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# Low carbon global economy: scenarios of sustainable development, power consumption and greenhouse gas emission control

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**Abstract.** This paper is devoted to problems of a gradual transfer to renewable energy sources and decarbonization of power systems. It presents the analysis of the structure and the trend in global power consumption, greenhouse gas emissions, and target values of decreased emissions by the largest greenhouse gas emitters. A trend in renewable energy sources in total global power consumption is analyzed. The authors study a potential for carbon capture and storage as an instrument of CO<sub>2</sub> emission neutralization in power and industrial processes. The paper contains indicators to evaluate efficiency of power resource utilization and greenhouse gas emission control.

## 1. Introduction

Modern society becomes more and more dependent on reliable and environment-friendly energy sources, which could provide the economic growth and wealth of people. Gradual decarbonization of energy systems by increasing a share of emission-free or “green” energy sources and decreasing fossil fuel consumption is a key challenge for all countries in the world.

Supporting sustainable development and combating climate change became integral aspects of planning, analyzing and developing the policy on the power industry, as the power sector of economy accounts for two-thirds of total greenhouse gas emissions and 80% of carbon dioxide (CO<sub>2</sub>) emissions. Any effort to cut emissions and mitigate climate change consequences should involve the power sector.

## 2. Literature review

Low carbon development of global economy is driven by performing tasks aimed at decarbonization of the economic complex – a gradual substitution of fossil fuel with alternative energy sources, and technological recovery (capture and storage) of green-house gas emissions.

There are many scenarios of low carbon development of global economy both in the world, for example, the 450 Scenario of the International Energy Agency [1], and in individual countries (the US Low Carbon Economy Act, China’s Pathway towards a Low Carbon Economy, the 20-20-20 Strategy of the European Union). Many of them are under implementation within latest decades. The authors



made conclusions about the most significant and efficient items of the above scenarios for decarbonization of economy of the countries.

Reducing fossil fuel consumption by developing low carbon and energy-efficient technologies is one of core issues of low carbon economy scenarios for developed and developing countries. Considerable progress in cutting greenhouse gas emissions was achieved by performing the mentioned tasks in the EU countries, having exceeded scenario targets and decreased greenhouse gas emissions by 23% from 1990 to 2014 already.

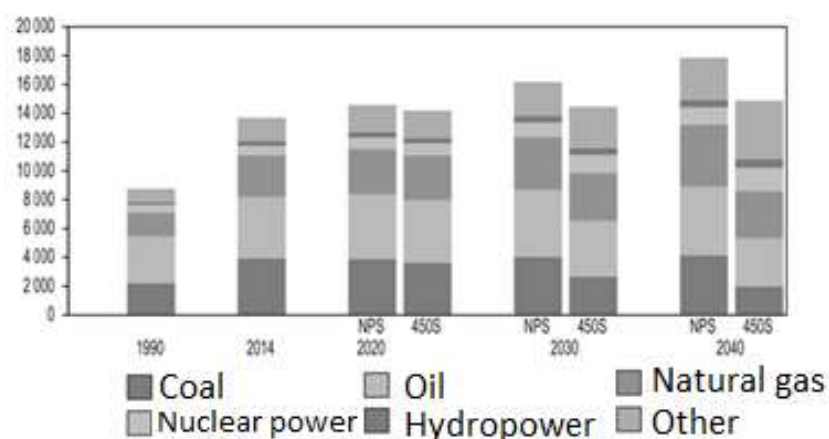
Leading trends in development alternative energy sources include wind and solar energy technologies [2].

Forecast development of carbon capture and storage technologies demonstrates that by 2060 CO<sub>2</sub> emissions will be fully neutralized [3].

To evaluate efficiency of actions in supporting sustainable development and combating climate change, it is required to provide a system of utilization indicators for different types of energy, direct and indirect greenhouse gas emissions, reduction and trapping of greenhouse gases [4,5].

### 3. Sustainable development scenarios – criteria and limitations

The structure and trends in global energy consumption as forecast by 2040 (figure 1) are analyzed in view of two scenarios: a new political scenario (NPS), and a so-called Scenario 450 (450S), that sets a structure and volume of fossil fuel consumption at 450 ppm, when a level of carbon dioxide concentration, critical for climate, will not be exceeded [1].



