider shutting down outdated units rather than sinking more money into them.

Introduction

What is BREF?

BREF stands for "Best Available Techniques Reference (BREF) document. "It refers to the Best Available Techniques (BAT) that large combustion plants must use to improve their efficiency and cut emissions of toxic pollutants such as dioxides of sulphur (SOX) and nitrogen oxides (NOX) under the European Union's Industrial Emissions Directive (IED). SOX is a major contributor to soil and freshwater acidification, and thus damages natural habitats. NOX can react with organic carbons in the atmosphere to form ground-level ozone, a dangerous cause of respiratory diseases. Both SOX and NOX contribute to the formation of secondary particulate matter (PM) in the atmosphere. In Europe, PM and ground-level ozone are the air pollutants most damaging to human health.[1]

BREF is intended to indicate the most effective processes and technologies, technically and economically, to control and reduce pollution. It is a powerful document, because its associated emissions levels (AELs) set the reference emissions levels for permitting large combustion plants (LCP) over 50 megawatts by member state regulators across the EU. These permits determine whether a new power plant can be built, and whether an existing power plant can continue to operate.

On April 28, a committee of European Union member states approved a new round of BAT, with the aim of reducing the environmental impact of large fossil fuel installations. The new BREF standards were developed over the past several years by a Technical Working Group (TWG) nominated by a forum comprising representatives of industry, environmental groups, EU member states and the European Commission. The updated standards take into account the development over the past decade of new technologies and processes to curb pollution. The Industrial Emissions Directive requires that national regulators apply these new conditions within four years—in this case by 2021.[2]

How Do the New BREF Emissions Limits Compare With Present Regulations?

Table 1 below summarises the new BREF emissions limits for existing power plants burning solid fuels, namely coal, lignite and biomass, focusing on NOX and SOX. Emissions limits are expressed in milligrams per normal cubic metre (mg/Nm3). In this report, we do not consider new power plants, given that very few new coal and lignite power plants will be built in Europe over the next five years and that this number is dwarfed by the size of the existing fleet.

BREF is replacing present emissions limits under the Industrial Emissions Directive (IED), which came into force in January 2016. These standards in turn replaced limits under the Large Combustion Plant Directive (LCPD). Table 1 compares the prospective 2021 BREF limits with the IED's 2016 emissions level values (ELVs).

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[1] http://www.eea.europa.eu/publications/reducing-air-pollution-from-electricity
[2] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:334:0017:0119:en:PDF

BREF standards are expressed in ranges, between least and most stringent. These ranges reflect specific conditions at individual power plants, such as age, location, climate, fuel quality, and so on, which will affect the achievable emissions reductions. The ranges also reflect the choice of abatement technology. However, there are exceptions (called derogations) which may widen these ranges, or release power plants from meeting BREF limits altogether:

- Many BREF emissions limits do not apply where power plants operate below 1,500 hours annually.
- Permits can be made more lenient than the BREF limits where national regulators are convinced that geographical location and or technical characteristics of a particular power plant add "disproportionately higher costs compared to the environmental benefits."[3]
- Limits are weaker in more specific circumstances, for example according to the age of a power plant, or its fuel type.

Table 1. Selected BREF Emissions Limits, Compared with the IED, Existing Power Plants Over 300mwth

Pollutant	Fuel and Capacity	BREF-AELs, from 2021	IED ELVs, from 2016	Selected BREF Exceptions
		Upper Annual Average	Mthly Average	
		mg/Nm3	mg/Nm3	
NOX	Coal (fluidised bed combustion, FBC) > 300 MWth	175	200	Does not apply where power plants operate < 1,500hr/year. The upper end is 175 mg/Nm3 only for FBC boilers put into operation before 2014.
	Coal (pulverised combustion, PC) > 300 MWth	150	200	Does not apply where power plants operate < 1,500hr/year
	Lignite > 300 MWth	175	200	The upper end is 175 mg/Nm3 only for lignite-fired PC boilers put into operation before 2014.
	Biomass & peat > 300 MWth	150	200	Does not apply where power plants operate < 1,500hr/year. The upper limit is 160mg/Nm3 where the plant was put into operation before 2014.

[3] http://ec.europa.eu/environment/industry/stationary/ied/legislation.htm

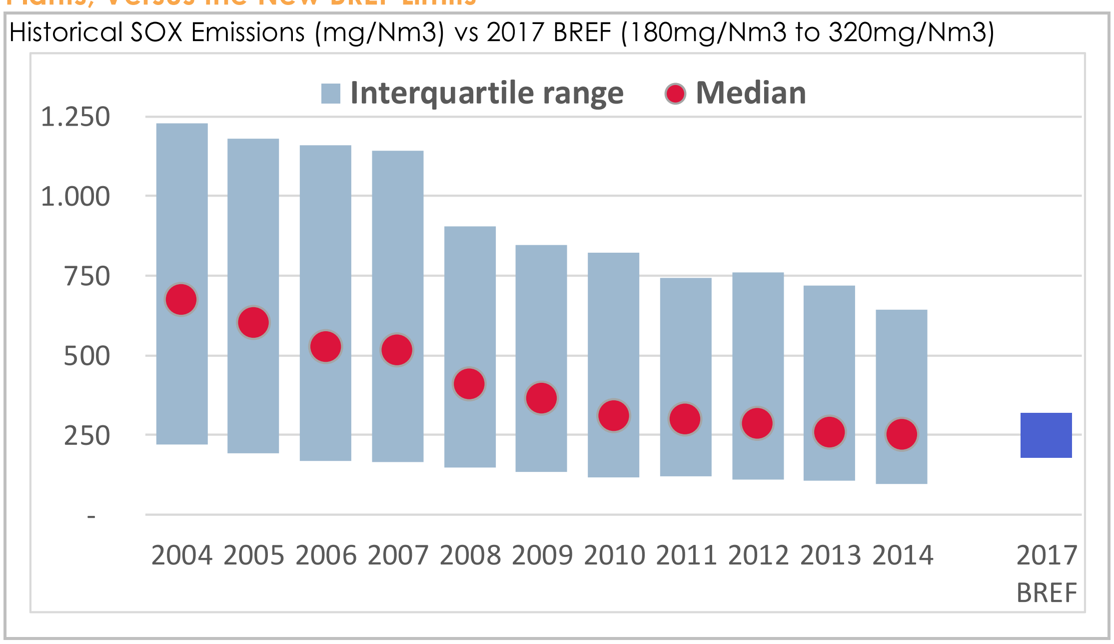
SOX	Coal & lignite FBC > 300 MWth	180	200	Does not apply where power plants operate < 1,500hr/year. The lower end of the range can be achieved by using high-efficiency wet FGD. Where specifically designed to fire indigenous lignite fuels, and can demonstrate that cannot achieve these BAT-AELs for techno-economic reasons, the upper limit is 200 mg/Nm3 for new FGD systems, and 320 for an existing FGD.
	Coal & lignite PC > 300 MWth	130	200	Does not apply where power plants operate < 1,500hr/year. The lower end of the range can be achieved with the use of low-sulphur fuels in combination with the most advanced wet abatement system designs. Where specifically designed to fire indigenous lignite fuels, and can demonstrate that cannot achieve these BAT-AELs for techno-economic reasons, the upper limit is 200 mg/Nm3 for new FGD systems, and 320 for an existing FGD.
	Biomass > 300 MWth	50	200	Does not apply where power plants operate < 1,500hr/year. The upper limit is 100mg/Nm3 in the case of fuels with a higher sulphur content.

Figure 1 below compares the new BREF limits with historical power plant emissions. The figure uses data from the European Environment Agency (EEA), which covers the vast majority of combustion plants in Europe. We focus here exclusively on power plants in the database that burn coal and lignite, with a few units additionally burning biomass. We do this because these plants are responsible for the vast majority of SOX and NOX emissions. This sample corresponds to about 600 installations.

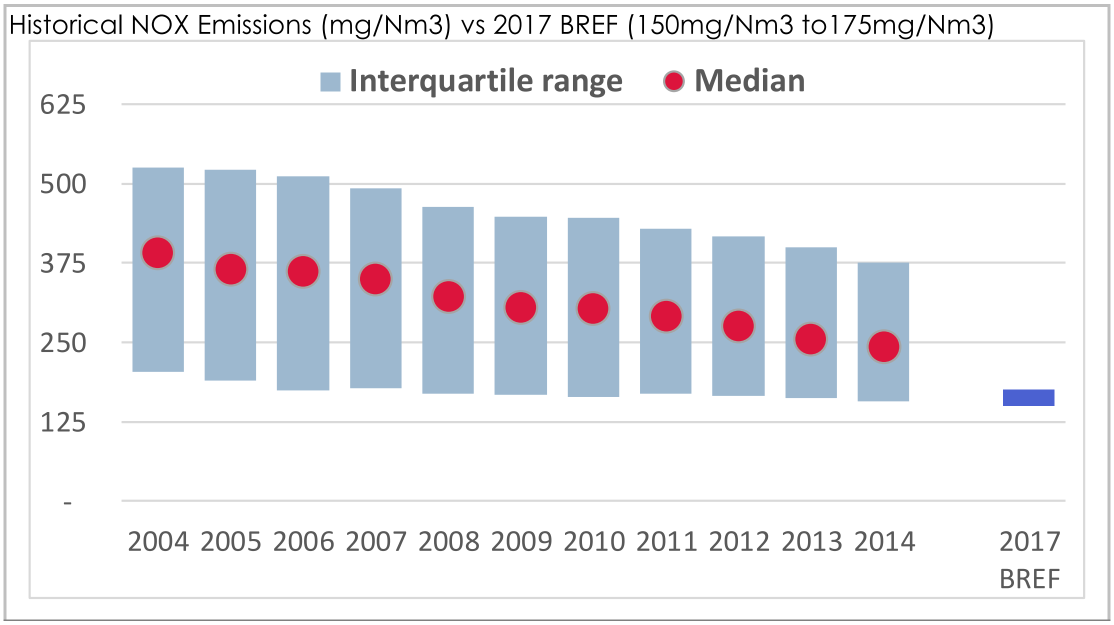
We generated estimates for emissions rates (mg/Nm3) from these EEA data (see Appendix for methodology) and compared these with the new BREF limits (in blue). For SOX BREF, the blue bar represents the most generous upper limits of 180-320 mg/Nm3, depending on the type of power plant (see Table 1). For NOX, we use the upper range of 150-175 mg/Nm3. Power plant emissions are represented by the grey bars. The top of the grey bars shows the emissions level below which 75% of power plants lie (the top quartile), and the bottom shows the emissions level below which 25% of power plants lie (bottom quartile). Thus, each grey column represents half of the data. There is a further 25% of most polluting installations above the top of the bars, and a further 25% of least polluting plants below the bottom. Median values are shown by the red dots.

First, Figure 1 shows a clear trend for falling emissions rates over the past decade, especially for SOX emissions, whose median fell 63% over the period. The NOX median fell 38%. The consistent downward trend underlines continuing regulatory pressure and development in abatement technology which seems likely to continue. BREF is very unlikely to be the last word on pollution limits for coal and lignite power plants. We see that the most polluting power plants, represented by the top quartile, have improved the most. The bottom quartile shows that the best performing 25% of power plants have been compliant for several years with the BREF limits, which are only due from 2021. But more than half the power plants are still more polluting than the BREF standard, as of 2014.

