Greenhouse gas balance of Russia: the specifics of the federal districts

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Abstract. The paper is devoted to the analysis of the greenhouse gas balance developed by the authors for the main participating sectors in the context of federal districts based on actual data for 2021. On the one hand, the energy industry is involved, which is the sector of the economy that occupies a leading position in terms of greenhouse gas emissions – up to 80% of total emissions. Greenhouse gas emissions from the main sectors of the fuel and energy complex were estimated: power generation from fossil fuels and production of fuel and energy resources. On the other hand, the volumes of CO_2 absorbed by managed forests of the forest fund, which are the main sink of CO_2, were calculated, taking into account losses caused by logging, fires and other causes. The calculated estimates of greenhouse gas emissions showed that the main inflow in all subjects of the Russian Federation comes from energy generation: the largest emission is in the Ural, Central and Siberian federal districts. In terms of greenhouse gas emissions, the Siberian Federal District stands out in coal production, and the Urals Federal District in hydrocarbon production. The largest contribution to the absorption of carbon dioxide is made by the Siberian and Far Eastern Federal Districts. The contribution of these districts to the total figure for Russia is almost half. The only federal district with a negative net balance of greenhouse gases, as determined by the study, is the Far East.

1 Introduction

In 2015, the Paris Agreement was adopted to strengthen the global response to the threat of climate change by keeping the global average temperature increase at 2°C by 2050 and preferably at 1.5°C by 2040. In the future, it is planned to build a climate-neutral world. In addition, the purpose of the Agreement is to strengthen the ability of countries to cope with the effects of climate change.

The task of the study is to compile a net balance of carbon dioxide for the main components in the context of the federal districts of Russia. According to the National Report of the Russian Federation on the Inventory of the anthropogenic emissions and sinks

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of greenhouse gases not controlled by the Montreal Protocol for the years 1990-2010 [1, 2] and in accordance with the classification of the Intergovernmental Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change up to 80% of all greenhouse gas emissions come from the energy sector. However, this sector includes emissions from the combustion of all types of fossil fuels, regardless of the sectors of the economy in which they occur. This paper assesses greenhouse gas emissions directly from the Russian fuel and energy complex, which includes two main activities: the generation of electrical and thermal energy, as well as the production of fuel and energy resources (FER), such as coal and hydrocarbons.

Assessment and analysis of the total volume of greenhouse gas emissions in the context of federal districts makes it possible to identify those territories where the need for a priority solution of climate problems in the operation of fuel and energy complex facilities is most acute.

One of the measures in the fight against climate change is the compensation of the emissions produced by the absorption of greenhouse gases by terrestrial ecosystems, in particular forests, which are the main sink [3]. The territorial structure of the absorptive capacity of forests makes it possible to identify those areas where such potential is absent or exhausted.

A territorial net balance of greenhouse gases was compiled, in which both positive and negative values are indicated. To do this, the obtained estimates of emissions from energy sector and the absorption capacity of forests by federal districts were compared.

2 Research methods and input data

The national report on the inventory of anthropogenic emissions from sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for 1990–2020 served as the basis for assessing the sinking capacity of forests. [1, 2], which was developed and presented in accordance with the obligations of the Russian Federation under the UN Framework Convention on Climate Change and the Kyoto Protocol to the UN Framework Convention on climate change. The territorial distribution is represented by federal districts (FD).

To quantify greenhouse gas emissions from the fuel and energy complex, the Guidelines of the Interstate Panel on Climate Change (IPCC) of 2006 [4] were adopted as a basis.

2.1 Methods for estimating greenhouse gas emissions from energy generation

To calculate greenhouse gas emissions from the generation of electricity and heat, one of the methods set out in The Ministry of Natural Resources and Environment of The Russian Federation No. 300 was used, which defines methodological guidelines and guidance for quantifying greenhouse gas emissions by organizations that carry out various economic activities [5]. The method is based on the data of the national fuel balance and emission factors, which are determined by the National Inventory [1]. It is important to note that all factors are designed for different types of fuel: solid, liquid and gaseous for stationary combustion in power plants. Calculation of carbon dioxide was made, which is the only compound entering the atmosphere from energy generation facilities using fossil fuels. The description of the method for estimating carbon dioxide emissions and the calculation sequence are most fully reflected in [6].