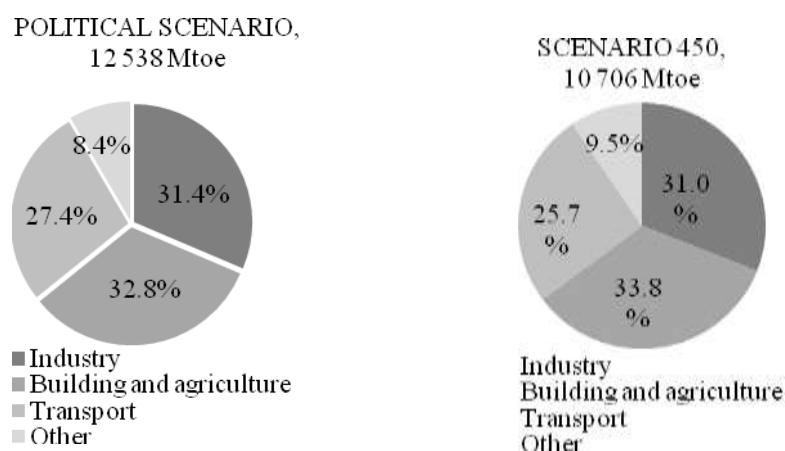
**Figure 1.** Structure and trends in global energy, Mtoe [6].

450S is based on calculations made by the Intergovernmental Panel on Climate Change (IPCC), confirming that to avoid the catastrophic and irreversible climate change with a 90 % probability, it is required by 2050 to keep carbon dioxide concentration in air at 450 ppm, corresponding to a growth of a global average temperature by 2°C [7].

In particular, this means that people should stop increasing a volume of fossil fuel combustion and CO<sub>2</sub> emissions; for reference, in a pre-industrial period carbon dioxide concentration in air did not exceed 280 ppm.

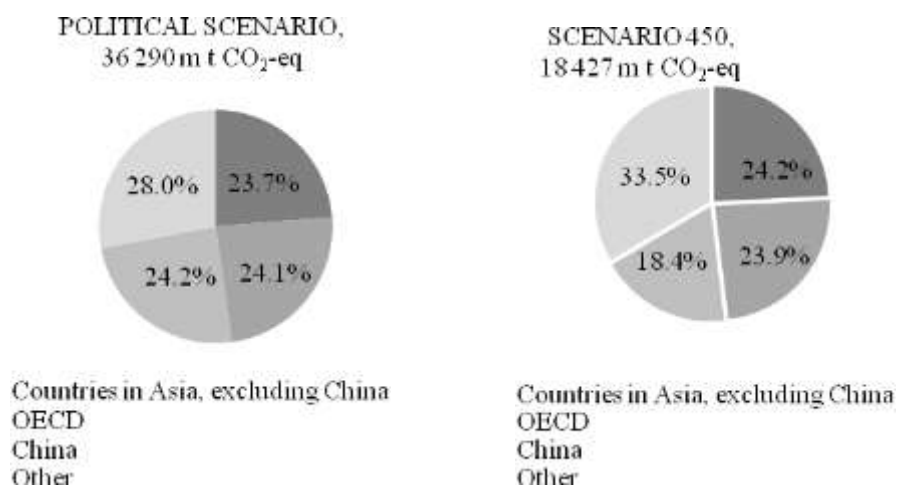
According to 450S, to comply with this critical condition, total energy consumption should be decreased by 14.5 %, with regard to energy consumption in line with the NPS forecast, mainly due to lower coal consumption (by over 50 %), lower oil and natural gas consumption.

In general, a drop of global fossil fuel consumption according to 450S (figure 2) to a level ensuring that carbon dioxide concentration in air critical for climate would not be increased is forecast without significant changes in a fuel consumption structure by industry sectors: the largest consumption (over 30 %) is kept in the industry, building, and agriculture; a 1.7 % decrease in fuel consumption by vehicles is forecast as a result of transferring to ecologically clean energy sources.



**Figure 2.** Structure of fossil fuel consumption by sectors, NPS and 450S scenarios.

Forecast greenhouse gas emissions corresponding to fossil fuel consumption under the NPS scenario (figure 3) will not curb the growth of carbon dioxide concentration in air and, consequently, a global average temperature growth of about 2°C. An increase in carbon dioxide emissions as compared to forecast values under 450S will amount to 17,863 m t of CO<sub>2</sub>-eq, totaling about 50 %.



**Figure 3.** Volume and structure of greenhouse gas emissions, NPS and 450S scenarios [3].

#### 4. Greenhouse gas emissions control – target values

Carbon dioxide emissions in the energy sector represent the majority of global greenhouse gas emissions; so, a need for measures to combat climate change has determined development of the energy policy, but consequences as a result of its implementation are not comforting. Achieved goals on greenhouse gas emissions announced by countries under the Framework Convention on Climate Change will result in maintaining 13.7 bn t CO<sub>2</sub>-eq, 60 % higher than a level required to curb a global average temperature growth of around 2°C by 2035.