Figure 1. Historical SOX and NOX Emissions (mg/Nm3), European Coal and Lignite Power Plants, Versus the New BREF Limits



Source: Own elaboration on EEA data; Note: 2017 BREF represents a range of 180-320 mg/nM3, depending on technology.



Source: Own elaboration on EEA data; Note: 2017 BREF represents a range of 150-175 mg/nM3, depending on technology.

How Many Power Plants Are Compliant With BREF?

Using the same data for emissions rates by large combustion plants, we can calculate the proportion that were compliant with the upper range of the new BREF limits. We note that in 2014 there were some 592 large combustion plants that corresponded to our definition of coal and lignite power plants. Of these, 69% were above the upper BREF limit for NOX in 2014. Meanwhile, some 43% exceeded the upper SOX emissions rate for lignite power plants of 320 mg/Nm3. Some 61% exceeded the upper SOX limit of 180 mg/Nm3 for coal power plants.

Our Approach: Structure of This Report

Following this introduction, in Section 2, we describe how we selected power plants for our analysis. Our starting point was a power plant emissions database published by the EEA, describing "an extract of the most relevant data" for large combustion plants affected by the Industrial Emissions Directive.[4] These data provide detailed, annual energy input and pollutant emissions for 3,447 installations across Europe from 2004 to 2014. We focus solely on combustion plants, almost entirely from the power sector, excluding other important sectors like iron and steel or oil refining. We focus further on those power plants that burn solid fuels, namely coal, lignite or biomass.[5] We exclude from our working sample power plants fired by either liquid or gaseous fuels. We recognize that both of these are contributing to emitting SOX and NOX. However, these are either less polluting than solid fuels (as is the case with natural gas), or are more polluting than solid fuels (as is the case with oil and oil products), but – given a much lower utilization rate – are a smaller source of NOX and SOX in the environment. This initial selection by sector and by polluting impact, leaves us with about 600 observations for 2014, the most recent year available in the EEA database. Each one of

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[4] http://www.eea.europa.eu/data-and-maps/data/lcp-2

[5] We adjust pollution rates to be a weighted average of solid fuels used; most plants use only one solid fuel (generally coal or lignite), but there are of course cases where a plant uses coal together with material amounts of biomass.

these observations from the EEA database represents therefore a coal or lignite power plant – active in 2014.

Section 3 describes how we use this set of installations to focus on large, heavy polluters. To identify such polluters, we first convert the EEA emissions data, which is tonnes of NOX and SOX emissions annually, to rates of emissions, in milligrams per standard cubic metre (mg/Nm3) of flue gases. This is a necessary step, since the BREF limits are expressed in mg/Nm3. We convert the EEA data, using published EEA and other benchmarks for the expected flue gas volume produced from burning different types of fuel, including biomass, lignite, coal, natural gas, blast furnace gases and liquid fuel.[6] The most polluting power plants stand to be the most affected by the new standards, being forced to choose between the best-in-class abatement, which is also likely to be the costliest, or to shut down. We select these "low-hanging fruit" power plants as those at least 40% above the BREF NOX and/ SOX upper emissions limits. We list these plants and their owners in the Appendix of this report.

In Section 4, we analyse the cost impacts of the BREF limits. We use published data from a variety of sources to assume costs for different abatement technologies. These cost estimates include considerations such as capital and operating cost, depreciation period, cost of capital and the enforced outage time to retrofit, with a resulting foregone revenue. We calculate cost per unit of power generation.

In Section 5, we draw implications from these costs for our "low-hanging fruit." In Section 6, we take a further step by identifying the owners of the heaviest polluters. We draw conclusions for particular utilities in particular countries, focusing on utilities in general in eastern Europe; EPH in Germany; Enel and Endesa in Spain and Italy; and RWE and Uniper in the U.K.

[6] http://www.eea.europa.eu/publications/reducing-air-pollution-from-electricity

Selection of Power Plants for Analysis

The EEA database provides historical emissions data from 2004 to 2014. These data show average SOX and NOX emissions of all large combustion plants have decreased materially, as a result of both environmental regulations and technological advances. The EEA data show that index SO2 levels in 2014 stood at 26, and NOX levels were equal to 53 (vs 100 in 2004 for both).

The EEA data show also that, as of 2014, the largest combustion plants in Europe (500 MWth or higher in size) were the ones most responsible for emissions. While these accounted for only 24% of large combustion plants, by number, they were responsible for around 80 % of all large combustion plant SOX, NOX and dust emissions. To put it another way, in 2014, half of all emissions came from just 42 and 82 plants for SOX and NOX, respectively.[7] This clearly points to a problem that is concentrated rather than pervasive.

Therefore, when choosing which installations to focus on in our analysis, we targeted some of the largest, most polluting plants, and we focused on plants that burn almost exclusively coal and lignite (labelled as "other solid fuels" in the EEA database), with a few units additionally burning biomass.

In order to achieve clarity and to bring attention to specific classes of polluters, we subdivided our sample of about 600 installations across Europe by type of solid fuel used (coal and lignite), and then according to their emissions of specific pollutants (SOX and NOX). In this way, we arrived at four lists of power plants.

Initial Observations

Below we provide a visualization of our final sample by fuel burned and by pollutant. Our results echo the EEA findings, confirming that both for coal and for lignite most SOX and NOX pollution comes from a few "bad apples" rather than being a system-wide problem. For example, we found that for coal-fired plants, the largest 150 units in our sample (ranked by decreasing flue gas volume – a proxy for fuel burn) are responsible for nearly 90% of all SOX emissions and almost 80% of all NOX emissions in DE, ES, IT, PL and the UK. Likewise, for lignite-fired plants, we found that the largest 50 units (again, ranked by decreasing flue gas volume) emit approximately 75% of all SOX emissions and 86% of all NOX emissions in the markets we examined.[8]

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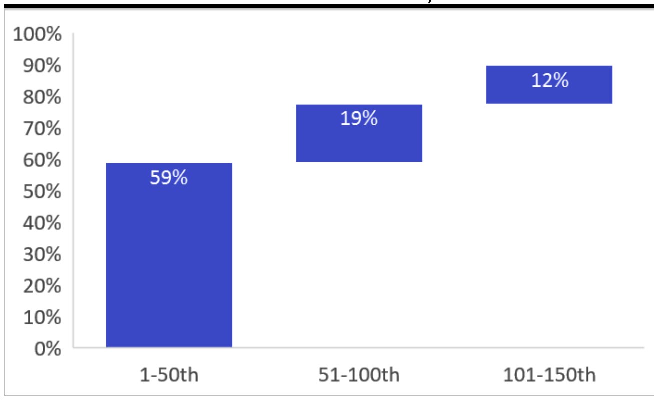
[7] http://www.eea.europa.eu/data-and-maps/indicators/emissions-of-air-pollutants-from/assessment

[8] It should be noted that – especially for lignite – the EEA database considers units belonging to single power plants separately (eg, Jänschwalde Blocks A-F figure as six plants in our analysis). Thus, the actual degree of concentration stands to be even higher.

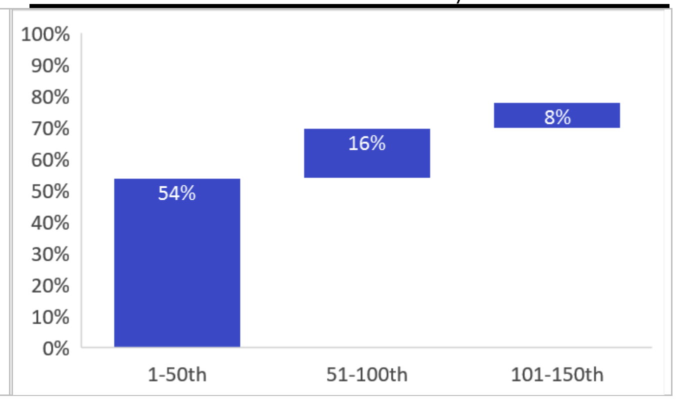
Figure 2. Percent of SOX and NOX Emitted by the Largest 150 Coal & Largest 100 Lignite Power Plants

Coal – Percent of SOX Emitted by Plant Size



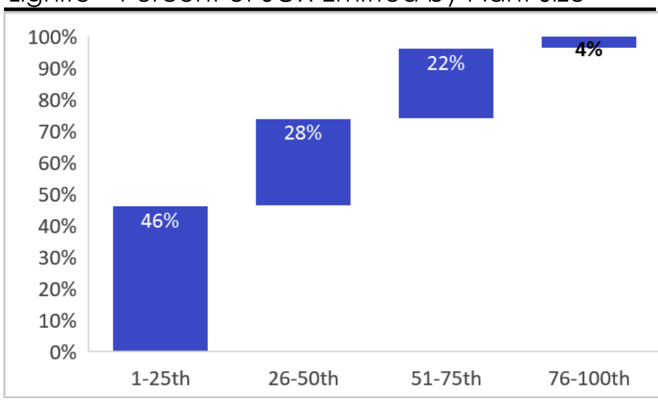
Source: Own elaboration on EEA data; Note: Plants ranked by yearly flue gas volume, top to bottom

Coal – Percent of NOX Emitted by Plant Size



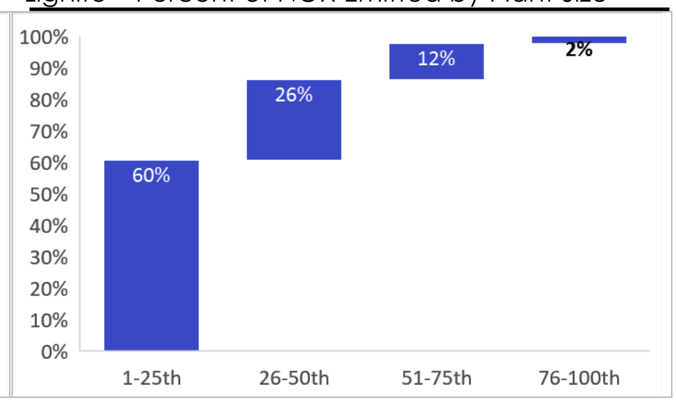
Source: Own elaboration on EEA data; Note: Plants ranked by yearly flue gas volume, top to bottom

Lignite – Percent of SOX Emitted by Plant Size



Source: Own elaboration on EEA data; Note: Plants ranked by yearly flue gas volume, top to bottom

Lignite – Percent of NOX Emitted by Plant Size



Source: Own elaboration on EEA data; Note: Plants ranked by yearly flue gas volume, top to bottom

Our Methodology for Selecting Europe's "Low-Hanging Fruit"

In this section, we focused on the EEA's cumulative amount of pollution, in tonnes. Our next - step was to examine these most polluting plants to find the ones least compliant with BREF. This is the most meaningful way to examine the plants' pollution, given that the owners of these plants and the politicians in respective countries will be the ones facing tough decisions as a result of the new standards. In particular, plant owners will have to make some difficult commercial and financial choices in the near future.

BREF: The Power Plants Most Affected

Europe's "Low-Hanging Fruit": A Closer Look at Who's Polluting

In this section, we consider the impact of BREF on the European fleet of coal and lignite-fired power plants. We calculated the rates of emission of SOX and NOX, per unit of flue gas volume, for each power plant in the lists of coal and lignite power plants described in Section 2. We then compared these emissions rates with the new, more stringent BREF standards. We excluded any unit smaller than 300MWth, and applied the upper limit of the new BREF limits – 175 mg/Nm3 for both coal and lignite NOX; and 180-320 mg/Nm3 for coal and lignite SOX, respectively.[9]

We focus here on plants that are well above (at least 40% above, in our analysis) the new emissions limits. In other words, it would be difficult to characterise these plants as "borderline" polluting. Given the new standards, these plants are all well above the mark. We find that some 108 installations in total correspond to this definition of "low-hanging fruit." These installations are listed in the Appendix.