2.2 Methods for estimating greenhouse gas emissions from energy production

The calculation of greenhouse gas emissions from the extraction of fuel and energy resources includes an assessment of the release of greenhouse gases into the atmosphere directly during extraction, as well as from subsequent operations with resources.

When coal is mined in accordance with the IPCC guidelines [4], the calculation is carried out only for methane, depending on the method of extraction (underground or opencast) and the geographical location of the deposits. It is believed that there are no carbon dioxide emissions from coal mining.

According to the methodology, calculations of greenhouse gas emissions from hydrocarbon production were carried out for three main components: 1) operations with oil and gas condensate; 2) operations with natural gas; 3) combustion of hydrocarbons during operations with oil and natural gas (flaring) [1].

In general, when assessing greenhouse gas emissions from the fuel and energy complex, the total emission is determined by bringing the emissions of individual ingredients (carbon dioxide and methane) to CO_2-eq, taking into account global warming potentials [5].

2.3 Methods for assessing the absorption capacity of forests

According to the principles of the IPCC National Greenhouse Gas Inventories, the following categories of land use are distinguished in the land use, land use change and forestry (LULUCF) sector: forest lands, croplands, grasslands and pastures, wetlands, settlements, other lands, harvested timber products, indirect emissions from managed lands. Forest lands as well as grasslands and pastures are greenhouse gas sinks. The remaining categories of land are involved in the formation of greenhouse gas emissions. This paper estimates the absorption capacity of managed forests, which account for 84.6% of the total.

The absorption capacity of forests is related both to CO_2 absorption, which is influenced by the climatic features of the territory, as well as the species of woody plants growing on it, and to CO_2 losses caused by clear-cutting, destructive fires and other causes of death of forest stands. The CO_2 budget is calculated as the difference between CO_2 absorbed by forests and CO_2 lost by forests [7].

The recalculation of absorptions of carbon into carbon dioxide was carried out by multiplying the corresponding value by the conversion factor for carbon into carbon dioxide in accordance with their molecular weights.

3 Estimation of greenhouse gas emissions from the fuel and energy complex

3.1 Greenhouse gas emissions from power generation

The calculation of greenhouse gas emissions was carried out in accordance with the consumption of various types of fuel for 2021 for three categories of power facilities: TPPs, DPPs and boiler houses. In Russia as a whole, the estimated emission of carbon dioxide from energy generation facilities is estimated at 764 million tonnes. As expected, large thermal power plants running on fossil fuel account for the largest share in emissions – up to 77% of the total values. In the territorial context, four federal districts stand out: the Urals - 21% of all carbon dioxide emissions, the Central – 20%, the Siberian – 19% and the Volga – 16%, Figure 1.