First commitments on decreased greenhouse gas emissions were set forth by the first Kyoto Protocol for 2008 - 2012. Participants of the Kyoto Protocol complied with their target values by reducing emissions from fossil fuel combustion, cutting emissions in other sectors (for example, in agriculture and land use), or by using flexible mechanisms of the Kyoto Protocol allowing the

countries to get loans for implementation of projects aimed at reducing greenhouse gas emissions in developing countries and countries in transition.

The Kyoto Protocol was a key driver for development of national emissions trading, acknowledging permits for CO<sub>2</sub> emissions to be traded goods.

Despite its wide coverage (192 countries), the Kyoto Protocol has a limited potential for further settlement of issues related to global emissions.

Commitments taken under the second Kyoto Protocol and the Copenhagen Accord on reducing emissions by 2020 were not turned out to be sufficient to limit a temperature increase to 2°C.

A need for expanding participation and commitments of countries emitting greenhouse gases established a framework for signing the Paris agreements. The global community in Paris in December of 2015 adopted a package of Agreements, expanding commitments of both developed and developing countries to mitigate consequences of climate change. As of 21 August 2017, the Paris agreement was signed by 195 participants, including 160 countries that had ratified the agreement.

Table 1 contains the analysis of information given by participants of the Copenhagen Accord about target greenhouse gas emissions as part of total economy of top greenhouse gas emitters by 2020, and relevant national actions taken to prevent climate change.

**Table 1.** Target values of the top greenhouse gas emitters.

Top greenhouse gas emitting countries	Greenhouse gas emission, m t CO <sub>2</sub> -eq			Target decrease in emissions by 2020
	1990	2005	2015	
China	2109	5399	9084	Decrease by 40-45 % per unit of GDP as compared to 2005
The USA <sup>a</sup>	4802	5702	4998	Decrease by near 17 % as compared to 2005
The European Union	4028	3921	3201	Decrease by 20 %
India	530	1080	2066	Decrease by 20-25 % per unit of GDP as compared to 2005
Russia	2163	1482	1496	Decrease by 15-25 % as compared to 1990
Japan	1042	1178	1142	Decrease by 3,8 % as compared to 2005
Korea	232	458	585	none
Iran	171	418	552	none
Canada	420	541	549	Decrease by 17 % as compared to 2005
Saudi Arabia	151	298	531	none

<sup>a</sup> On 1 June 2017 the United State of America announced about their intention to quit the Paris Agreement

## 5. Research discussion

Renewable energy sources are in a focus of transition to less energy-intensive and more reliable energy system; by 2023 renewable electrical energy production is expected to increase by one third or higher [8].

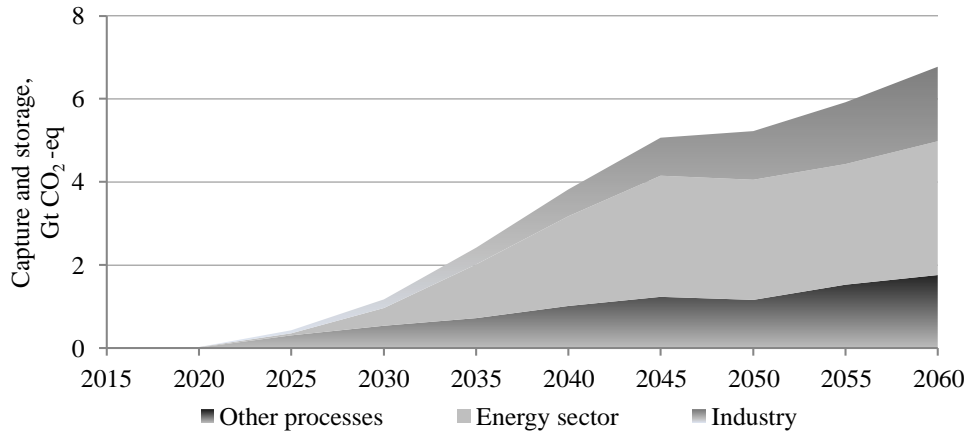
In recent years, the renewable energy source market showed accelerated rates exceeding forecast indicators. In 2017, a key market driver was solar photovoltaics, fostering a global growth of renewable energy sources. With decreasing expenses for its generation, wind and solar energy become more and more compatible with the fossil fuel utilization cost.

Renewable energy sources are forecast to satisfy almost 30% of demand for electrical energy in 2023 as compared to 24% in 2017. Within this period renewable energy sources are expected to provide over 70% of a global growth of electrical energy production.