We restricted our geographical focus to a selection of member states based on size (installed MW) and prevalence of fuel used in the country. For coal we looked at Germany, Spain, Italy, Poland and the U.K. UK. For lignite we analysed Bulgaria, the Czech Republic, German, Greece, Poland and Romania.[10] In this way we were able to analyse different polluters covering a wide geographic area and comprising some of Europe's largest markets.

We illustrate our findings in four bubble charts. For all bubble charts in the rest of the paper, each bubble in each chart represents a single power plant. The different colours of the bubbles indicate different countries. The bubble size shows its annual flue gas volume in 2014. Power plant bubbles neatly lie on what we term the exceedance line. The Y axis measures by what percent a given plant (bubble) exceeds the BREF limits. The X axis represents our calculated plant emission rates (mg/Nm3). The right-hand charts zoom into data on the left-hand charts (only the size of Y and X axis changes between the two charts).

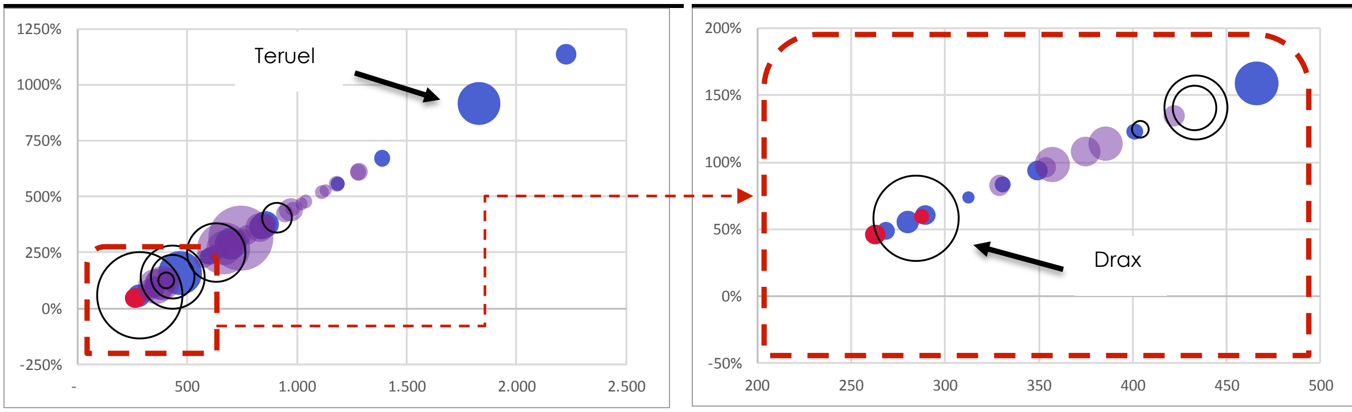
SOX Emissions: Coal Power Plants

First let us consider SOX emissions, examining coal and then lignite. The left-hand coal chart below illustrates coal-fired SOX pollution rates. The two blue bubbles on the upper right represent two Spanish plants, Teruel I-II-III and Anllares I (see Appendix). Teruel's SOX 2014 emission rate is almost 10 times the limit for plants of similar size. What is worse, Teruel's bubble size indicates that it is a very large and active plant in 2014.

[9] These ranges are taken from the BREF limits detailed in Table 1
[10] We also looked at lignite plants from HU, SK and ES.

Figure 3. Coal Power Plant SOX Emissions Vs BREF Limit

Coal – % Above SOX Limit Vs Actual Emissions | Coal – % Above SOX Limit Vs Actual Emissions



Source: Own elaboration on EEA data; Notes: bubble size represents yearly flue gas volume. Red detail area is portrayed in chart on right hand side.

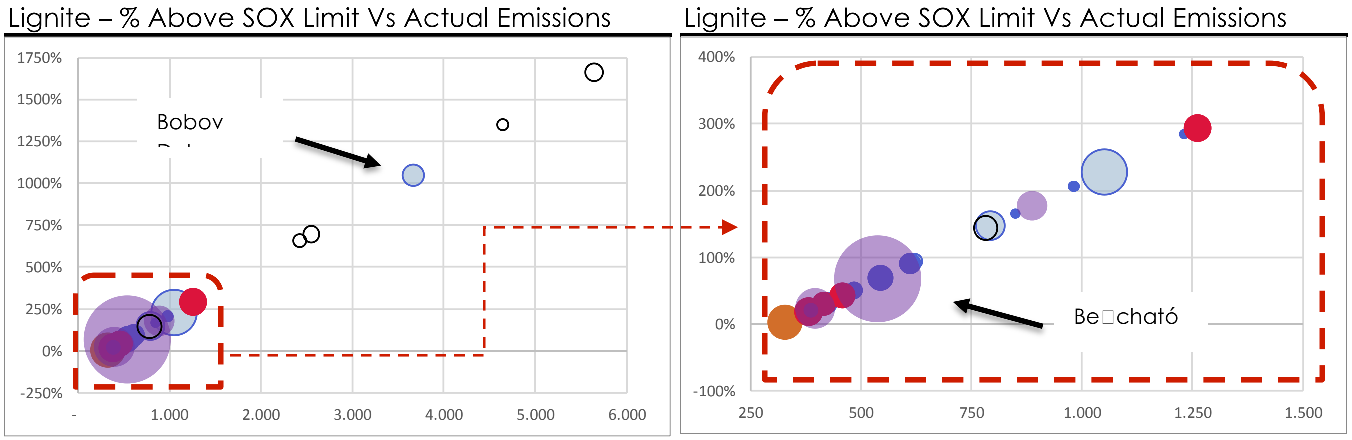
Source: Own elaboration on EEA data; Notes: Plants ranked by yearly flue gas volume, top to bottom. Chart is a detail of the same on the left-hand side.

Focusing more closely on the lower part of the left-hand bubble chart, the right-hand chart zooms in on plants that pollute at a lower rate, but happen to be very large in size. First, let us consider Drax, a U.K. power plant represented by a black circle and annotated in the chart. Drax was "only" emitting at a rate about 60% above the new BREF standards in 2014. But Drax's size makes it a very large polluter. Of course, we acknowledge that Drax has already taken steps to improve its emission profile, trying to reduce its carbon emissions by converting to biomass. Sadly, this may not be enough to warrant Drax's inclusion into the pool of SOX-compliant plants, absent some additional investment. Second, we note the prevalence of mauve bubbles in both charts. These represent coal plants located in Poland and are prevalent both in terms of number of high SOX polluters (32 out of 57) and in terms of rate of pollution, with rates that range from 80% to 600% above the new limits.

SOX Emissions: Lignite Power Plants

Now let us consider lignite SOX. A brief look at the charts below shows that some of the really "ugly" power plants in terms of lignite-related SOX pollution are in Poland and Southeast Europe (with Greece – red bubbles, Bulgaria – azure, and Czech Republic – blue, all contributing to the problem). The azure bubble in the chart below left represents "Bobov dol", a sizable Bulgarian power plant that we calculate emits SOX at a rate of 3,671 mg/Nm3, more than ten times the limit sanctioned by BREF. It is impossible to miss Bełchatów, the giant Polish plant, represented by the largest mauve bubble and emitting extremely high amounts of SOX (in 2014), at a rate of 537 mg/Nm3, about 70% above the limit sanctioned by BREF. For lignite SOX emissions, there are even more extreme outliers than among coal SOX emissions.

Figure 4. Lignite Power Plant SOX Emissions Vs BREF Limit



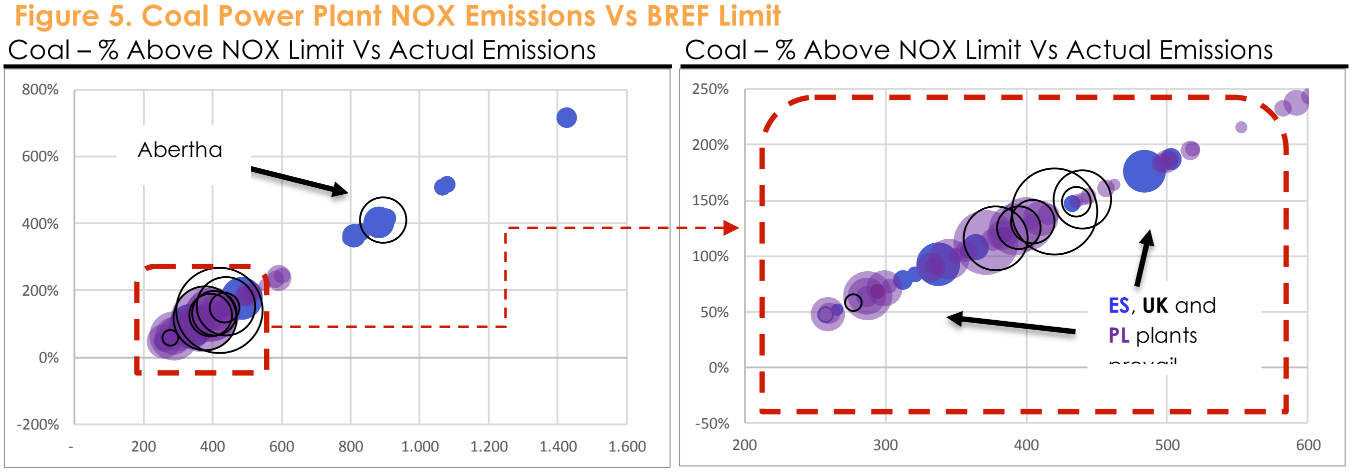
Source: Own elaboration on EEA data; Notes: bubble size represents yearly flue gas volume. Red detail area is portrayed in chart on right hand side.

Source: Own elaboration on EEA data; Notes: Plants ranked by yearly flue gas volume, top to bottom. Chart is a detail of the same on the left-hand side.

NOX Emissions: Coal Power Plants

Now let us turn to NOX emissions, again examining coal first and then lignite. The coal chart below left illustrates coal-fired NOX pollution rates. The blue bubbles on the upper right of the chart represent several sizable Spanish plants with NOX emission rates that range between four and six times above the limit for plants of similar size. The even larger black-rimmed bubble represents Aberthaw, a power plant in Wales. We can see from this data visualization that it is no wonder that such plants have been singled out by environmental movements.[11]

Figure 5. Coal Power Plant NOX Emissions Vs BREF Limit



Source: Own elaboration on EEA data; Notes: bubble size represents yearly flue gas volume. Red detail area is portrayed in chart on right hand side.

Source: Own elaboration on EEA data; Notes: Plants ranked by yearly flue gas volume, top to bottom. Chart is a detail of the same on the left-hand side.

