Indicators of Environmental Performance and Energy Efficiency of Businesses under the Low-Carbon Economy Development

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***Abstract*—The long-established patterns of economic development and the associated nature of production and consumption can be no longer suggested as an example since wealthy countries and developed economies do not find these phenomena sustainable, while poor and hard developing countries cannot replicate them. In order for all countries of the world to progress to the level of development and consumption of the advanced countries, it is necessary to increase consumption of natural resources (namely, energy resources being an economic powerhouse) and, consequently, to increase the pollution level, which is impossible due to scarcity of natural resources and natural environmental restraints. In order to bring into balance economic development, environmental safety, and social welfare, there is a need to evaluate and analyse the situation especially in the sphere of production industry and energy consumption as well as emerging or potential risks and put in place appropriate measures. Traditional economic evaluation criteria are inadequate for this. This requires an integrated evaluation system of companies' economic, environmental and energy efficiency. The problem is urgent for modern Russian energy-consuming industrial sectors tending to settle down to a course of the low-carbon development. To solve this problem, the authors explore the existing evaluation system of environmental efficiency of Russian companies and propose additional evaluation criteria and indicators of the efficiency of the environmental management system from the standpoint of carbon-intensity reduction and production energy-efficiency increase.**

Keywords—sustainable development; environmental indicators; energy resources, greenhouse gases; corporate social responsibility

I. INTRODUCTION

At present, the concept of sustainable development built up and accepted by the UN World Commission on Environment and Development in 1992 [1] is a commonly-accepted philosophy in the field of use of resources and environmental protection. Sustainable development as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [2] implies integration of economic, environmental, and social targets [3,4] at all levels: global, national, and especially corporate – industrial enterprises are among the key entities ensuring sustainable use of resources, environmental safety, and, consequently, well-being of present and future generations.

The necessity to implement a sustainable development strategy requires a company to create responsible business practices and to follow effective environmental management on the basis of business's key responsibilities of the Business Charter for Sustainable Development [5] and basic principles [6] which determine:

- Recognition of global environmental impacts associated with the business activities and the environmental impact on the economy;
- Maintenance of ecosystems and protection of the biodiversity as a priority rather than a side effect of the business activities;
- Evaluation of the development sustainability should include not only traditional indicators of economic growth but also indicators of environmental safety and social well-being.

Over the last decades, universal recognition of environmental priorities has resulted in the fact that an environmental factor has gained in importance in economic relations, assurance of international competitiveness, and development of a company's reputation.

Making environmentally responsible decisions and evaluation of environmental efficiency require the use of reliable environmental criteria and indicators being out of standard market criteria [7-10].

II. RUSSIA'S STRATEGY

Being one of the industrial heavyweights with rich deposits of natural resources, Russia cannot sideline global tendencies associated with prevention of a threat of climate change and environmental degradation.

Implementation, certification and development of environmental management systems [5] as well as disclosure of environmental aspects of business activities in a corporate social reporting in accordance with the legal requirements and

voluntary initiatives have been among the corporate priorities of Russian businesses recently.

However, Russian businesses' reporting normally ensures transparency of information about traditional pollutants such as atmospheric emissions of SO2, NOx, ashes, and dust, effluent discharge, and disposed industrial wastes. Environmental policies of most Russian businesses do not ensure accounting and monitoring of direct and indirect greenhouse gas emissions and, consequently, a programme on their reduction.

At the same time, the analysis of greenhouse gases emission dynamics per Russian economy sectors shows a stable growth. Being a power-consuming industry, metal manufacture processes generate the greatest volume of greenhouse gas emissions (Tabl. 1).

TABLE 1 INDUSTRIAL EMISSIONS OF GREENHOUSE GASES

Processes	**Volume of greenhouse gas emissions, Mte of CO_2 -equivalent/year**		
	2000	***2010***	***2014***
Metal manufacture	89,72	94,76	91,83
Production of products from mineral raw materials	37,97	46,77	49,45
Chemical industry	17,92	21,71	22,42
Other	22,31	12,31	18,0

The necessity to solve one of the strategic problems of Russia's development by 2020, namely, reduction of the economy's power intensity down to 40 %, reduction of greenhouse gas emissions and emissions by 2.4 Gt of CO_2-equivalent requires Russian businesses to achieve new economic and environmental goals. Solving these problems is especially critical for mining, power, and metal manufacture industries.