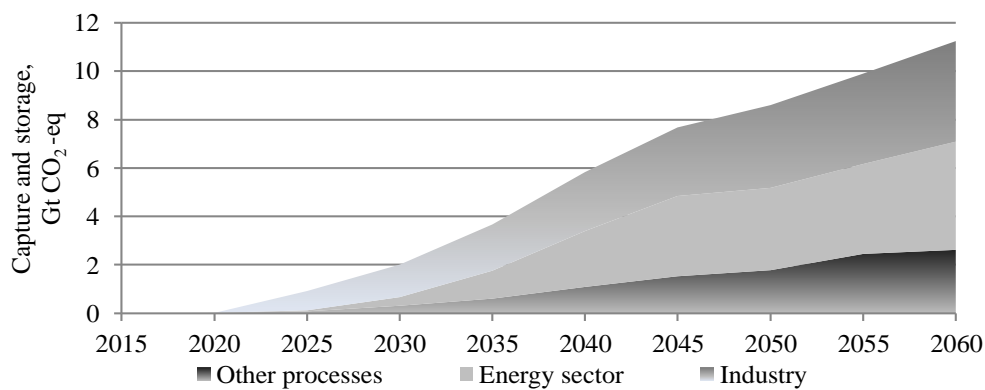
Another instrument for an efficient solution to climate change, carbon capture and storage (CCS), represents a family of technologies, which are used to capture CO<sub>2</sub> from fuel combustion in the energy sector and industrial processes, transport, and store it underground, in depleted oil and gas deposits.

CCS technology potential for generating negative emissions in combination with the bioenergy sector is an integral part of using fuel in the energy sector and industrial processes to fully neutralize CO<sub>2</sub> emissions by 2060. Figures 4 and 5 show a progress of CCS technologies by sectors till 2060;

consequently, according to 2DS, a growth of global average temperature is about 2°C, and according to B2DS, a growth of global average temperature is below 2°C.



**Figure 4.** Forecast progress of CCS technologies, 2DS.



**Figure 5.** Forecast progress of CCS technologies, B2DS.

**6. Methodology**

From 1997, the Coalition for Environmentally Responsible Economies (CERES) partnering with United Nations Environment Programme (UNEP) implements the Global Reporting Initiative (GRI) to increase significance and quality of reporting on sustainable development to the level comparing to a level of financial reporting. One of GRI’s main tasks has been and remains development of a standard ensuring compatibility, integrity, reliability, accuracy and verifiability of information mentioned in a report.

A GRI standard is one of the most popular systems of reporting in the sustainable development field; the report is issued following the Triple Bottom Line principle: the company’s financial indicators, ecological compatibility of production lines, and social policy.

To take environmentally responsible decisions at different levels of managing energy systems and greenhouse gas emissions (state and corporate levels), we need a system of ecological criteria and environment quality indicators. Such criteria are usually beyond conventional market value appraisals, excluded from conventional financial reporting, making it difficult to evaluate a company with regard to its sustainable development [9,10].

Regarding the utilization rate of energy resources and greenhouse gas generation, the authors suggest that the following indicators should be used [11,12]:

- specific direct greenhouse gas emissions, t CO<sub>2</sub>-eq/unit of production,
- specific indirect greenhouse gas emissions, t CO<sub>2</sub>-eq/unit of production,
- specific hydrocarbon fuel consumption, GJ/unit of production,
- specific consumption of energy resources, GJ/unit of production,
- greenhouse gas emission reduction, t CO<sub>2</sub>-eq/year,
- greenhouse gas emission capture, t CO<sub>2</sub>-eq/year.

The above indicators with regard to consumption of different types of energy and direct and indirect greenhouse gas emissions characterize the environmental impact of a plant in view of the utilization rate of energy resources and greenhouse gas emissions, reflect a reduction and capture of greenhouse gases, characterize efficiency of measures taken to support sustainable development and combat climate change.

## 7. Conclusion and further research

Timely and accurate statistics on CO<sub>2</sub> emissions supplemented with such indicators of the energy sector as energy efficiency and energy intensity, providing for an understanding of mechanisms of economy transition to a low carbon way of development, has a central value to assess achievement of global climate goals and distribution of information about the policy of carbon market participants. Society becomes more and more dependent on reliable and environment-friendly energy sources, which could provide the economic growth and wealth of people. Gradual decarbonization of energy systems by increasing a share of emission-free or “green” energy sources and decreasing fossil fuel consumption is a key challenge for all countries in the world.

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