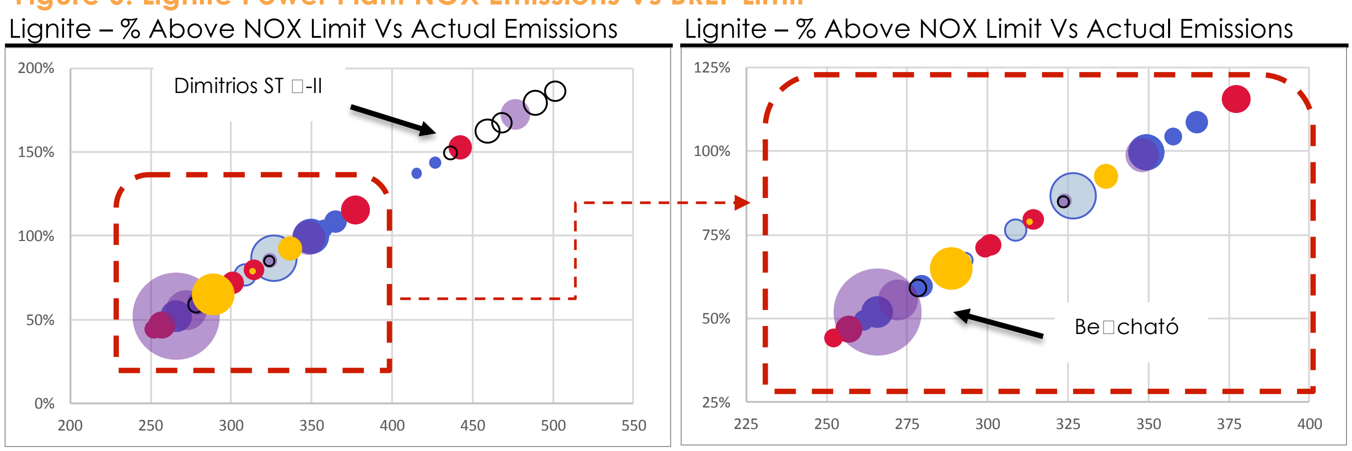
[11] Regarding comments on Aberthaw, see recent article: http://www.independent.co.uk/environment/coal-fired-power-station-aberthaw-rwe-barry-thousands-deaths-blame-10-million-uk-state-subsidy-a7566836.html

In the right-hand chart we find plants that pollute at a lower rate, but still anywhere from about 50% to 250% above BREF standards for NOX emissions, and that are especially large. Again, note the prevalence of mauve (Poland) and blue bubbles (Spain). These represent coal plants in eastern and western Europe and make up the vast majority of our coal NOX plant list (51 out of 65 heavy polluters), with the remainder of polluters mainly located in the U.K.

NOX Emissions: Lignite Power Plants

Turning to lignite NOX, the charts are more colourful, betraying a more widely spread problem. For example, Greece is a contributor with its plants (red bubbles) peppered along the exceedance line, and with NOX emission rates in the range of 50-150% above BREF standards (Dimitrios ST I-II being the largest emitter). We also note the prevalence of plants from Poland (mauve), Czech Republic (blue) and Bulgaria (azure). Orange bubbles denote plants in the "other" geographic category, containing large lignite plants from Spain, Hungary and Slovakia. When we zoom into the data on the right-hand size, we recognize Bełchatów, the largest mauve bubble, nearly five times larger than the next largest Polish lignite plant in our list, Turow. Turow emitted NOX (in 2014) at a rate of 266 mg/Nm3, about 50% above the limit sanctioned by BREF.

Figure 6. Lignite Power Plant NOX Emissions Vs BREF Limit



Source: Own elaboration on EEA data; Notes: bubble size represents yearly flue gas volume. Red detail area is portrayed in chart on right hand side.

Source: Own elaboration on EEA data; Notes: Plants ranked by yearly flue gas volume, top to bottom. Chart is a detail of the same on the left-hand side.

In conclusion, these are some of the biggest polluters in the European Union, responsible for the vast majority of SOX and NOX emissions. Many of these plants are the ones furthest from meeting the new BREF emissions limits. It should come as no surprise, therefore, that the operators of some of these plants have already said they plan to shut these units down (e.g. Endesa's Teruel) by 2021.[12] Such statements support the validity of our findings. They also add compelling weight to arguments that operators of comparable power plants on the list should make similar commitments.

[12] http://www.platts.com/latest-news/coal/barcelona/spain-reduces-thermal-coal-burn-23-in-2016-to-26672055

BREF: Retrofit Costs

Operators of existing, non-compliant power plants will have to choose either to retrofit or close them by 2021. In this way, BREF will add to existing headwinds for coal plant operators, including reforms to the EU emissions trading scheme (EU ETS), and higher carbon prices, as well as continuing growth in renewables and resulting low wholesale power prices. Utilities acknowledge that BREF will disadvantage coal power plants. For example, the Czech electric utility ČEZ, recently stated that it was planning to sell one of its most efficient coal power plants, at Počerady, partly as a result of BREF, stating that coal power plants without captive mines will be increasingly unprofitable.[13]

Retrofit Options

Non-compliant operators have various abatement techniques to choose from to meet BREF. These are briefly described and compared.

NOX abatement technologies can be divided into during-fuel combustion ("primary"), which aims to produce fewer NOX emissions in the first place, and after combustion ("secondary"), which aim to remove NOX from power plant flue gases. Primary techniques include low-NOX burners (LNB) and lignite fuel drying. LNB works by optimising combustion in the boiler, for example, reducing excess air. Secondary technologies include selective catalytic reduction (SCR), and the cheaper, less effective, selective non-catalytic reduction (SNCR), as well as NOX oxidation. SCR creates an ammonia/flue gas mixture, which is passed over a vanadium/titanium catalyst. SCR has a lifespan of up to 15 years, while the catalyst needs replacing every three to five years. SNCR uses direct ammonia injection, without use of a catalyst. In both SCR and SNCR, NOX gases are reduced to harmless molecular nitrogen. SNCR and LNB can be used in tandem with a compact SCR to avoid the cost and power plant downtime associated with a full-scale SCR. However, this application requires more frequent catalyst upgrades, and is less tested. NOX oxidation involves oxidation of NOX in the flue gas to a soluble product which can be removed using scrubbers.

SOX abatement options include: wet flue-gas desulphurisation (FGD); dry and semi-dry FGD; spray dry absorber (SDA) and circulating fluidised bed (CFB) scrubbers. Most of these approaches have in common the use of a limestone or other absorbent, which reacts with SOX, to form various precipitates. Wet and semi-dry FGD are proven, reliable systems for removing SOX, but also the costliest. Other scrubbers may be more cost-effective on smaller coal power plants where a single unit is sufficient.

Comparing the effectiveness of abatement technologies is an inexact science, given that it depends on highly specific factors such as fuel type; power plant size and efficiency as well the design of the plant itself; and the choice and quality of abatement technology. Nevertheless, some general conclusions can be made:

- NOX Abatement

[13] http://byznys.ihned.cz/c1-65656750-blizi-se-konec-uhelne-energetiky-prodej-elektrarny-pocerady-dava-smysl-rika-clen-predstavenstva-cez-cyrani

- SCR is the best in class option to reduce NOX emissions, achieving results below 100mg/Nm3, comfortably within BREF limits for existing power plants (150-175). However, it has a high capital cost and requires considerable space, which may complicate a retrofit. The latter may be aided by fitting an after the flue gas scrubber in a "tail end" location. In addition, SCR is reported to be problematic for mid-merit, flexible operation.14 That may be a serious drawback, given more frequent ramping up and down is likely to be an increasing role for thermal power, to balance variable wind and solar power.
- The capital cost of SNCR is less than that of SCR, but on its own is insufficient to meet BREF standards. Various combinations of SNCR with multiple other approaches could meet the BREF limits at lower capital cost. However, many of these combinations are untested, and operating costs may be higher. For example, a compact SCR (which treats less flue gas, and so is cheaper) can run alongside SNCR and LNB, but is relatively untested and has higher operating costs, with more frequent SCR catalyst replacement. LNB can run alongside lignite drying and NOX oxidation. But NOX oxidation has its own problems, including a high-energy input, and a requirement for costly wet FGD.

- SOX Abatement
  - Wet FGD is the best-in-class technology for SOX removal, but also the most expensive. It is marginally more expensive than semi-dry FGD.
  - Scrubbers such as spray dry absorber (SDA) and fluidised bed scrubbers (FBS) can achieve up to 95% desulphurisation. They cost a fraction of wet FGD on smaller coal power plants where only a single unit is required, below 600 MW capacity. They are limited to a lower sulphur content fuel, at up to 2.5% for SDA and 3.5% for FBS.

Retrofit Costs

Table 2 shows our calculated, total retrofit cost per unit of power generation (MWh), for power plants running at two representative load factors: 30% and 70%. Load factor is the actual generation of a power plant as a percentage of its theoretical maximum. Table 2 also shows the effectiveness of the different technologies at reducing NOX and SOX emissions, compared with the new BREF emissions limits.

Us per MWh cost estimates are based on quotes in the literature for capital and operating cost of retrofit, plus various assumptions for depreciation and cost of capital, and estimates for foregone revenues during installation, when the power plant must be shut down ("outage time"). These cost assumptions are briefly described:

- The cost of abatement will vary hugely according to site-specific factors, including the size of power plant. We focus on estimates for larger power plants, as they are the focus of this report. Where several cost estimates are available in the literature, we generally take a mid-point or median.

[14] https://www.gov.uk/government/publications/coal-and-gas-assumptions

- We note potentially large discrepancies between real 2017 and nominal historical prices, and sometimes poor clarity regarding which is quoted in the literature.
- We assume that only advanced, tested abatement technologies will be able to meet the BREF NOX and SOX limits. We do not consider less tested, emerging alternatives, which may be less costly.
- We note that retrofit costs at existing power plants are often far higher than abatement costs at new-build power plants. This report exclusively focuses on existing power plants.
- We do not account for the fact that site space restrictions may make retrofits of flue gas desulphurisation or selective catalytic reduction impractical or impossible at some power plants.
- We use an estimate for the outage time required to retrofit SCR at about six months, to calculate resulting forgone revenues. Given a lack of data, we assume two months for all other technologies. Outage time will depend on the complexity of the project, and the degree to which operators can fit a retrofit intervention into its regular overhaul/ inspection schedule. In the U.K., for example, coal-fired power plants typically have a four-year cycle of major overhauls (with outage time of 10 weeks) and minor overhauls every two years (outage time three to four weeks).15
- We use a straight-line method to amortise today's capital costs of retrofit and foregone revenues over 15 years. We discount these future cash flows at a weighted average cost of capital (WACC) of 5%. The depreciation period is from estimates in the literature for SCR. In reality, this is probably an upper estimate, and especially so for other technologies. This may make our calculations per unit of power generation under-estimates.
- To calculate foregone revenues, we assume a wholesale power price of €40, based on a basket of continental European spot prices at the time of writing.16
- We generally do not account for the value of gypsum, a potentially saleable waste product of sulphur scrubbers.

Table 2. Comparing the Environmental Effectiveness and Cost of Abatement Technologies

Pollutant	Technology	Load Factor, %	Emissions Rate, mg/Nm3	BREF Limit, mg/Nm3	Capital Cost, €/MW	Cost per Unit Power Generation, €/MWh
NOX	SCR	30%	<100	150-175	€ 138,000	€ 3.30
		70%	<100	150-175	€ 138,000	€ 1.91
	SCR Upgrade	30%	100-200	150-175	€ 27,600	€ 0.90
		70%	100-200	150-175	€ 27,600	€ 0.63

[15] https://www.gov.uk/government/publications/coal-and-gas-assumptions
[16] http://www.epexspot.com/de/

	SNCR/ SCR Hybrids	30%	<100 – 150	150-175	€ 120,000	€ 3.97
		70%	<100 – 150	150-175	€ 120,000	€ 2.76
SOX	Wet FGD	30%	<100	130-320	€ 300,000	€ 7.00
		70%	<100	130-320	€ 300,000	€ 5.99
	Wet FGD Upgrade	30%	100	130-320	€ 22,500	€ 2.13
		70%	100	130-320	€ 22,500	€ 3.90
	SDA	30%	100-500	130-320	€ 90,000	€ 3.62
		70%	100-500	130-320	€ 90,000	€ 5.11
	CFB	30%	50-200	130-320	€ 110,000	€ 3.37
		70%	50-200	130-320	€ 110,000	€ 3.88

Sources: Parsons Brinckerhoff,[17] the International Energy Agency,[18] and a Joint Research Council (JRC) draft published last year of Best Available Techniques.[19]

Wait or Hurry: Wider Considerations of Cost

When considering the costs discussed above, utilities will also weigh the value of investing immediately to retrofit non-compliant units versus adopting a "wait and see" approach, either to invest later, or to close them.

