Increasing the environmental cleanliness of industrial enterprises

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Abstract. The article discusses important issues to improve the environmental friendliness of industrial enterprises. Emissions of harmful substances into the atmosphere by coal-fired power plants are analyzed. As well as emissions of pollutants (kg) of various fuels per 1 ton of equivalent fuel, 1 Gcal of heat and 1 MWh of electricity. Potentially possible emissions of the main pollutants when using coal, firewood and diesel fuel for domestic needs are given. An estimate of the reduction in emissions of pollutants into the atmosphere is projected, thousand tons/year. The effects of environmental and energy-saving measures in the energy sector are assessed. The following are the negative impacts of overhead power lines: the biological impact of electromagnetic fields on fauna, including humans; cutting down trees and alienation of significant land plots for power transmission lines; disturbance of the natural landscape; interference to radio and television reception from corona discharge on power line wires.

1 Introduction

The foundations of the current legislation in the environmental sphere were formed in the early 90s, when, due to a drop in production volumes, a reduction in the volume of pollution was expected. This led to a reduction in environmental barriers, which did not so much promote economic growth as create conditions for the preservation of outdated technologies to the detriment of production modernization [1].

In the electric power industry, this led to a significant lag behind advanced countries in terms of economic and environmental efficiency and an imbalance in the fuel balance, Table 1.

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Emissions, g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Germany</td>
</tr>
<tr>
<td>NOx</td>
<td>0,5</td>
</tr>
<tr>
<td>CO2</td>
<td>0,3</td>
</tr>
<tr>
<td>PM*</td>
<td>0,06</td>
</tr>
</tbody>
</table>

PM* – volatile macroparticles (particulate matters).

2 Materials and Methods

There are four main ways to reduce (or at least reduce the growth rate) the load on the environment with increasing energy consumption, which we will consider below.

1. Increasing the environmental friendliness of technologies for the extraction, primary processing and transportation of traditional energy resources.

The increase in the production of energy raw materials is accompanied by an exacerbation of environmental problems due to the manifestation of such effects as:

- accumulation of drill cuttings,
- salinization of groundwater due to violations of technologies for the operation and abandonment of oil and gas wells,
- emissions of combustion products into the atmosphere when burning associated petroleum gases and oil sludge,

- pollution of the air, soil and water with petroleum products,
- soil subsidence during hydrocarbon gas production.

Environmental problems are so large-scale that they may complicate the economic situation in the near future.

Considering the state of the production equipment of oil companies, it can be stated that over the coming years the problem of eliminating emergency oil spills will remain relevant. The most cost-effective is the
prevention of emergency situations: prevention of oil spills during production, automated monitoring of the condition of pipelines and identification of pipeline sections requiring replacement or overhaul [2-4].

During production and transportation, between 1.5% and 10% of oil is lost, which is equivalent, according to a minimum estimate, to approximately 4.5 million tons per year. Penalties for 1 ton of spilled oil correspond to the cost of 80 tons of extracted oil, and the cost of collecting it is equivalent to the cost of 0.8–1.3 tons of oil. Consequently, the economic effect of taking measures to prevent emergency oil spills will be significantly higher than the costs of their implementation.

The production and transportation of natural gas, compared to oil, poses a significantly lower environmental hazard, because the gas has a relative density of 0.6 and, when released, quickly dissipates into the atmosphere. A fairly high degree of technological safety is ensured by a number of measures: mainly underground laying and placement of gas pipelines outside residential buildings, regular and fairly strict monitoring of the condition of all elements of the gas pipeline system. Their result is a decrease in the intensity of accidents on gas pipelines over the past 20–25 years by approximately 2.5 times [5-10].

Significant damage to nature is caused by the extraction and preliminary preparation of solid fuel (primarily coal): land alienation and landscape disturbance during open-pit mining, soil subsidence during open-pit mining, waste rock storage problems in both mining methods (large-scale dumps), air pollution and soil. When transporting solid fuel, contamination of land adjacent to railways and roads is almost inevitable.

2. Changing the fuel and energy standards and improving the environmental friendliness of fuel combustion. The load on the environment decreases with an increase in the fuel and energy balance (TEB) of the share of more environmentally friendly sources of primary energy: fuel with less carbon or no carbon at all (uranium, hydrogen), renewable energy sources, and in the long term - fuel for thermonuclear power plants [11-16].

