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CONTENTS

Abstract

The generation of utilizable forms of energy, mainly electricity and heat, carries an environmental impact – as does any human industrial activity. In the case of the power industry based on fossil fuels, this impact is connected with the emission of technological by-products, not necessarily of a material character. It is obvious that the Polish point of view on this problem is connected with the unique degree of dependence of the national power industry on coal. Two aspects of the emission reduction problem are analyzed in this article: the technological, connected with the permanent development of flue-gas cleaning; and the administrative, connected with limiting the permissible polluter concentration in flue gases. It is shown that during the development of the power industry to date, those relations led to an effectiveness (efficiency) of flue-gas cleaning installations which seemed impossible at the moment of its implementation. The main goal of this work is to demonstrate that the regulations being introduced by the European Commission strongly disturb the present relations between technical capabilities and administrative requirements.

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Résumé

La production de toutes formes d'énergie et tout particulièrement d'électricité et de chauffage a son impact sur l'environnement aussi bien que chaque type d'activité industrielle de l'homme. Dans le cas de l'industrie énergétique qui utilise des carburants organiques, cet impact est lié aux émissions de la poussière d'oxyde de soufre, d'oxyde nitrique, de monoxyde et de dioxyde de carbone. La position de la Pologne concernant ce problème est affectée par la forte dépendance de son industrie énergétique de l'exploitation du carbone. Dans cet article nous avons analysé deux problèmes de réduction de l'émission de pollutions: technologique, lié au développement de la technologie de la purification des gaz d'échappement et législatif, lié aux réductions de niveaux de pollution autorisés. Il a été démontré que au fur et à mesure de développement de l'industrie énergétique, la corrélation entre ces deux aspects (technologique et législatif) a permis d'arriver à un niveau d'efficacité des installations de purification qui n'avait jamais été envisageable au moment de leur implantation. L'intérêt majeur de cette publication est de démontrer que les réglementations introduites par la Commission Européenne déséquilibrent fortement les relations entre les capacités techniques et les exigences administratives.

Classifications and key words: power industry, emission reduction, development of technology of flue-gas cleaning , low regulation on industrial emission

I. Introduction

Just like any human industrial activity, the generation of useful energy forms, primarily electricity and heat, leaves an environmental footprint. In the case of the power industry, based as it is on fossil fuels, this footprint includes various emissions occurring as by-products that are not necessarily of a material character. These can include noise or electromagnetic wave emissions, but also particulates, sulphur dioxide, nitrogen oxides, carbon monoxide, and carbon dioxide discharges. Process by-products include ash, slag, and effluents. The word 'emissions' is typically taken to mean the products released directly into the ambient air. Not so long ago the substances in question were limited to carbon monoxide, particulates, sulphur dioxide, and nitrogen oxides, while carbon dioxide was believed to have no impact on the environment. In recent years, however, the attitude toward CO_2 has changed drastically. CO_2 emissions have been declared the main driver of climate change, and cutting CO_2 emissions has been declared one of the greatest challenges facing humankind in the upcoming decades.

The Polish outlook as regards the issue of emissions in the power industry is obviously driven by the dependency of the country's power sector on coal.

The magnitude of dependency is higher than elsewhere in Europe. Hence, this study will be primarily focused on analyzing the impact of emission limitations on the development of coal-based power technologies while still referring to the traditional 'dirty' pollutants, i.e., particulates, sulphur dioxide, and nitrogen oxides.

II. Historical background

In terms of ambient air pollution the development of the coal-based sector can be divided into four stages. The first stage was the time when the emission issue had not yet been identified, mainly due to a lack of observable environmental changes. This situation continued until large urban areas found themselves covered by smog. It was easy to find the cause – particulate emissions. Technology for particulate emission abatement was not a problem. Power stations and other industrial plants were equipped with cyclone dust separators or electrostatic precipitators. Small-scale sources used for individual residential heating, however, proved to be a bigger problem. In this case gas or electricity were adopted as energy sources and domestic coal fires were banned by law in certain areas.

From the technical point of view the problem of smog was largely solved, and that seemed to be the end of the matter until it became evident that some forests were withering. The diagnosis proved simple: acid rain caused by the emission of sulphur dioxide and nitrogen oxides. The sulphur content in the combusted coal – and hence in flue-gas – was high, leading to the introduction of a new requirement: sulphur dioxide emission abatement. The technology was ready and flue-gas desulphurization (FGD) systems appeared at power plants, soon followed by NO_x abatement systems.