Russian legislation did not require accounting and monitoring of greenhouse gas emissions until 2016. The current accounting system does not contain data on greenhouse gas emissions for particular enterprises. That is why reliable indicators of environmental performance and energy efficiency are required to follow environmental requirements to business activities at the global and national levels, to develop and implement an efficient environmental policy, and to determine target values of greenhouse gas emission reduction.

III. ENVIRONMENTAL PERFORMANCE AND ENERGY EFFICIENCY INDICATORS

In order to put together indicators of environmental performance and energy efficiency of businesses, most informative indicators have been selected and additional indicators have been included according to the criteria selected [11]:

- direct greenhouse gas emissions;
- indirect greenhouse gas emissions;
- greenhouse gas emission reduction;
- greenhouse gas occlusion (conservation).

The selected indicators have been grouped after the pressure-state-response (PSR) model [12] according to the principles and methodology of the Organization for Economic Cooperation and Development (OECD). Considering the criteria of energy intensity and energy efficiency of production, additional indicators specifying power consumption of a business have been included into the "pressure" category (Table 2):

- fossil fuel consumption;
- overall consumption of energy resources.

TABLE 2 UPDATED SET OF INDICATORS OF ENVIRONMENTAL PERFORMANCE AND ENERGY EFFICIENCY OF BUSINESSES

"Pressure" indicators
Basic:
$x_{1.1}$ – Overall water supply, m^3/year
$x_{2.1}$ – Surface water consumption, m^3/year
$x_{3.1}$ – Discharge of pollutants into water sources, tpa
$x_{4.1}$ – Air pollution emissions, tpa
$x_{5.1}$ – Specific emissions of air pollutants, t/unit
$x_{6.1}$ – Wastes generation, tpa
Additional:
$x_{7.1}$ – Direct greenhouse gas emissions, t CO_2-e/unit
$x_{8.1}$ – Indirect greenhouse gas emissions, t CO_2-e/unit
$x_{9.1}$ – Fossil fuel consumption, GJ/unit
$x_{10.1}$ – overall consumption of energy resources, GJ/unit
"State" indicators
Basic:
$x_{11.2}$ – Air pollution concentration, mg/ m^3
$x_{12.2}$ – Water pollution concentration, mg/ m^3
$x_{13.2}$ – Contaminated (disturbed) land area, m^2
"Response" indicators
Basic:
$x_{14.3}$ – Circulating water supply, m^3/year
$x_{15.3}$ – Reduction of discharges to the water supply system, tpa
$x_{16.3}$ – Reduction of water disposal, m^3/year
$x_{17.3}$ – Environmental service fees and charges, RUB/year
$x_{18.3}$ – Waste water facilities costs, RUB/year
$x_{19.3}$ – Air pollution emission reduction, tpa
$x_{22.3}$ – Environmental service fees and charges, RUB/year
$x_{23.3}$ – Air protection costs, RUB/year
$x_{24.3}$ – Waste disposal, tpa
$x_{25.3}$ – Use of wastes, tpa
$x_{26.3}$ – Protection and sustainable use of lands, RUB/year
$x_{27.3}$ – Environmental service fees and charges, RUB/year
Additional:
$x_{20.3}$ – Greenhouse gas emission reduction, t CO_2-e/year
$x_{21.3}$ – Greenhouse gas occlusion (conservation), t CO_2-e/year

Let us use an updated set of indicators of environmental performance and energy efficiency of businesses to calculate indices or integral characteristics per each category: "pressure", "state", and "response". We will arrive at comprehensive assessment of environmental management efficiency of businesses through calculation of an integral indicator *I*.

The I_1 index for the "pressure" category is calculated as follows, (1):

$$I_1 = \sum_{i=1}^{n} c_i \cdot \tilde{x}_{i1} \quad (1)$$

where $x_{i.1}$ is the *i*-th valuated indicator of the "pressure" category;

c_i is the weighting factor of the *i*-th valuated indicator of the "pressure" category.

The I_2 index for the "state" category is calculated as follows, (2):

$$I_2 = \sum_{i=1}^{n} c_i \cdot \tilde{x}_{i2} \quad (2)$$

where $x_{i.2}$ is the *i*-th valuated indicator of the "state" category;

c_i is the weighting factor of the *i*-th valuated indicator of the "state" category.

Indices I_1, I_2, indicators $\boldsymbol{x_{1.1} - x_{10.1}}$ of the "pressure" category and indicators $\boldsymbol{x_{11.2} - x_{13.2}}$ of the "state" category are related with a monotone decreasing dependence: the higher the value of indicators, the lower the value of an index and, consequently, environmental performance under the "pressure" and "state" category.