### Table 2

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Specific emissions of pollutants, kg/t of standard fuel; kg/Gcal of heat; kg/(MWh)</th>
<th>Fuel</th>
<th>Specific emissions of pollutants, kg/t of standard fuel; kg/Gcal of heat; kg/(MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>30; 5.4; 10.5 4.57; 0.82; 1.6 10; 1.8; 3.5</td>
<td>Fuel oil</td>
<td>20; 3.6; 7.0 6; 1.1; 2.1 -</td>
</tr>
<tr>
<td>Natural gas</td>
<td>- 2.3; 0.41; 0.8 -</td>
<td>Coke gas</td>
<td>5.7; 1.03; 2 2.8; 0.51; 1.0 -</td>
</tr>
<tr>
<td>Blast gas</td>
<td>- 1.43; 0.26; 0.5 -</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3

Potentially possible emissions of major pollutants when using coal, firewood and diesel fuel for domestic needs

<table>
<thead>
<tr>
<th>Release source</th>
<th>Fuel</th>
<th>Emission of pollutants from fuel combustion products, kg/t e.g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating boiler with manual layer firebox</td>
<td>Coal</td>
<td>Ash 3-8 Soot 11-22 SO₂ 4-15 NO₂ 6-9 CO 19-60 Hydrocarbons 0.03-0.2 Benz(a)pyrene 0.001-0.008</td>
</tr>
<tr>
<td></td>
<td>Peat</td>
<td>Ash 1-3 Soot 10 NO₂ 2 NO₂ 3.5 CO 15-50 Hydrocarbons 0.02-0.1 Benz(a)pyrene 0.001</td>
</tr>
<tr>
<td>House stove</td>
<td>Coal</td>
<td>Ash 1.5-2.4 Soot 9-13 NO₂ 0.4-7 NO₂ 5-11 CO 5-420 Hydrocarbons 0.08-0.5 Benz(a)pyrene 0.007-0.0013</td>
</tr>
<tr>
<td></td>
<td>Firewood</td>
<td>Ash 0.6 Soot 0.9 NO₂ 0.3 NO₂ 3 CO 20-350 Hydrocarbons 0.002-Benz(a)pyrene 0.00006</td>
</tr>
<tr>
<td>Diesel electric generator</td>
<td>Diesel fuel</td>
<td>Ash 0 Soot 5 NO₂ 25 CO 13 Hydrocarbons 1-Benz(a)pyrene No data</td>
</tr>
</tbody>
</table>

Table data 2, 3 show that coal combustion is accompanied by the release of the largest volume of pollutants and, above all, such dangerous ones as benzopyrene. Accordingly, the greatest environmental damage in monetary terms in the production of electrical energy occurs at coal thermal power plants - 64 cents per 1 kWh; they pollute the atmosphere not only with emissions from chimneys, but also with volatile substances released when coal is stored in open areas. The development of coal-fired energy, while simultaneously solving the problem of reliable energy supply (thanks to the world's huge coal reserves), aggravates the problem of environmental pollution. Annual emissions from energy installations in the world are: carbon dioxide – (2–3)*10¹⁰ tons, fly ash (particulate matters) – 2.5*10¹⁰ tons, NOₓ – 1.2*10¹⁰ tons, SOₓ – 1.5*10¹⁰ t, significant volumes of toxic components. The share of coal energy in total CO₂ emissions is 30% of the total for all sectors of the economy and 2% of the world. One coal-fired power plant with a capacity of 150 MW with today's average technical characteristics produces more than 1 million
tons of greenhouse gas emissions per year (equivalent to the exhaust of 300 thousand cars).

The experience of highly developed countries (primarily Germany, England, Japan, South Korea) shows that the current level of technology makes it possible to minimize the environmental impact of coal-fired power plants, but only by implementing additional measures that complicate and increase the cost of the construction and operation of such thermal power plants.

In table 4 presents a forecast assessment of the reduction in emissions of pollutants into the atmosphere as a result of the implementation of two groups of measures: technological and organizational.