By hurrying, a utility will avoid a potential bottleneck in abatement, and/or resulting price inflation. In addition, the utility will avoid sanctions or outages if it fails to retrofit in time, i.e. by 2021. Where the utility opts for the most advanced abatement technology, it will also send a clear signal to investors that it is adopting a best-in-class approach. By down-timing to retrofit now, a utility may also avoid the present low wholesale power price, low-margin environment. The value of adopting a "wait" approach would include avoiding a deteriorating power price environment, if that materialised, and to benefit from a potential retrospective relaxation in the new BREF standards, for example, as a result of industry lobbying.

We argue that – if a power plant operator decides to retrofit – a "hurry" approach (akin to buying insurance) has greater value than a "wait" one (which would be based on value coming from the option to delay). This is chiefly because the probability of future events related to environmental regulation is skewed toward outcomes that would increase costs. In other words, just about anything that happens is going to increase cost of compliance, barring some kind of "Trump" event with a potentially single-handed effacing of environmental regulation.

We conclude that not only do operators of coal and lignite power plants have to consider potentially costly retrofits, but that they would do well to be aware that any delay in this investment may raise these costs further.

[17] https://www.gov.uk/government/publications/coal-and-gas-assumptions
[18] http://www.iea-coal.org.uk/site/2010/blog-section/blog-posts/how-to-improve-the-performance-of-lignite-power-plants?
[19] http://eippcb.jrc.ec.europa.eu/reference/BREF/LCP_FinalDraft_06_2016.pdf

Implications of Abatement Cost: To Close or Retrofit?

Factors to Consider

Utilities will compare the investment returns to retrofit versus the returns to shutting a coal or lignite power plant down—and investing in new, cleaner, more modern generation.

In the case of retrofit, costs will include the abatement costs outlined above in the previous section. Our review of costs indicates that such NOX abatement will add about €2-4/MWh to the cost of power generation, over an assumed 15-year depreciation period. SOX abatement will add about €6-7/MWh. Where power plants exceed both limits, operators will have to install both, adding €8-11/MWh to generation costs. These costs range from 5% to 30% of expected European wholesale power prices in 2021 (€40), a highly significant burden.

Furthermore, the cost of capital for a utility to finance a retrofit may be affected by an increasing reluctance among some banks to finance coal-fired power. Utilities may consider the financing environment for coal generation already quite poor. Being BAT compliant could make the difference in securing financing. At the same time, considerations will arise on how additional CAPEX needed to meet BAT might impact the value of equity. In other markets (e.g. the U.S.), the recycling of capital via securitization has been an attractive cost mitigant for utilities, and especially so for utilities with a high cost of capital and a large, potentially stranded asset base.

Returns from retrofitting will take into account the expected remaining lifespan of a power plant, and its likely profitability, considering expected load factor and power prices. Utilities will want to weigh the prospective regulatory environment and the likelihood of further pollution and other environmental controls further down the road.

Regarding age, coal and lignite-fired power plants are typically designed for a 25- to 40-year lifespan. Age will affect retrofit economics in several significant ways. First, age critically determines the time period over which an operator can generate a payback on abatement investment. Second, the greater the age of the power plant, the greater the potential need for additional investment in life extension work to ensure the integrity of the whole power plant for an extended period.[20] We assume away these costs as a part of the regular, operating and maintenance costs associated with running a coal or lignite-fired power plant, and therefore beyond the scope of this study. Third, older power plants will already be disadvantaged, running less efficiently, and therefore less frequently than their equivalent, more modern peers, meaning they are more likely to be financially stranded by any additional costs.

Regarding further policy risk, most polluting power plants should take seriously the prospect of further regulatory change. In Europe, this will likely include changes to limits on NOX and SOX pollutants regulated under BREF and other regulatory changes that will affect coal and lignite power plant profitability via carbon pricing. The latest BREF standards are unlikely to be the last word on pollution limits. Table 3 compares the BREF standards to be introduced from

[20] https://www.gov.uk/government/publications/coal-and-gas-assumptions

2021 with those already in place in China and the United States, according to the World Resources Institute.[21] The table shows that European standards due by 2021 are in some cases less ambitious than those already in place in China.

Table 3. A Comparison of Thermal Power Pollution Limlts, China, U.S. and Europe

Pollutant	Power Plant Status	Emissions Standard, mg/Nm3		
		China	United States	Europe (BREF)
NOX	New	100	117	85
	Existing (built in the last 20 years)	100-200	117-160	150-175
SOX	New	100	160	75-320
	Existing	200-400	160	130-320
Dust	New & Existing	30	23	5-12

EEA emissions data show how power plants have improved over time, with a similar implication that the regulatory trend is for ever-more ambitious and therefore restrictive emissions standards. Figure 1 above, in the Introduction of this report, shows the NOX and SOX emissions trends for European power plants since 2004.

The prospect for further regulatory change would be expected to drive coal and lignite power plant operators either to sweat their assets, before closing them in 2021, or to invest in the more expensive, best-in-class abatement options to hedge against further rule changes. As the IEA states: "Given the implementation of tighter international NOx limits … it could be beneficial to consider retrofit technologies that may be adapted to achieve the stricter limits of <100 mg/m^3 on existing plants."

Another prospective regulatory change in Europe would affect the emissions trading scheme, potential change that implies carbon price rises. All else being equal, these increases would result in a deterioration of net cash flows of operational margins ("clean dark spreads") to coal and lignite power plants.

Beyond Compliance?

Highly polluting power plants that are furthest from BREF compliance, as identified in Section 3 above, are most likely to have to install best-in-class abatement technologies, rather than stop-gap solutions or upgrades. We conclude from the consideration of costs in Section 4 that these best-in-class technologies will be SCR or an SCR/SNCR hybrid for NOX abatement, and wet FGD for SOX abatement.

In the light of the costs in these technologies, we conclude that most of our "low-hanging fruit" are so far beyond compliance that they should be closed instead of being forced to go for the most expensive of retrofits and continue operating beyond 2021. Consider, moreover,

[21] http://www.chinafaqs.org/files/chinainfo/China%20FAQs%20Emission%20Standards%20v1.4_0.pdf

that some of these plants have already installed pollution prevention systems in order to be compliant with existing regulation. Closing these plants would be a classic win-win outcome, in which society is immediately better off in terms of achieving lower pollution, capital is re-circulated through the economy, while plant stock is renewed and becomes more environmentally friendly.

In the case of power plant retirement, costs would include the balance sheet impairment to write off the remaining, undepreciated value of a power plant. Returns would include alternative investments such as developing renewable power. In the case of these most-polluting power plants, most are old and therefore fully depreciated, with zero write-off cost.

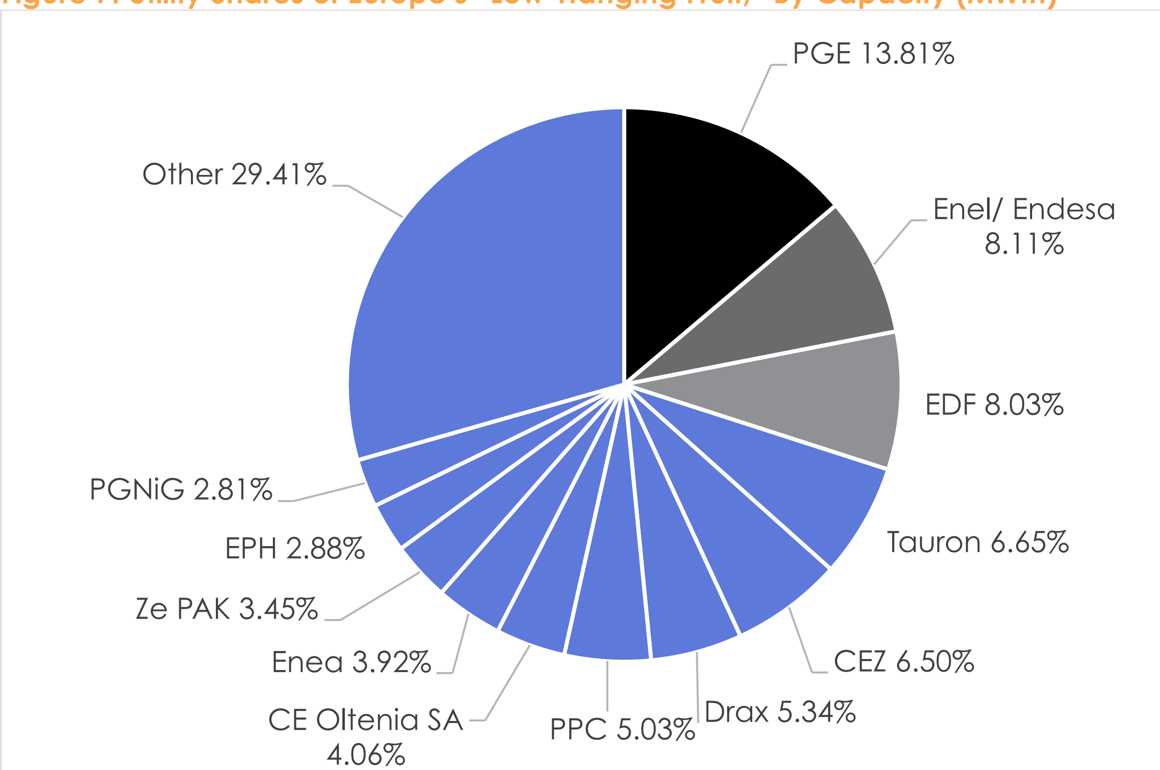
Implications for Utilities, Investors and Policymakers (and Recommendations)

Who owns Europe's most-polluting power plants?

We identified, in Section 3 above, some 108 installations whose NOX and/ or SOX emissions we found to be more than 40% above the relevant BREF limits. We termed these the "low-hanging fruit", as installations that it made most sense to close, both from a public health and environmental perspective. In this section, we discuss the implications for the owners of these installations. The power plants and their owners are listed in the Appendix of this report.

Figure 7 below aggregates these 108 installations by owner. The category "Other" accounts for owners with fewer than 5 GWth of most polluting assets, and for power plants retired since 2014, but still part of the EEA database.

Figure 7. Utility Shares of Europe's "Low-Hanging Fruit," By Capacity (MWth)



In the rest of this section, we focus on the following groups of owners: utilities in general in eastern Europe; EPH in Germany; Enel and Endesa in Spain and Italy; and RWE and Uniper in the U.K.

Poland and the Balkans: Public Health Versus Abatement Costs

Our review of the "low-hanging fruit" showed that some of the really "ugly" power plants in terms of SOX and NOX emissions are in central and southeastern Europe, including in Poland, the Czech Republic, Greece and Bulgaria. As Figure 7 shows above, of the 12 top owners, by capacity of "low hanging fruit," 10 are based in eastern Europe.