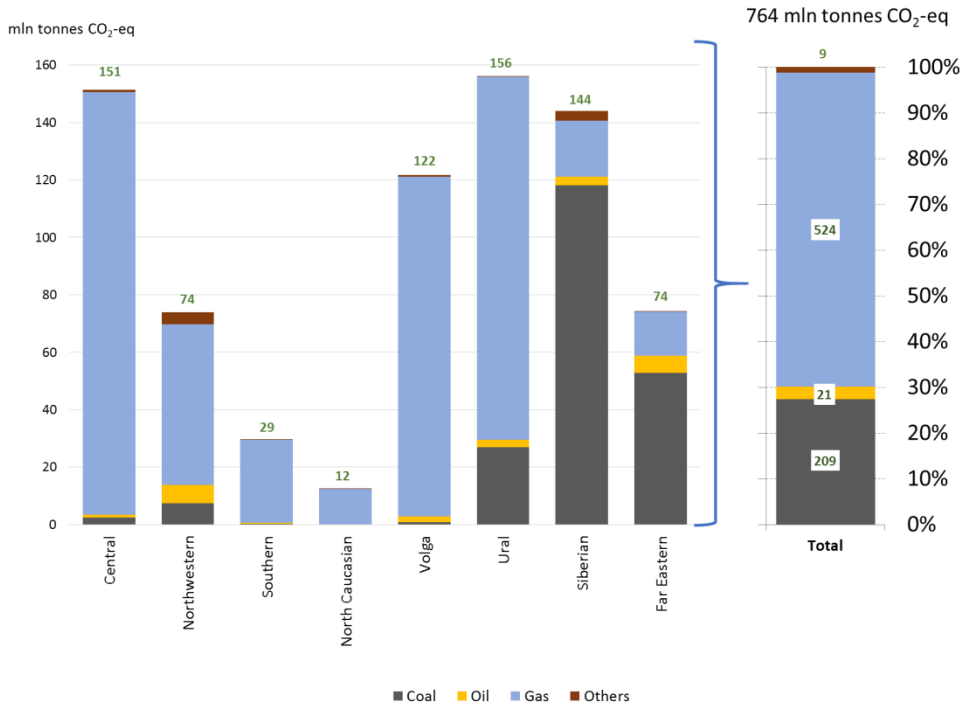


Fig. 1. Territorial distribution of estimated carbon dioxide emissions from energy generation in 2021.

At the same time, the Siberian and Far Eastern federal districts stand out significantly, CO_2 emissions in these districts occur mainly due to coal combustion, while in the rest – due to gas fuel, as in Russia as a whole.

3.2 Greenhouse gas emissions from energy extraction

The calculations of greenhouse gas emissions from the extraction of all types of fuel and energy resources in Russia showed that the oil and gas industry makes a significant contribution – up to 65% of the total emission of 204.6 million tonnes of CO_2-eq., Table 1.

Table 1. Estimated greenhouse gas emissions from the extraction of fuel and energy resources by federal districts in 2021, mln tonnes CO_2-eq.

Federal District of the Russian Federation, Russia	Production		Total
	Coal	Hydrocarbons	
Central	-	2.3	2.3
Northwestern	4.8	5.0	9.7
Southern	4.2	2.2	6.5
North Caucasian	-	0.6	0.6
Volga	-	15.8	15.8
Ural	-	66.7	66.7
Siberian	50.5	28.6	79.1
Far Eastern	11.8	12.0	23.8
Total	71.3	133.3	204.6

The analysis of total greenhouse gas emissions by type of activity in the production of fuel and energy resources showed that in the Siberian Federal District the contribution of

coal mining exceeds all activities in the oil and gas industry, which also makes a significant contribution to the total figures for Russia as a whole up to – 35%, Figure 2.

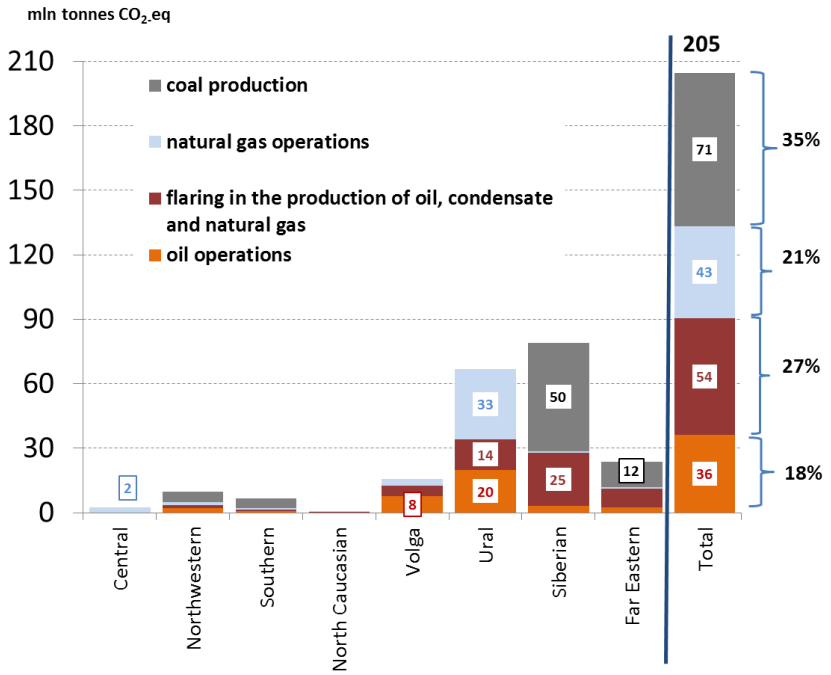


Fig. 2. Territorial distribution of estimated greenhouse gas emissions from the production of fuel and energy resources in 2021, mln tonnes CO_2-eq.