<table>
<thead>
<tr>
<th></th>
<th>Use of CCGT and GTU when burning natural gas</th>
<th>Improving combustion efficiency</th>
<th>Installation of highly efficient gas cleaning equipment</th>
<th>Implementation of measures to achieve technical standards</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOₓ</td>
<td>5,5</td>
<td>10,0</td>
<td>11,5</td>
<td>304,6</td>
<td>331,6</td>
</tr>
<tr>
<td>SO₂</td>
<td>37,2</td>
<td>165,3</td>
<td>58,2</td>
<td>260,7</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>30,1</td>
<td>295,3</td>
<td>280,0</td>
<td>605,3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1197,6</td>
</tr>
</tbody>
</table>

The most effective measures in terms of reducing emissions and the proceeds from their implementation are given in Table 5. In addition, projects for replacing boiler-turbine equipment with a sharp increase in its efficiency, as well as local technological improvements combined into program projects (introduction of variable-frequency electric drives, low-power turbines for using reduced steam, use of turboexpanders, recycling) can be considered as “carbon” measures: waste heat, etc.).

<table>
<thead>
<tr>
<th>Event</th>
<th>Reduction of CO₂ emissions (at 100 MW plants), thousand tons</th>
<th>Funds from the sale of reduced emissions over 5 years (at a price of 10 euros per 1 ton of CO₂), million euros</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement of steam turbines of gas-fired thermal power plants with combined-cycle units.</td>
<td>100–250</td>
<td>9–13</td>
</tr>
<tr>
<td>Introduction of gas turbine superstructures at thermal power plants</td>
<td>90–130</td>
<td>5–7</td>
</tr>
<tr>
<td>Conversion of existing thermal power equipment from coal to gas</td>
<td>190–270</td>
<td>10–14</td>
</tr>
<tr>
<td>Development of district heating and improvement of heat supply systems with the elimination of small boiler houses</td>
<td>90–240</td>
<td>4–12</td>
</tr>
<tr>
<td>Distribution of renewable energy sources, including small and medium-sized hydropower plants</td>
<td>220–460</td>
<td>11–23</td>
</tr>
</tbody>
</table>

When determining ways to develop heat supply to the residential and public consumption sectors, one of the main factors becomes environmental. Limits for the maximum content of harmful gases in the air basin of populated areas have been established and, on their basis, norms for maximum permissible concentrations of harmful substances in the air basin have been adopted, Table 6 [17].

The concentration of pollution in the active impact zone depends on such factors as: the quality and type of fuel burned, the location of the source of pollution, the type of boiler, the state of the atmosphere, etc. This indicator is significantly different for decentralized (DCT) and centralized (DCT) heat supply systems.

Along with the undeniable advantages of DCTs in a number of indicators, in environmental terms they have significant disadvantages [18-19]:

The concentration of pollution in the active impact zone depends on such factors as: the quality and type of fuel burned, the location of the source of pollution, the type of boiler, the state of the atmosphere, etc. This indicator is significantly different for decentralized (DCT) and centralized (DCT) heat supply systems.
The damage to nature at this technological stage is not as great as during the production of electrical and thermal energy. Environmental problems during the production of thermal energy are many times greater than those during its transmission. For this reason, the distance of the heat source from its consumer and, accordingly, the length of heating mains increases, the likelihood of accidents with serious consequences increases: disruption of transport communications due to excavation work and flooding, and in some cases human casualties [26-31].

Negative impacts of overhead power lines (EPLs) include:
- biological impact of electromagnetic fields on representatives of fauna, including humans;
- cutting down trees and alienation of significant land plots for power transmission lines;
- disturbance of the natural landscape;
- interference with radio and television reception from corona discharge on power line wires.

4. Reducing the release of greenhouse gases into the atmosphere.

**Conclusion**

One way to solve this problem is to inject greenhouse gases into cavities formed during oil and gas production, into saline porous aquifers, and into coal seams unsuitable for development. To date, at least two such industrial-scale projects have been implemented. In the USA, carbon dioxide, which is a waste product from the methanization of synthetic gas, is pumped into a depleted oil field, simultaneously ensuring the resumption of oil recovery from the reservoir. In the Norwegian Sea, CO₂ separated from produced natural gas is injected into a porous aquifer. EU countries plan to equip 12 power plants (existing and under construction) with underground storage facilities – greenhouse gas repositories – by 2035 [32-33].
The implementation of this method is hampered by a high price - with the technologies available today, the separation and disposal of each ton of CO₂ requires up to $60. Large-scale use of such technology would significantly increase the cost of electricity. What is needed is a technology with a price no higher than $20–30 per 1 ton of CO₂. In the United States, more than $1 billion has been spent on the development of such technologies.

References

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