The fourth stage can be observed today. This is a period when the main challenge is to limit carbon dioxide emissions, an issue that will be discussed further on in this study.

When investigating the history of limiting the emission of traditional pollutants, two aspects need to be highlighted: the technical and the legal. Of course, the key devices used in cutting particulate emissions are electrostatic precipitators (ESPs). The ESP concept can be traced back to the 19^{th} century, when in 1821 M. Hohlfeld precipitated smoke in an earthed tube[1]. Further important steps were taken in 1911 and 1982. The former saw installation of the first electrostatic precipitator with a system of plate electrodes, the latter the commissioning of the first ESP with a joint electrode area of 100,000 m^2.

1 See J. Kucowski, D. Laudyn, M. Przekwas, *Energia i środowisko*, WNT, Warszawa 1997.

The breakthrough in flue-gas desulphurization (FGD) technology was the installation of scrubbers at the Battersea power station in London in the early 1930s[2]. The 1950s and 60s saw intensive research into new desulphurization techniques involving lime or limestone, and this resulted in commercial application of the now common wet scrubbing technology. By 1982 in the United States alone this technology had been installed in power plants with a total capacity exceeding 28,000 MW, and new ones were under construction at plants with a total capacity over 14,000 MW[3].

When discussing technical aspects of curbing traditional emissions we must not forget the Dürnrohr power station in Austria, commissioned in 1986, which was equipped with[4]:

- Preliminary single field electrostatic precipitators with 90% efficiency and main four-field ESPs with 99.9% efficiency
- Semi-dry FGD system with 90% efficiency
- SCR NO_x abatement system with 80% efficiency.

Therefore by the mid-1980s technologies to minimize emissions of the particulates, sulphur dioxide, and nitrogen oxides had not only become commercially available, they were in wide use.

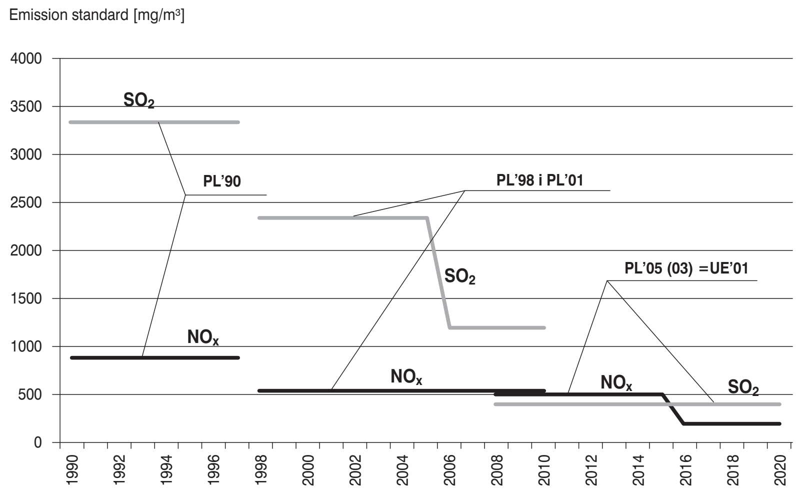
Technical progress in flue-gas cleaning systems was accompanied by the introduction of legal restrictions on permissible emission levels. This process commenced in 1979 when the Convention on Long-Range Transboundary Air Pollution was signed in Geneva. In order to implement its stipulations developed countries started to enact local regulations determining permissible levels of pollutants – mainly particulates, sulphur dioxide, nitrogen oxides, and carbon monoxide – in flue gas. Hitherto, most countries had only regulated locally on emission levels, with resulting localized effects. For instance, in 1983 Germany introduced harsh limits on sulphur dioxide emissions, e.g., for systems with a fuel input power exceeding 300 MW the maximum allowed level was 400 mg/m^3, while for 100 to 300 MW plants the reduction efficiency had to be at least 60%[5].

The first regulation determining maximum permitted emission levels was issued in Poland in 1990 (designated as PL'90 in Fig. 1)[6]. It has been amended many times since – in 1998 (PL'98)[7], 2001 (PL'01)[8], 2003 (PL'03)[9] and 2005

2 Ibidem.
3 Ibidem.
4 Ibidem.
5 Ibidem.
6 Journal of Laws 1990 No. 15, item 92.
7 Journal of Laws 1998 No 121, item 793.
8 Journal of Laws 2001 No 87, item 957.
9 Journal of Laws 2003 No 163, item 1584.