Estimated emissions of greenhouse gases (carbon dioxide and methane) from the extraction of fuel and energy resources are characterized by their significant predominance in the Siberian and Ural Federal Districts, which together account for 72% of the Russian figure.

3.3 Total greenhouse gas emissions from energy generation

The total greenhouse gas emissions from energy generation and production of fuel and energy resources are estimated at 968 million tonnes of CO_2-eq. In the structure of activities, almost 80% are generating power facilities, Figure 3. The territorial structure of greenhouse gas emissions is characterized by the predominance of the Urals and Siberian Federal Districts.

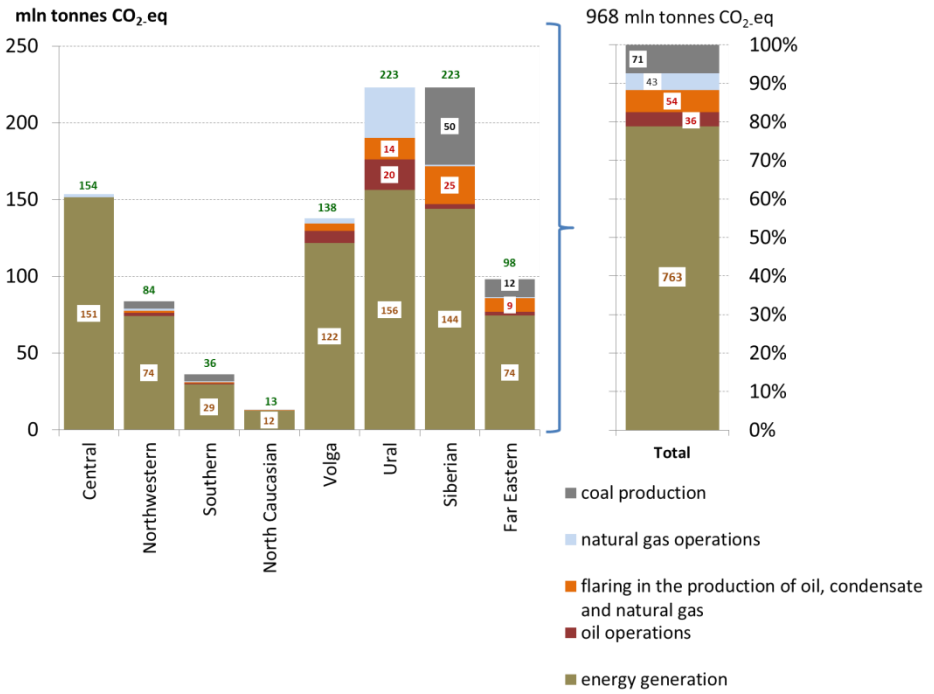


Fig. 3. Territorial distribution of estimated greenhouse gas emissions from fuel and energy facilities.

4 Estimation of carbon dioxide absorption by managed forests

The study of the structure of the CO_2 budget of managed forests in the context of federal districts in 2021 showed that the largest volumes of CO_2 are absorbed and lost by managed forests in the Far Eastern and Siberian Federal Districts (Fig. 4). This is due to the fact that the area of forests in these federal districts is the highest.

For the same reason, absorption and emissions of CO_2 by managed forests of the forest fund in the North Caucasus and Southern federal districts are insignificant on a national scale. Table 2 presents data on the CO_2 budget of managed forests by federal districts of the Russian Federation. Table 2 shows that the highest absolute value of the budget of absorbed CO_2 is observed in the Far Eastern and Siberian federal districts. However, the specific budget of absorbed CO_2 in these federal districts is quite low compared to others. The highest value of the specific budget of absorbed CO_2 is observed in the Central, North Caucasian and Southern districts.