Many of these polluters are lignite power plants. Regarding lignite SOX emitters in eastern Europe, notable cases include "Bobov dol," a sizable Bulgarian power plant that we calculate emits SOX at a rate of 3,671 mg/Nm3, more than 10 times the limit sanctioned by BREF. Bełchatów, the giant Polish plant, emits extremely high amounts of SOX (in 2014), at a rate of 537 mg/Nm3, about 70% above the limit sanctioned by BREF. Regarding lignite NOX emitters, significant polluters are in Greece, with emission rates in the range of 50-150% above BREF standards (Dimitrios ST I-II being the largest emitter), as well as in Poland, where we call out Bełchatów, for its size, and Turow, which emits NOX (in 2014) at a rate of 266 mg/Nm3, about 50% above the limit sanctioned by BREF. There are also lignite power plants with NOX emissions rates more than 40% above the BREF limit in the Czech Republic and Bulgaria.

We note that there appears to be a choice for these east European operators and legislators. Either these countries/plants are given more leeway to meet the targets, and western European power plants are treated more firmly, to maintain the same pan-European ambition. Or all are treated equally. Given that NOX and SOX have especially local health impacts (compared with the global climate impact of carbon emissions, for example), we believe the latter constitutes a better solution. That said, if East European countries feel they are being pushed into a GDP growth versus human health dilemma, then the EU must resolve this with financial support. Greater EU support for clean energy investment in eastern Europe makes sense from a cost-effectiveness perspective, given that Britain and Germany alone accounted for more than two thirds of all European renewables investment from 2013-2015.

Germany: EPH's Strategy to Buy Distressed Lignite Assets

Energetický a Průmyslový Holding (EPH) is a privately-owned Czech-based company formed in 2009 by the financial firms J&T Group and PPF Group. According to the company's website, the vast majority of the company (94%) is owned by a single individual, Daniel Křetínský.[22] EPH operates in the Czech Republic, Slovakia, Germany, Italy, the U.K., Poland and Hungary. The group comprises more than 50 companies. Its power generation business is almost entirely based on fossil fuels. In addition, it has operations in coal extraction; gas, electricity and heat distribution; energy trading; and gas storage and supply. In aggregate, its companies employ nearly 25,000 people.[23]

In recent years, EPH has become a specialist in purchasing out-of-favour, fossil fuel assets at distressed prices. In 2016, the company acquired a portfolio of lignite mining and power generation assets from the Swedish state-owned utility Vattenfall.[24] The generation assets included three power plants in the Lausitz region of eastern Germany, Jänschwalde (units A, B, C, D, E and F), Boxberg (Units N, P, Q and R) and Schwarze Pumpe (units A and B), plus part

[22] http://www.epholding.cz/en/shareholder-structure/
[23] http://www.epholding.cz/en/profile/
[24] http://ieefa.org/wp-content/uploads/2016/09/A-Foundation-Based-Framework-for-Phasing-Out-German-Lignite-in-Lausitz_September2016.pdf

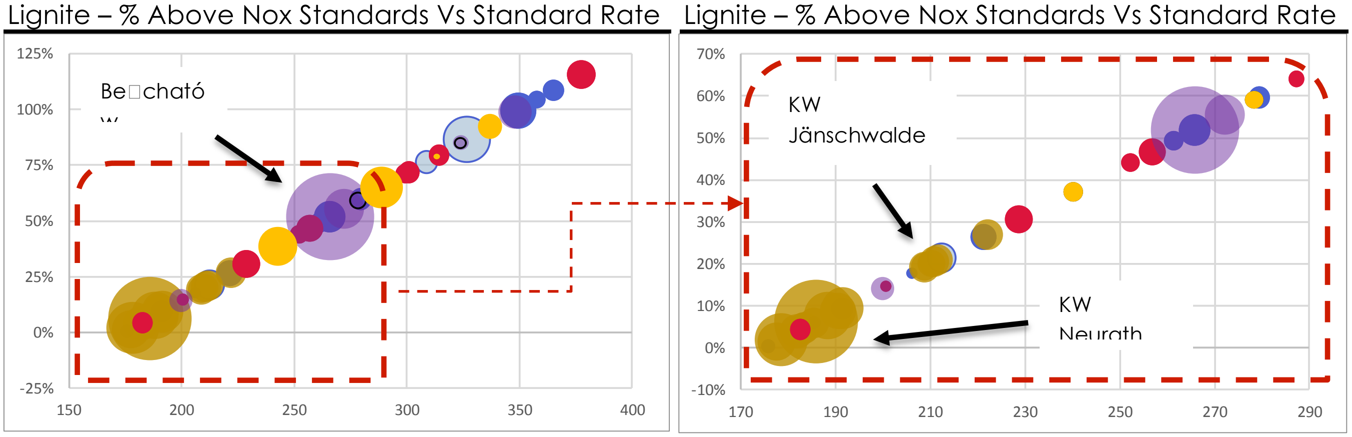
ownership in the Lippendorf plant near Leipzig. These power plants had a combined net electrical capacity of 7.6 GW. EPH paid Vattenfall an undisclosed nominal sum, and in return received the assets plus €1 billion in cash, and substantial mine rehabilitation liabilities. In addition, EPH will receive cash which will accrue to Janschwalde units E and F for their 34% share (by capacity) of a €1.6 billion standby capacity reserve. EPH will receive these funds in return for mothballing the two units in 2018 and 2019, and closing them in 2022 and 2023.[25]

Vattenfall gave the assets away on the understanding that they had little strategic value as some of the most polluting assets in Europe. As Vattenfall Chairman Lars Norstrom said, explaining the rationale for the sale to EPH: "The financial reasons are obvious, given our views on current and expected price development and market conditions. We see some additional regulatory and financial risks, such as additional costs for (mine) re-cultivation; additional cost for restructuring; additional, maybe costly, negotiations with different stakeholders in Germany; and an increasing scepticism among financial institutions regarding CO2-heavy industries."[26] EPH presumably aimed to profit by buying the assets at distressed prices. After all, the power plants were highly cash generative, located at the pithead, thus benefiting from their own cheap fuel source.

We illustrate the environmental opportunity from closing the Janschwalde units with the scatter plots below. These follow the same approach as those used in Section 3 to identify "low-hanging fruit," except that here we relax the requirement that they are at least 40% in excess of the new BREF limits. Nevertheless, we can see from the y-axis in the charts below that all these power plants are still non-compliant with the BREF NOX limit of 175mg/Nm3. In the left-hand chart below, we compare NOX emissions at German lignite power plants (gold bubbles), with European power plants exceeding the BREF standards in 2014. In the right-hand chart, we zoom in more closely to the German power plants, including the Janschwaldes units. We might label KW Neurath as a "borderline" case, given it is in the bottom left corner of each chart, with the smaller polluters. But what about other German lignite plants? The NOX emissions rates of the six Janschwalde units range from 209 mg/Nm3 to 233 mg/Nm3, or from 19% to 27% above the BREF limit.

Figure 8. Comparing NOX Emissions Between German And Other European Power Plants

Lignite – % Above Nox Standards Vs Standard Rate | Lignite – % Above Nox Standards Vs Standard Rate



Source: Own elaboration on EEA data; Notes: bubble size represents yearly flue gas volume. Red detail area is portrayed in chart on right hand side.

Source: Own elaboration on EEA data; Notes: Plants ranked by yearly flue gas volume, top to bottom. Chart is a detail of the same on the left-hand side.

[25] http://ec.europa.eu/competition/state_aid/cases/261321/261321_1762503_157_2.pdf
[26] http://energyandcarbon.com/coal-giveaway-vattenfall-risks-pr-problem/

In Janschwalde, EPH has acquired six units with a net electrical generating capacity of 2.8 GW, whose average age will be 36 years when BREF enter into force. Given that all these units far exceed the BREF NOX limits, we conclude that EPH would have to invest in best in class abatement to meet these limits. That is notwithstanding Vattenfall spending €2 billion since 1996, just to stay within present pollution controls.[27] Such historical expenditure has reduced the power plant's SOX emissions, but it is now about to fall foul of new NOX limits. BREF shows how ageing fossil fuel power plants are constantly overtaken by stricter targets, and must invest to stand still. Our cost estimates for SCR NOX abatement indicate that this would add €2-4/ MWh of power generation, if depreciated over 15 years. A shorter depreciation period of five years, to reflect the advanced age of the Janschwalde power plants, would raise these abatement costs to €7-12/ MWh.

We conclude that the Janschwaldes units probably have no economic future post-2021. We recommend that the German state reconsider its agreement to pay EPH to decommission two of the units in 2022 and 2023 under the standby capacity reserve. We recommend against rewarding ageing and highly polluting power plants under similar schemes in the future.

EPH's strategy of targeting distressed assets is working in the short term. Since its acquisition of the Vattenfall assets, power prices have risen, and EPH has profited handsomely. However, the company now approaches a crossroads in 2021, either to lose a large chunk of its European generation, or else must invest heavily in ageing power plants only to preserve market share. BREF crystallises the risk of EPH's strategy, increasing its exposure to environmental liabilities exactly when these are growing, as governments, investors and consumers respond to the problems of air pollution and climate change.

Italy & Spain: Enel's Commitment to a Coal Phase-Out

Enel stated in a "Capital Markets Day" presentation in November 2016 that improvement in its environmental footprint was a key industrial strategy, including reductions in emissions of NOX, SOX and CO2.[28] The presentation also outlined Enel's plans to close some 5.6 GW of coal plants in 2019, indicating that a transition away from coal was part of that strategy. Such messages follow a statement in 2015 that the company was committed to a medium to long-term withdrawal from coal,[29] and the company's pledge never to build another coal plant and to be carbon neutral by 2050.[30]

When we consider the list of power plants that are furthest in excess of BREF limits, and therefore will struggle most to comply, we note that Enel and its subsidiary Endesa are major players. Enel accounts for 8% of these most polluting power plants by capacity, a share second only to Poland's PGE. Relevant assets include: Enel's Teruel, Compostilla, Litoral and Alcudia in Spain, and Enel's Pontes and the Produzione E Camino 2, and Produzione W Camino 1 power plants in Italy. Endesa's power plants, among the "low-hanging fruit," are all far in excess of both NOX and SOX limits, indicating that they are furthest from compliance. Our cost analysis in Section 4 indicated that combined SOX and NOX abatement would add €8-11/ MWh to generation costs if depreciated over 15 years, and far more if depreciated

[27] https://www.leag.de/fileadmin/user_upload/pdf-en/fb_kw_jaewa_10seiter_engl_2013.pdf
[28] http://strategy2016.enel.com/files/Enel_Group_2016_Capital_Markets_Day.pdf
[29] https://www.enel.com/en/media/press/d201503-senior-management-of-enel-and-greenpeace-meet.html
[30] https://www.theguardian.com/environment/2015/oct/22/former-foes-greenpeace-and-energy-giant-enel-stand-together-in-low-carbon-push

over shorter periods. We conclude that BREF represents an ideal opportunity for Enel and Endesa to back up their commitment to a low-carbon transition, and we recommend a commitment to close these power plants by 2021.

UK: RWE and Uniper: Throwing Good Money After Bad

The examples of RWE and Uniper in the U.K. show how BREF will cut across the existing strategies of generating companies, challenging their emerging business strategies. In the U.K., as elsewhere in Europe, utilities with large fleets of coal and lignite power plants are looking to regulated payments – for example under capacity markets – to boost their flagging incomes and revive broken balance sheets after years of massive impairments. The trouble is that BREF will add to their costs further, threatening to bump them back to square one. The added costs imposed by BREF will add to investments that these generators have already made, to these existing power plants, even as they increasingly struggle to compete, even in the capacity markets that they were betting on.