(PL'05)[10]. The history of the limits is presented in Fig. 1. The last two editions of the regulation relate to the implementation of EU Directive 2001/80/EC[11] (the LCP Directive – UE'01).

Fig. 1. Changes in SO_2 and NO_x emission standards for large combustion plants (power P > 500 MW) fired with hard coal for which a building permit had been issued prior to July 1, 1987.



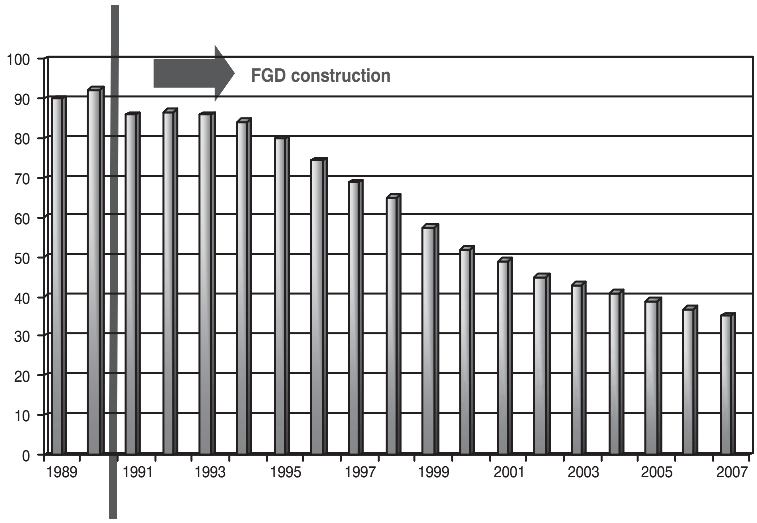
Poland's 1990 regulation for plants that were already operating was of a purely symbolic character, although it did presage a significant standard tightening in 1998 to a level similar to that imposed by the 1998 regulation. With this prospect looming, most large Polish power sector boilers had their burners replaced with low-emission models equipped with over-fire air (OFA) systems during the 1990s. This allowed restriction of NO_x emissions to approximately 500 mg/m³. Construction of FGD systems, mainly of the wet scrubbing variety, also commenced at plants with a fuel input exceeding 500 MW. The results of those investment projects are presented in Fig. 2.

This historical discussion illustrates that while mature flue-gas cleaning technologies preceded the related legal regulations in developed countries, the introduction of thorough flue-gas treatment systems in Poland was enforced by the enactment of emissions standards. In no case did the new

[10] Journal of Laws No. 260, item 2181.

[11] Directive 2001/80/EU of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants, OJ [2001] L 309/1.

Fig. 2. Actual-to-theoretical emission ratio for large combustion plants (LCPs) in 1989–2007.



restrictions cause any noticeable alterations in the main electricity or heat generation process, such as for example a change of fuel from coal to natural gas and resulting process change from the steam cycle into a combined cycle. While some combined cycle CHPs have actually appeared since 2002, it is hard to see any real connection between those few projects and the emission regulations.

It also needs to be pointed out that due to the interdependency between technical development and legal regulations discussed above, the flue-gas treatment systems have reached efficiency levels which had seemed impossible when they were first invented. Modern electrostatic precipitators can achieve an efficiency of 99.9%, wet FGD units – 99%, and SCR NO_x abatement more than 90%.

Emission regulations in the early years of the new century have been primarily marked by the Kyoto Protocol and the European Union Emission Trading Scheme for CO_2 allowances, a tool designed to achieve the Protocol's objectives in EU member states. The system has been stirring a lot of excitement. The combination of caps on emission allowances distributed among plant operators and a market in allowances together were supposed to drive allowance prices to a level which would on the one hand eliminate those systems with the highest emission levels from the market, and on the other precipitate the development of low-emission technologies. Nonetheless, the first ETS phase between 2005 and 2007 ended in failure.

Too large a pool of assigned allowances resulted in erratic price variability, which is shown in Fig. 4[12]. In late 2007 the allowance price dropped to EUR 0.01/Mg. The second ETS phase, *in situ* at the time of writing, runs from 2008 until 2012. Thus far the allowance price has proved much more stable than during phase one, ranging between EUR 8 and EUR 16/Mg. Nonetheless, this does not alter the cost balance sufficiently to affect the feasibility of commonly used power generation technologies. It does however increase the feasible efficiency of a power generation system – a fact which had not been taken into account during development of the newest Polish power generation units (Pątnów II, Łagisza II, Bełchatów II).