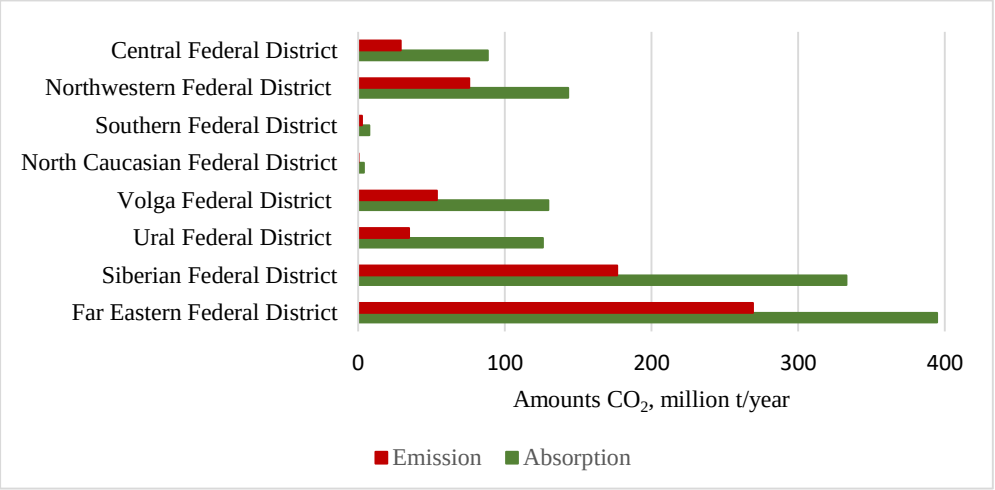


Fig. 4. The structure of the CO_2 budget of managed forests of the forest fund by federal districts in 2021.

Table 2. CO_2 budget of managed forests by federal districts in 2021.

Federal District of the Russian Federation, Russia	Area, million hectares	Balance absorbed CO_2, mln tonnes/year	Specific balance absorbed CO_2, mln tonnes/year from 1 hectare
Central	22.7	63.4	2.8
Northwestern	90.1	72.7	0.8
Southern	3.0	6.5	2.2
North Caucasian	1.6	3.8	2.3
Volga	38.5	80.1	2.1
Ural	71.2	94.2	1.3
Siberian	186.8	164.3	0.9
Far Eastern	276.3	137.3	0.5
Total	690.1	622.2	0.9

5 Territorial balance of greenhouse gases

The calculation of all indicators that make up the balance of greenhouse gases: inflow and absorption, was carried out in units of CO_2-eq. An analysis of the balance of emissions and removals of greenhouse gases in the context of federal districts showed that throughout Russia, the supply of greenhouse gases from the energy sector prevails over their absorption by managed forests. The only federal district with a negative balance (-39 million tonnes of CO_2-eq./year) is the Far East. This is due to the relatively low CO_2 emissions from the energy sector and the significant amount of CO_2 absorbed due to the large area of managed forests (Figure 5). The highest value of the difference between the inflow and absorption of greenhouse gases is typical for the Ural and Central federal districts. Approximately the same values in the Volga and Siberian federal districts.