When valuating indicators $\boldsymbol{x_{1.1} - x_{13.2}}$, the maximum threshold of an indicator is set to a basic level or a value of a similar indicator for a base year, while the minimum threshold of an indicator is set depending on the target value of an environmental policy of a business.

The I_3 index for the "response" category is calculated as follows, (3):

$$I_3 = \sum_{i=1}^{n} c_i \cdot \tilde{x}_{i3} \quad (3)$$

where $x_{i.3}$ is the *i*-th valuated indicator of the "response" category;

c_i is the weighting factor of the *i*-th valuated indicator of the "response" category.

The index I_3 and indicators $\boldsymbol{x_{14.3} - x_{16.3}}$; $\boldsymbol{x_{18.3} - x_{21.3}}$; $\boldsymbol{x_{23.3}}$; $\boldsymbol{x_{25.3}}$; $\boldsymbol{x_{26.3}}$ of the "response" category are related with a monotone increasing dependence: the higher the value of indicators, the higher the I_3 value and, consequently, environmental performance and energy efficiency under the "response" category.

The index I_3 and indicators $\boldsymbol{x_{17.3}}$; $\boldsymbol{x_{22.3}}$; $\boldsymbol{x_{24.3}}$ of the "response" group are related with a monotone decreasing dependence: the higher the value of indicators $\boldsymbol{x_{17.3}}$; $\boldsymbol{x_{22.3}}$; $\boldsymbol{x_{24.3}}$, the lower the I_3 value and, consequently, environmental performance and energy efficiency under the "response" category.

Let us calculate an integrated indicator I specifying business environmental management efficiency using equation (4):

$$I = \sum_{l=1}^{3} c_l \cdot I_l \quad (4)$$

where I_l is the *l*-th index of environmental performance and energy efficiency;

c_l is the weighting factor of the *l*-th index.

In order to study dynamics of greenhouse gas emissions and consumption of energy resources, we suggest that indices of environmental performance I_1, I_2, I_3 comprehensively specifying the "pressure", "state", "response" aspects should be supplemented with special indices (5-10):

1) Greenhouse gas emission intensity index I_{GHG}, (5):

$$I_{ПГ} = \frac{1}{2}\left(\tilde{x}_{7.1} + \tilde{x}_{8.1}\right) \quad (5)$$

where $x_{7.1}$ is a valuated indicator of direct greenhouse gas emissions;

$x_{8.1}$ is a valuated indicator of indirect greenhouse gas emissions;

1/2 is the weighting factor.

Let us calculate a valuated indicator of direct greenhouse gas emissions using equation (6):

$$\tilde{x}_{7.1} = \begin{cases} \dfrac{x_{7.1} - x_{7.1\min}}{x_{7.1\max} - x_{7.1\min}} \\ 0, if\ x_{7.1} \le x_{7.1\min} \\ 1, if\ x_{7.1} \ge x_{7.1\max} \end{cases} \quad (6)$$

where $x_{7.1}$ is an actual value of a direct greenhouse gas emission, t CO_2-e/unit of production;

$x_{7.1max}$ is a direct greenhouse gas emission indicator in a base period, t CO_2-e/unit of production;

$x_{7.1min}$ is a target value of direct greenhouse gas emissions, t CO_2-e/unit of production.

Let us calculate a valuated indicator of indirect greenhouse gas emissions using the same equation.

2) Production energy intensity index I_E, (7):

$$I_{Э} = \frac{1}{2}\left(\tilde{x}_{9.1} + \tilde{x}_{10.1}\right) \quad (7)$$

where $x_{9.1}$ is a valuated indicator of fossil fuel consumption;

$x_{10.1}$ is a valuated indicator of overall consumption of energy resources;

1/2 is the weighting factor.

Let us calculate a valuated indicator of fossil fuel consumption using equation (8):

$$\tilde{x}_{9.1} = \begin{cases} \dfrac{x_{9.1} - x_{9.1\min}}{x_{9.1\max} - x_{9.1\min}} \\ 0, if\ x_{9.1} \le x_{9.1\min} \\ 1, if\ x_{9.1} \ge x_{9.1\max} \end{cases} \quad (8)$$

where $x_{9.1}$ is an actual value of a fossil fuel consumption, GJ/unit of production;

$x_{9.1max}$ is a fossil fuel consumption indicator in a base period, GJ/unit of production;

$x_{9.1min}$ is a target value of fossil fuel consumption, GJ/unit of production.