Fig. 4. CO_2 allowance price in 2005–2007 [9].

III. A glance toward the future

It seems very probable that the future of the power industry, including the selection of technologies, will be determined by the latest European Union legal regulations, primarily the new Directive on the CO_2 emission trading scheme[13] which has already been adopted, and the new Industrial Emissions Directive or IED[14]. According to the former document, eventually there will

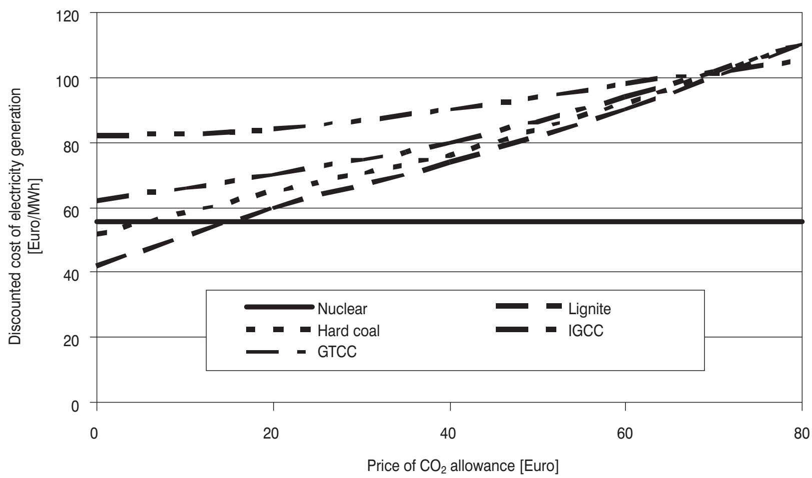
[12] K. Badyda, J. Lewandowski, 'Determinants of energy development in Poland using coal' (2008) 3 *Energetyka*.

[13] Directive 2009/29/EU of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EU so as improve and extend the greenhouse gas emission allowance trading scheme of the Community, OJ [2009] L 140/63.

[14] Directive 2010/75 /EU of 24 November 2010 on industrial emissions (integrated pollution prevention and control), OJ [2010] L 334/17.

be no free-of-charge distribution of CO_2 emission allowances for power and heat generators. Rather, plant operators will need to purchase their allowances at auctions. The assumption at play is that the emission allowance price should reach a level which would make carbon capture and storage (CCS) systems feasible. It is estimated that for this purpose the allowance price should reach approximately EUR 60/Mg. The relationship between emission allowance prices and electricity generation costs is presented in Fig. 5[15]. A glance at this figure immediately begs the question of whether high allowance prices will drive CCS development, or rather lead to a renaissance in nuclear power.

Fig. 5. Discounted electricity generation cost as a function of the CO_2 emission allowance price with assumed plant operation for 6500 h/a (baseload plant) [11].



It also needs to be pointed out that at this emission allowance price level it will no longer be feasible to generate heat at coal-fired boiler plants. For the increase in the generation cost caused by the emission allowance purchase obligation will exceed PLN 20/GJ, which means that it will almost double current operating costs. In comparison, the rise in the cost of natural gas-based heat generation will be a mere PLN 10. We therefore need to hope that the emissions issue will result in a change of fuel, and a further spread in CHP technologies – not a return to domestic heating sources, as they are not affected by the emission trading scheme.

[15] 'Prognoza zapotrzebowania na paliwa i energię do 2030 r.', Agencja Rynku Energii S.A., Warszawa, luty 2009.

Fig. 6. Comparison of the SO_2 emission limits for lignite and hard coal [mg/m³] from 2016 on, as per the Regulation of the Minister of the Environment of December 20, 2005 [5] and the Industrial Emissions Directive for "existing" plants.