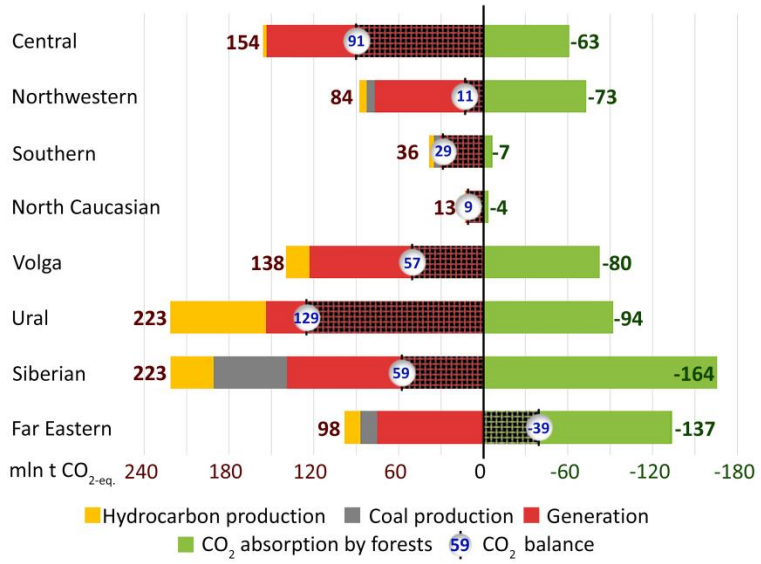


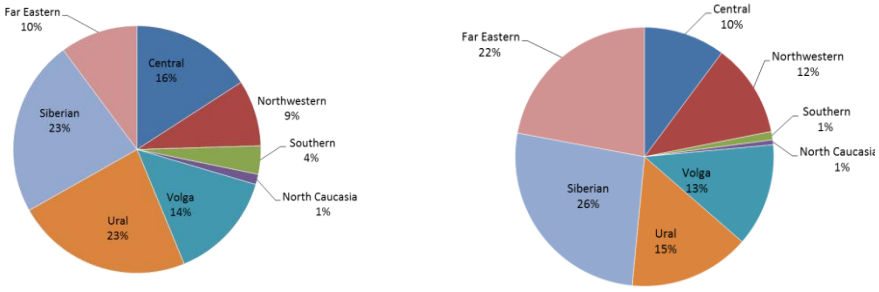
Fig. 5. Territorial balance of greenhouse gases in the Russian Federation in 2021.

6 Conclusion

Among the main measures aimed at combating climate change within the framework of the Paris Agreement, states single out both reducing emissions from the energy sector and increasing the absorption of carbon dioxide by terrestrial ecosystems.

An assessment of greenhouse gas emissions from energy generation in the territorial context showed that the highest values are typical for the Urals, Central, Siberian and Volga federal districts. Estimated greenhouse gas emissions from the extraction of fuel and energy resources are characterized by their predominance in the Urals and Siberian districts –23% each (Figure 6*a*).

In the structure of activities, 80% is greenhouse gas emissions from energy generation. Assessment of CO_2 absorption by managed forests of the Russian Federation in the territorial context showed that the largest volume of CO_2 is absorbed in the Siberian and Far Eastern districts – 26% and 22%, respectively (Figure 6*b*).



a) *б)*

Fig. 6. Share of federal districts in greenhouse gas emissions from energy and their share in CO_2 absorption by managed forests.

The net balance of greenhouse gases in Russia is estimated at 346 million tonnes of CO_2-eq in 2021. In terms of territory, the Urals and Central Federal Districts are

characterized by the greatest predominance of CO_2 inflow over absorption. The negative net balance of greenhouse gases is only in the Far Eastern Federal District, where absorption by managed forests exceeds emissions from energy facilities, Figure 7.

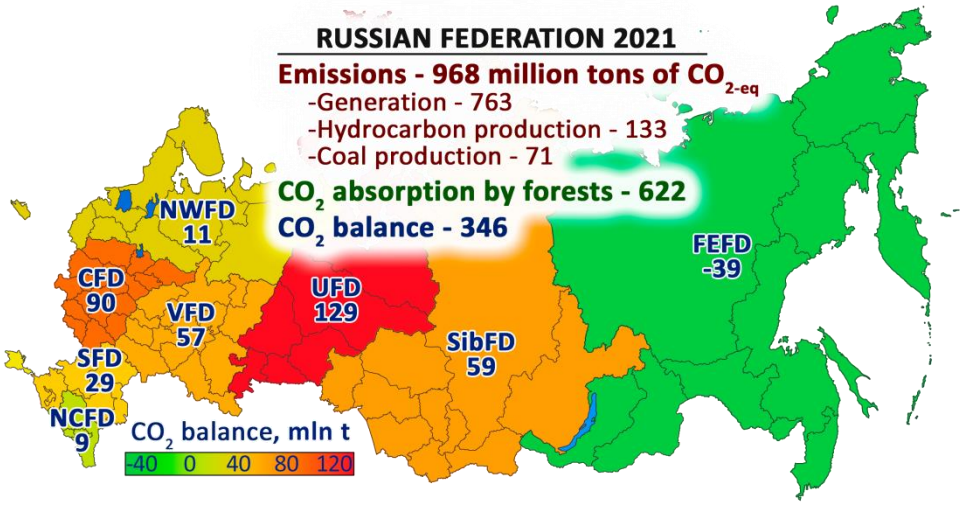


Fig. 7. Net balance of greenhouse gases in Russia.
Note: CFD - Central Federal District; NFD - Northwestern Federal District; SFD - Southern Federal District; NCFD - North Caucasian Federal District; VFD - Volga Federal District; UFD - Ural Federal District; SibFD - Siberian Federal District; FEFD - Far Eastern Federal District.

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