Let us calculate a valuated indicator of overall consumption of energy resources using the same equation.

3) Production decarbonation index I_D, (9):

$$I_{Д} = \frac{1}{2}\left(\tilde{x}_{20.3} + \tilde{x}_{21.3}\right) \quad (9)$$

where $x_{20.3}$ is a valuated indicator of greenhouse gas emission reduction;

$x_{21.3}$ is a valuated indicator of greenhouse gas occlusion (conservation);

1/2 is the weighting factor.

Let us calculate a valuated indicator of greenhouse gas emission reduction using equation (10):

$$\tilde{x}_{20.3} = \begin{cases} \dfrac{x_{20.3} - x_{20.3\min}}{x_{20.3\max} - x_{20.3\min}} \\ 0, if\ x_{20.3} \le x_{20.3\min} \\ 1, if\ x_{20.3} \ge x_{20.3\max} \end{cases} \quad (10)$$

where $x_{20.3}$ is an actual value of a greenhouse gas emission reduction, t CO_2-e/year;

$x_{20.3max}$ is a greenhouse gas emission reduction indicator in a base period, t CO_2-e/year;

$x_{20.3min}$ is a target value of greenhouse gas emission reduction, t CO_2-e/year.

Let us calculate a valuated indicator of greenhouse gas occlusion (conservation) using the same equation.

The obtained zero value of a valuated indicator of the "pressure" category will correspond to the highest negative environmental impact, while the highest 1 – to the lowest negative environmental impact.

The analysis of dynamics of greenhouse gas emissions and energy consumption using the indicators proposed makes it possible to reveal and prevent risks and to distinguish new possibilities of production efficiency improvement. Nonfinancial reporting on the intensity of greenhouse gas emissions and fossil fuel consumption will make it possible for a company to demonstrate the results of its environmental activities and sustainable business development to parties concerned.

Nonfinancial reporting on greenhouse gas emissions and fuel consumption by Russian businesses lacks maturity if compared with foreign practices [13]. Most Russian businesses use the Main indicators of economic, social and environmental performance specified by the Russian Union of Industrialists and Entrepreneurs to report on key business performance results [14].

We have made a conclusion that a list of environmental indicators disclosed in nonfinancial reports by Russian companies should be completed in order to show the results of business activities on reduction of fossil fuel consumption and greenhouse gas emissions (Tabl. 3).

TABLE 3 BASIC AND RECOMMENDED ENVIRONMENTAL INDICATORS

Energy aspect
Basic indicators:
Energy consumption: gross consumption of energy from all types of energy supplies, GJ
Specific energy consumption in physical terms: ratio of gross energy consumption to the quantity of production, GJ/unit
Recommended (additional) indicators:
Specific fossil fuel consumption in physical terms: ratio of fossil fuels consumed to the quantity of production, GJ/unit
Fossil fuel consumption efficiency: ratio of generated (added) cost to the volume of fossil fuel consumed, RUB/GJ
Energy consumption efficiency: ratio of generated (added) cost to overall energy consumption, RUB/GJ
Emissions-discharge-wastes aspect
Basic indicators:
Greenhouse gas emissions: total volume of greenhouse gas emissions, t CO_2-e/year
Recommended (additional) indicators:
Specific direct greenhouse gas emissions in physical terms: ratio of direct greenhouse gas emissions to the quantity of production, t CO_2-e/year
Specific indirect greenhouse gas emissions in physical terms: ratio of indirect greenhouse gas emissions to the quantity of production, t CO_2-e/year
Greenhouse gas emission reduction: reduction of direct greenhouse gas emissions to base period, t CO_2-e/year
Removal of greenhouse gases: occlusion (conservation) of greenhouse gases following implementation of actions, t CO_2-e/year

CONCLUSION

The proposed assessment system of business environmental performance and energy efficiency is built on the principles of the Social Charter of Russian Business and the United Nations Global Compact and supports assessment systems of sustainability indicators set by legal requirements and voluntary initiatives. Complemented with indicators and indices of greenhouse gas emission intensity and energy efficiency ratio, basic environmental indicators will make it possible for Russian businesses to create a system of balanced and appropriate reporting on their environmental performance, to improve the environmental management system and to enhance efficiency of monitoring, control and assessment of key performance results under the low-carbon economy development.

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