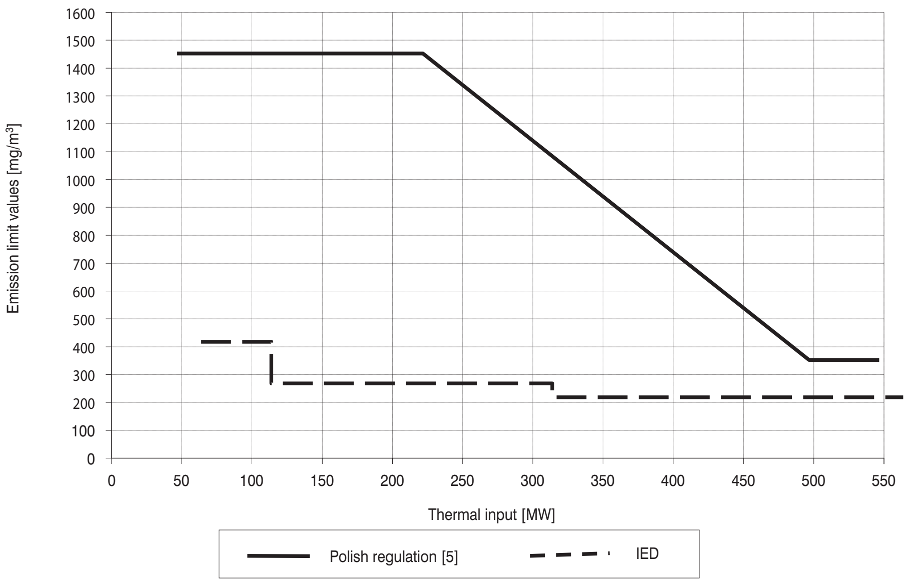


Fig. 7. Comparison of the NO_x emission limits for lignite and hard coal [mg/m³] from 2016 on, as per the Regulation of the Minister of the Environment of December 20, 2005 [5] and the Industrial Emissions Directive for "existing" plants"

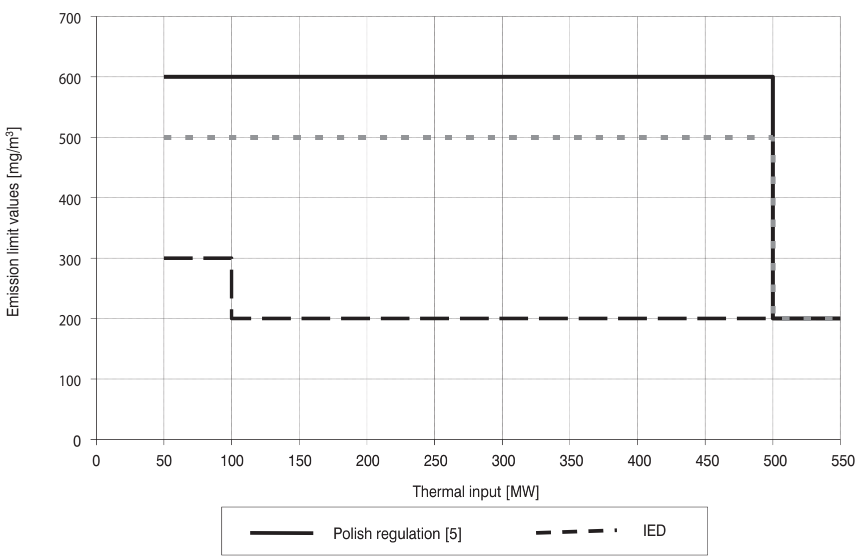


Table 1. Cost of investments required to construct new capacities if the IED is implemented in 2016 with a definition "combustion plant = stack" [14].

Variant	Without IED		IED implemented in 2016	
Plant type	Installed capacity	Investment cost	Installed capacity	Investment cost
New combined heat and power plants	3,036	12,751	6,211	26,086
New condensing power plants	1,338	7,359	5,429	29,860
New peakload power plants	2,347	3,638	2,163	3,353
Total cost of the new plants	6,721	23,748	13,803	59,298

Fig. 8. Comparison of the particulates emission limits for lignite and hard coal [mg/m³] from 2016 on, as per the Regulation of the Minister of the Environment of December 20, 2005 [5] and the Industrial Emissions Directive for "existing" plants