Two examples of such ageing plant in the U.K. are Uniper's 2GW Ratcliffe-on-Soar coal plant, opened in 1968, and RWE'S 1.5GW Aberthaw coal plant, which would celebrate its 50th anniversary in 2021. Both plants have invested in pollution abatement in recent years. Ratcliffe invested £1 billion in 2008. Aberthaw has invested £230 million in SOX abatement, adding Flue Gas Desulphurisation (FGD) to cut its sulphur emissions by 95%. More recently, RWE decided to invest in a retrofit of the "Low NOX boiler technology" at Aberthaw, expecting to reduce the station's emissions of Nitrogen Oxides (NOX) by more than 60%. In Q2 2016 RWE announced further investments in NOX emissions improvements to all units. Richard Little, station manager at Aberthaw, recently declared in a Bloomberg interview: "We believe that with plant efficiencies, modifications, and changes to our operating regime, the station can continue to support security of supply into the 2020s."[31] Our analysis shows that this may be inadequate; we calculate Aberthaw had NOX emissions 411% above the BREF limit (in 2014).

Both Ratcliffe and Aberthaw face additional headwinds, besides pollution controls. Their age places them beyond their original intended design life. As a recent government report said of ageing coal plants in general: "While stations have been upgraded and modified over time to extend life and improve efficiency (including: refurbishing boilers, upgrading turbines and installing equipment to clean up flue gas), *they are nevertheless relatively inefficient by modern standards and require continued investment*."[32] *(emphasis added)*. To make matters worse, economic conditions have deteriorated for the coal fleet in the last couple of years. Gas-fired generation – coal's main generating competitor at the margin – has benefitted from a sharp and sustained drop in international gas prices and has consistently seen its operational margins increase at the expense of coal generation. Coal generation is also less flexible than its main competitor.[33] The level of penetration of low carbon generation continues to increase, consistent with the U.K. government's policy ambitions. According to a recent government report, "[coal] stations are therefore likely to close in the near term as further investment becomes necessary to remain operational, to comply with strengthened

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[31] https://www.bloomberg.com/news/articles/2016-09-21/rwe-to-comply-with-eu-ruling-on-emissions-at-aberthaw-coal-plant

[32] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577080/With_SIG_Unabated_coal_closure_consultation_FINAL__v6.1_.pdf

[33] In fact, coal-fired generation needs longer than its gas-fired counterparts to ramp up thus taking longer to respond to changes in demand. This shortcoming is exacerbated at times of low generation from intermittent renewable sources.

pollution standards and as policies to encourage decarbonisation of electricity generation take effect."[34]

Given these market conditions, emission standards, and the characteristics of the plants themselves – the owners of such coal-fired power stations will probably find it increasingly difficult to justify the case for such investments. One may ask what has allowed the owners of these two plants to be so keen on keeping them online and to continue with ambitious capital expenditure programs as opposed to retiring them? Uniper made it clear to investors, as recently as March 2017, that Ratcliffe's owner is betting on capacity markets for a lifeline. Last summer, Uniper's management stated that it believed it was "well positioned to benefit from schemes remunerating flexibility and back-up value" and saw "upside from upcoming and potential capacity markets".[35] In its FY 2016 financial statements report, Uniper's CEO said: "Uniper's power stations in the United Kingdom were successful in the latest capacity market auction, which is for October 2020 to September 2021." A December 2016 press release by the company provided more details: "During this period, they will help ensure the reliability of the U.K. electricity system during periods of *peak demand*. […] The clearing price £22.50 per kilowatt is for keeping capacity available and is paid regardless of how often the power stations are actually dispatched. […]. All seven of Uniper's power stations in the United Kingdom, which together comprise almost 6 gigawatts of capacity, were awarded agreements in this year's auction." As recently as Q1 2017, the company continued to mention reliance on capacity payments in connection to its FY 2017 earnings outlook. [36] RWE's Aberthaw has also successfully competed in the U.K.'s recent Capacity Market Auctions, winning contracts requiring the plant to be available to generate until at least September 2020.

But coal's participation in capacity markets is under threat. In a recent speech from November 2016, Secretary of State Greg Clark stated that the aim of his policy "is to harness the potential of storage, demand side response and other technologies to create the most efficient, most productive electricity system in the world."[37] The so-called "Early Auction" in January 2017, for capacity to be delivered in 2017/18, saw tentative steps in this direction.[38] First, it has cleared at £6.95 per kilowatt per year – by far the lowest price in any of the auctions so far. While this can be seen as a sign that the taxpayers will be paying less to have additional generation capacity on the sides to make sure that the lights stay on, it is important to note that such a low price also implies that there is not – after all – such a shortage of capacity for the winter ahead. Second, as in previous auctions, the Early Auction was dominated by existing generation, but the cumulative share awarded to distributed flexible technology (battery storage and DSR) is on the rise. Combined-cycle gas turbine (CCGT) plant won most contracts (22GW or 41% of awarded capacity agreements, with 1.5GW losing out) and coal/biomass won the next largest share (10GW or 19%, with 1.5GW losing out). Finally – and most tellingly – two of the four units at Uniper's Ratcliffe-on-Soar (totalling 1GW) dropped out of the auction and have not been awarded additional capacity agreements. What is more, a prospective UK coal phase-out may disqualify coal power plants from the UK capacity market in the near future.[39]

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[34] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577080/With_SIG_Unabated_coal_closure_consultation_FINAL__v6.1_.pdf
[35] UNIPER – Sustaining value in challenging times – Capital Markets Story, July 2016
[36] UNIPER – 2016 Full year results – released 09 March 2017
[37] https://www.gov.uk/government/speeches/greg-clark-speech-at-energy-uk
[38] National Grid runs two annual auctions; one to procure capacity for four years ahead and the other for the next winter.
[39] https://www.gov.uk/government/consultations/coal-generation-in-great-britain-the-pathway-to-a-low-carbon-future

Cracks are starting to appear in the strategy of investing in old polluting plant and keeping them alive in government-backed regulatory schemes. Those cracks are driven by economic and technological trends, as well as by targeted policies such as BREF. As part of the IED, large combustion plants must apply Best Available Techniques (BAT), and it should be remembered that BAT can require more stringent emission limits than the "backstop" emissions levels contained in the IED. Increasingly, old coal plants are performing all sorts of acrobatics (blending types of coal, changing running regime, relying on capacity markets etc.) to keep running, when their demise is approaching, regardless.[40] Investing in technology will only delay the inevitable, while continuing to impose on the environment and having a negative impact on social health.

Investors should be wary. In the U.K., their questions should include: how long will it take for Aberthaw – or any other old plant in a similar situation – to install new NOX abatement? Will the required investment make sense in the context of a UK coal phase-out by 2025? How many hours will the power plants run? How many more million-man hours will be spent to retrofit the units? Investing in pollution prevention and control is generally a good idea, but not in the absolute. Coal generators are painting themselves into a corner of low operating hours while relying on capacity-market auctions. We recommend that operators of the plants in question now consider shutting down these units rather than investing more in them. It is time to unlock the capital frozen in these old coal plants.

Going forward, we recommend that the U.K. government hold to its promise to "harness the potential of storage, demand side response and other technologies to create the most efficient, most productive electricity system in the world." This promise implies "reassessing regulation which is biased against storage and aggregators so they can compete on a level playing field with large-scale generation" to create "an energy system which is *reliable and clean and cheap*" [41] *(emphasis added)*.

If current policies are successful, the U.K. will become increasingly reliant on a much wider range of technologies, including storage, DSR and interconnection to keep the lights on – not just on existing, large-scale, fossil fuel generation. We recommend that this lesson not just be taken in the U.K. Policymakers all across Europe would do well to make sure future power systems can be *reliable and clean and cheap*. We encourage investors in capital markets to question strategies and investments that – based on a worsening economic environment for coal-fired generation and further weakened by forthcoming (just approved) BREF standards – already appear not fit for purpose.

[40] For example, at Aberthaw Welsh coal has to be blended with imported low sulphur coal to meet standards. One cannot have it all: Welsh jobs are important, but so is the health of the Welsh people – it would be prohibitive in cost terms to have it all, if at all achievable technically.

[41] https://www.gov.uk/government/speeches/greg-clark-speech-at-energy-uk

Appendix

EEA Database

This report is based on data from the EEA for emissions of air pollutants from large combustion plants, and it uses 2014 data, except for historical trends, where the entire 2004-2014 database is used.[42] The report identifies some 108 installations, each greater than 300 MWth and burning solid fuels, whose NOX and/ or SOX emissions are more than 40% above upper BREF limits. These installations are therefore likely to have to retrofit the costliest, best-in-class abatement. These power plants, termed "Low Hanging Fruit", are the focus of this study, as those most challenged by BREF, and most likely to close as a result.

List of Power Plants Defined as "Low-Hanging Fruit"

The **108 Most Polluting Installations** are listed in the table below.

Plant Owner	Mwth	Plant Name (EEA Database)	Country	Fuel	Applicable Pollutant	
A2A	418	A2A A (Camino 1)	Italy	Coal	Nox	
Będzin	495	Elektrociepłownia "Będzin" S.A.	Poland	Coal	Nox	Sox
Brikel	510	TPP "Brikel"	Bulgaria	Lignite	Nox	Sox
Bulgarian Energy Holdings	4,312	TPP "Maritsa Iztok 2"	Bulgaria	Lignite	Nox	Sox
CE Oltenia SA	946	S.E Craiova Nr.1	Romania	Lignite	Nox	Sox
CE Oltenia SA	1,756	S.E Rovinari Nr. 1	Romania	Lignite	Nox	
CE Oltenia SA	1,756	S.E Rovinari Nr. 2	Romania	Lignite	Nox	Sox
CE Oltenia SA	1,578	SE Turceni Nr.2	Romania	Lignite	Nox	
CE Oltenia SA	1,578	S.E Turceni Nr. 3	Romania	Lignite	Nox	
CEZ	596	Elektrarna Ledvice 2	Czech	Lignite	Nox	Sox
CEZ	614	Elektrarna Melnik II	Czech	Lignite	Nox	Sox
CEZ	1,356	Elektrarna Melnik III	Czech	Lignite	Nox	
CEZ	2,937	Elektrarna Prunerov 2	Czech	Lignite	Nox	Sox
CEZ	2,830	Elektrarna Pocerady, A.S.	Czech	Lignite	Nox	
CEZ	1,270	- Elektrarna Melnik I	Czech	Lignite	Nox	
CEZ	562	Lokalita Trmice	Czech	Lignite	Nox	Sox
CEZ	638	Elek Chorzów "ELCHO" Sp. Z O.O.	Poland	Coal		Sox
CEZ	1,376	Elektrownia Skawina S.A.	Poland	Coal	Nox	Sox
CIECH Soda Polska	394	Elektrociepłownia Inowrocław	Poland	Coal	Nox	Sox