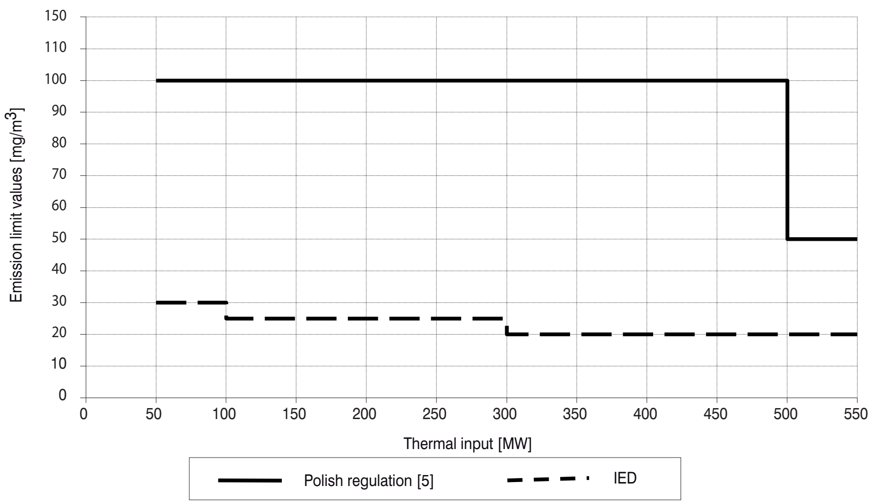
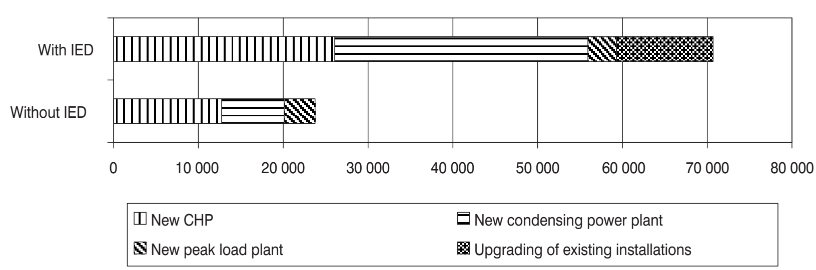


Fig. 9. Total cost of investments in the Polish power industry in variants with and without IED implementation [14].



IV. Directives and the competitive market

The IED in its current form with the gradual introduction of very stringent requirements will result in major changes in the competitiveness of individual firms. It will create a situation in which one company with four boilers such as WR-10 (thermal input > 50 MW, but each of the boilers <15 MW) will not have to equip the high exhaust gas cleansing systems, but a company with such two boilers WR -25 and one WR-5 will. IED significantly differentiates between the conditions of business and splits companies into 7 groups:

1. Plants with a capacity < 20 MW and boilers <5 MW – no restrictions emission.
2. Plants with a capacity < 20 MW of power boilers > 5MW – to reduce emissions of sulphur dioxide, nitrogen oxides and particulates in accordance with Regulation of the Minister of Environmental Protection of December 20, 2005[16].
3. Plants with a thermal input > 20 MW, boilers <5 MW – reducing CO_2 emissions through the trading scheme (ETS).
4. Plants with a thermal input > 20 MW and boilers > 5 MW – reducing CO_2 emissions through the trading scheme (ETS) and emissions of sulphur dioxide, nitrogen oxides and particulates in accordance with Regulation of the Minister of Environmental Protection of December 20, 2005[17].
5. Plants with a thermal input of common stack > 50 MW, but without boilers > 15 MW reduction in CO_2 emissions through the trading scheme (ETS) Regulation of the Minister of Environmental Protection of December 20, 2005[18].
6. Plants of new installations (after 1987) > 50 MW ("born too late"), and boilers > 15 MW, even if thermal input on the common stack < 50 MW – are subject to trading and the new IED.
7. Plants in a thermal input of common stack > 50 MW and boilers > 15 MW – are subject to trading and the new IED.

[16] See above the note No. 10.
[17] Ibidem.
[18] Ibidem.

V. Conclusions

The history of limiting pollution emissions from power and heat generation plants has been that of an improvised but seemingly orderly interplay of technological development and legal regulations setting permissible levels. This resulted in the emergence of extremely effective flue-gas treatment systems without an excessive increase in operating costs. Unfortunately, there is a threat that the regulations defined by the new directives – ETS[19] and IED[20] – will increase generation costs to such an extent that the operators will run short of funds for technological development.

The increase in the cost of electricity and heat generation caused by the directives ETS and IED apply to medium and large installations. They are in a much worse market position than small plants. This mainly applies to the cost of heating buildings. Meanwhile, small heating installations generate "low emissions", which in fact are usually more burdensome for the environment than large systems. Application of regulations similar to those in the directives ETS and IED to such small installations is not possible in Poland, mainly for social reasons – and therefore for political reasons, too.

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[20] 'Prognoza zapotrzebowania na paliwa i energię do 2030 r.', Agencja Rynku Energii S.A., Warszawa, luty 2009.