42 http://www.eea.europa.eu/data-and-maps/data/lcp-2

CIECH Soda Polska	406	Elektrociepłownia Janikowo	Poland	Coal	Nox	Sox
Consortium Energia MK	1,300	TPP "Bobov Dol"	Bulgaria	Lignite	Nox	Sox
Dalkia Łódź	537	Elektrociepłownia Zakład EC2	Poland	Coal	Nox	Sox
Dalkia Łódź	1,172	Elektrociepłownia Zakład EC3	Poland	Coal	Nox	Sox
Dalkia Łódź	1,160	Elektrociepłownia Zakład EC4	Poland	Coal	Nox	Sox
Drax	10,000	Drax Power Station	UK	Coal	Nox	Sox
EDF	1,821	EDF Kraków S.A.	Poland	Coal	Nox	Sox
EDF	4,712	EDF Rybnik S.A.	Poland	Coal	Nox	Sox
EDF	1,035	Elektrociepłownia Gdańska	Poland	Coal	Nox	Sox
EDF	695	Elektrociepłownia Gdyńska	Poland	Coal	Nox	Sox
EDF	1,213	KOGENERACJA S.A.	Poland	Coal	Nox	Sox
EDF	2,790	EDF West Burton LCP 1	UK	Coal	Nox	
EDF	2,790	EDF West Burton LCP 2	UK	Coal	Nox	
EDP	750	CT SOTO DE RIBERA I-II	Spain	Coal	Nox	Sox
EDP	830	CT SOTO DE RIBERA III	Spain	Coal	Nox	
EDP	919	CT ABOÑO I	Spain	Coal	Nox	Sox
EDP	1,364	CT ABOÑO II	Spain	Coal	Nox	
Endesa	3,000	CT TERUEL I-II-III	Spain	Coal	Nox	Sox
Endesa	1,332	CT COMPOSTILLA I (G 2 Y 3)	Spain	Coal	Nox	Sox
Endesa	1,960	CT COMPOSTILLA II (G 4 Y 5)	Spain	Coal	Nox	Sox
Endesa	2,490	CT LITORAL I-II	Spain	Coal	Nox	Sox
Endesa	360	CT ALCUDIA I	Spain	Coal	Nox	Sox
Endesa	360	CT ALCUDIA II	Spain	Coal	Nox	Sox
Endesa	345	CT ALCUDIA III	Spain	Coal	Nox	Sox
Endesa	345	CT ALCUDIA IV	Spain	Coal	Nox	Sox
Enea	7,346	Elektrownia "KOZIENICE" S.A.	Poland	Coal	Nox	Sox
Enel	410	ENEL PRODUZIONE E - Camino 2	Italy	Coal	Nox	Sox
Enel	800	ENEL PRODUZIONE W - Camino 1	Italy	Coal		Sox
Enel	3,800	CT AS PONTES I-II-III-IV	Spain	Lignite	Nox	
Energa	1,668	Elektrownia Ostrołęka B	Poland	Coal	Nox	Sox
Engie	4,681	Energia Polska	Poland	Coal	Nox	
EPH	5,392	Eggborough Power Station	UK	Coal	Nox	Sox
Gas Natural	1,437	CT MEIRAMA I	Spain	Lignite	Nox	Sox
Gas Natural	993	CT NARCEA III	Spain	Coal	Nox	
Gasnatural	691	CT LA ROBLA I	Spain	Coal	Nox	Sox
Gasnatural	951	CT LA ROBLA II	Spain	Coal	Nox	Sox

Govora	586	S.C. C.E.T. GOVORA S.A. Nr.2	Romania	Lignite	Nox	Sox
Grupa Azoty	630	Grupa Azoty S.A.	Poland	Coal	Nox	Sox
Grupa Azoty	470	Kędzierzyn S.A.	Poland	Coal	Nox	Sox
Grupa Azoty	850	Puławy S.A.	Poland	Coal	Nox	Sox
Grupa Azoty	360	Chemiczne "POLICE" S.A.	Poland	Coal	Nox	Sox
Iberdrola	986	CT LADA IV	Spain	Coal	Nox	Sox
Iberdrola	1,010	CT VELILLA II	Spain	Coal	Nox	Sox
International Paper	539	Kwidzyn S.A.	Poland	Coal	Nox	Sox
Martinská Teplárenská	301	Martinská Teplárenská, A.S. Tepláreň K4-7	Slovakia	Lignite	Nox	Sox
Oradea	869	S.C. ELECTROCENTRALE ORADEA S.A Nr. 2	Romania	Lignite	Nox	Sox
PGE	13,712	PGE Bełchatów	Poland	Lignite	Nox	Sox
PGE	3,594	PGE Turów	Poland	Lignite	Nox	
PGE	3,808	PGE Opole	Poland	Coal	Nox	
PGE	920	PGE Bydgoszcz II	Poland	Coal	Nox	Sox
PGE	3,379	PGE Odra	Poland	Coal	Nox	
PGE	474	PGE Pomorzany	Poland	Coal	Nox	Sox
Pgnig	3,040	Elektrociepłownia Siekierki	Poland	Coal	Nox	Sox
Pgnig	2,219	Elektrociepłownia Żerań	Poland	Coal	Nox	Sox
Plzenska Teplarenska	410	Teplarna ELU III - Source A	Czech	Lignite	Nox	Sox
PPC	1,574	PPC S.A. - Ag. Dimitrios ST III-IV	Greece	Lignite	Nox	
PPC	892	PPC S.A. -Ag. Dimitrios ST V	Greece	Lignite	Nox	Sox
PPC	1,524	PPC S.A. -Ag. Dimitrios ST I-II	Greece	Lignite	Nox	
PPC	1,525	PPC S.A. -Amyntaio ST I-II		Lignite		Sox
PPC	762	PPC S.A. -Kardia ST I	Greece	Lignite	Nox	
PPC	762	PPC S.A. -Kardia ST II	Greece	Lignite	Nox	
PPC	812	PPC S.A. -Kardia ST III	Greece	Lignite	Nox	
PPC	812	PPC S.A. -Kardia ST IV	Greece	Lignite	Nox	
PPC	763	PPC S.A. -Ptolemaida ST IV	Greece	Lignite	Nox	
Raan	990	RAAN - Suc. ROMAG TERMO, Nr.2	Romania	Lignite		Sox
Retired	6,400	Longannet Power Station	UK	Coal	Nox	Sox
RWE	4,135	RWE Npower Aberthaw PS	UK	Coal	Nox	
Sembcorp Utilities	321	Wilton Main Power Station	UK	Coal	Nox	Sox
Severni Energetica	2,299	Elektrarna Chvaletice A.S.	Czech	Lignite	Nox	
Solvay	376	TORRELAVEGA SOLVAY	Spain	Coal	Nox	Sox
SSE	1,500	Ferrybridge C Units 1 & 2	UK	Coal	Nox	Sox

SSE	800	Ferrybridge C Units 3 & 4	UK	Coal		Sox
STEAG	607	Modellkraftwerk Völklingen	Germany	Coal	Nox	
Synthos	538	Synthos Dwory 7	Poland	Coal	Nox	Sox
Tauron	696	Zakład Wytwarzania Katowice	Poland	Coal		Sox
Tauron	1,748	Siersza W Trzebini	Poland	Coal	Nox	Sox
Tauron	548	Jaworzno III W Jaworznie – Elektrownia II	Poland	Coal	Nox	Sox
Tauron	3,360	Jaworzno III W Jaworznie – Elektrownia III	Poland	Coal	Nox	
Tauron	2,052	Łagisza W Będzinie	Poland	Coal	Nox	Sox
Tauron	2,920	Łaziska W Łaziskach Górnych	Poland	Coal	Nox	Sox
Tauron	1,140	Stalowa Wola W Stalowej Woli	Poland	Coal	Nox	Sox
Teplarna Ceske Budejovice	464	Novohradska Ulice	Czech	Lignite	Nox	Sox
Termicas De Anllares	953	CT ANLLARES I	Spain	Coal	Nox	Sox
Viesgo	976	CT PUENTE NUEVO I	Spain	Coal	Nox	Sox
Viesgo	1,419	CT LOS BARRIOS I	Spain	Coal	Nox	
Ze PAK	1,758	ZE PAK S.A. Elektrownia Adamów	Poland	Lignite	Nox	Sox
Ze PAK	1,075	ZE PAK S.A. Elektrownia Konin	Poland	Lignite	Nox	
Ze PAK	3,624	ZE PAK S.A. Elektrownia Pątnów I	Poland	Lignite	Nox	
ZEC	1,324	Elektrociepłownia EC II Karolin	Poland	Coal	Nox	Sox

Calculation of flue rates

The EEA provides data for emissions of NOX and SOX, in tonnes annually, for all large combustion plants in Europe. Unfortunately, there is no such centralised reporting of emissions flow rates, in milligrams per normal cubic metre (mg/Nm3) of flue gases. BREF limits are expressed in such flow rates. It was therefore necessary to convert tonnes of emissions into mg per Nm3 of flue gas.

To do this, we used EEA and other, unpublished, estimates for the flue gas volumes associated with burning biomass and different fossil fuels. These estimates do not account for excess oxygen in the flue gas, which we correct for by making certain, standard assumptions for excess oxygen associated with burning particular fuels. We note the assumptions involved in this calculation process, and notably the impact that the highly variable moisture content and calorific value of certain fuels, such as lignite and biomass, will have on flue gas volumes. The steps in our calculation process are summarised in the table below. These steps are summarised in the table below.

Fuel	Dry Flue Gas Vol Per MJ Of Fuel Burned	Surplus Oxygen Conversion		Dry Flue Gas Vol Per MJ Of Fuel Burned
	Before Allowing For Surplus Oxygen	Oxygen Content In Flue Gas	Extra Air In Intake, %	After Allowing For Surplus Oxygen
	Nm3/MJ	%	%	Nm3/MJ
Biomass	0.260	6%	40%	0.364
Coal	0.271	6%	40%	0.380
Lignite	0.300	6%	40%	0.420
Liquid fuel	0.249	3%	17%	0.291
Natural gas	0.236	15%	250%	0.826
Other gases	0.537	3%	17%	0.627

Limitations of This Study

We note the theoretical nature of this study, and limitations which include:

1. We only consider existing power plants with a thermal capacity above 300 megawatts (MWth).
2. We assume the same BREF limits apply to all power plants, and thus assume away BREF exceptions and derogations, such as the exceptions applied to power plants which run less than 1,500 hours per year.
3. We apply the most generous emissions limits, at the top of the allowed BREF range. In reality, some power plants will be required to achieve much lower emissions, for example on the basis of their age, fuel choice, design or existing abatement.
4. We base our power plant analysis on 2014 emissions data. These will be an over-estimate, where we have not accounted for subsequent power plant upgrades, for example where operators have since invested in relevant emissions abatement technology.
5. We consider only NOX and SOX emissions. However, BREF regulates much broader power plant operation, including emissions of dust and mercury, water consumption and energy efficiency. As a result, the real cost impacts of BREF will be greater than considered here.

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About the Author

Gerard Wynn

IEEFA Energy Finance Consultant, Gerard Wynn, is a U.K.-based 10-year veteran of energy and economics reporting at the Thomson Reuters News Agency and has authored numerous papers on energy issues ranging from solar power in Great Britain to coal-burning in China and India. He blogs at EnergyandCarbon.com.

Paolo Coghe, President, Acousmatics

Acousmatics provides tailor-made services and professional advice on energy markets and commodities. Paolo is an international financial economist with over 20 years of experience entirely focused on energy markets and commodities research, analysis and strategy. Before founding Acousmatics in October 2016, Paolo held different positions with the Brattle Group, Centrica, Koch Supply and Trading, and most recently with Societe Generale. Paolo's research at Societe Generale, was recognized by clients as No. 1 in the Risk & Energy Risk commodity rankings in from 2013 to 2017.

Important Information

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