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Analysis of the Leading Environmental Impacts of Greenhouse Gas Emissions

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Abstract The goal of this paper is the analysis of conditions and dynamics of greenhouse gas emissions produced by leading countries and the leading impacts they cause to the environment. Our investigation leads to the statistical observations of greenhouse gas emissions collected by the International Energy Agency and National statistical service and containse their inconsistency proofs. We discover that the main greenhouse gas in Ukraine is carbon dioxide CO2. We anlyse the dynamic of CO2 emissions in Ukraine according to economy sectors. In addition, we evaluate Ukraine's impact on world air pollution based on comparison of total greenhouse gas emissions in Ukraine and emissions datas by leading countries. We define thaat indexes metrics of greenhouse gas emissions (including CO2) are not showing full characteristics of Ukraine's economic situation relative to its carbon intensity.Our results indicate that more informative would be using ratios by which one can compare the amount of emissions with the economy sizes (GDP and carbon intensity, specific emissions per capita etc). The appropriate analysis was produced with that indication. Our research indicated that during the analysed period (1990-2017) the greenhouse gas emissions in Ukraine significantly improved but that improvement was not caused by effective state policy actions including providing effective decarbonisation policy and country's transition to low carbon development. Instead, this improvement was the result of the man-made load on the Ukraine's environment (caused by the economic decline, deindustrialisation and certain structural economic chengings). Some inductions exist that Ukraine places a much lower stage of decarbonisation than the leading countries. According to the responsibilities and commitments, the expected level of emissions in Ukraine in 2030 may not exceed 60% of 1990 emissions. In absolute numbers it means that formally Ukraine would have to comply with the United Nations Framework Convention demands. To achieve this goal Ukraine should follow the requirements of the development of renewable energy and the decarbonisation of its economy (which are contained in a number of international treaties). Therefore, there exists a necessity of developing and implementation the effective state policy of economic decarbonisation in the near future.

Keywords: *environmental impacts, greenhouse gas emissions, environment, leading technologies*

1 Introduction

One of the most important global problems for humanity is the increase of greenhouse gas emissions, first of all it is carbon dioxide, and climate change as a result. World leaders concluded a number of international agreements that provide for the reduction of greenhouse emissions in order to to solve this problem (Niño-Amézquita et al. 2017).

Among other countries, Ukraine also committed to significantly reduce greenhouse gas emissions. The implementation of this solution should accordingly affect the socio-economic growth of the country, since the main division of its economy that produces carbon dioxide is industry, which includes electricity as well (Strielkowski 2017).

Hence, in these conditions, it is necessary to analyze the actual state of the problem of greenhouse gas emissions in Ukraine for ulterial elaboration of an effective concept for reducing greenhouse gas emissions in the country

and scenarios for its implementation which would help to achieve the objectives without a negative impact on the socio-economic development of Ukraine and the quality of life of people.

The most significant studies of the problem of reducing greenhouse gas emissions in the energy sector were carried out by: International Energy Agency (IEA), US Energy Information Administration, World Energy Council (WEC). Also within the substance of this issue, it is necessary to highlight the work of foreign and domestic experts. Lisin et al. (2015), Newbery et al. (2018), Lisin et al. (2018) or Pollitt (2019) analyze the prospects for development of the global carbon market as a central issue in reducing greenhouse gas emissions. The focus of the study is to figure out what policies should be implemented to support global decarbonization.

Another interesting research (see Strielkowski et al. 2016) is devoted to assessing climate change provisions and EU policies used for reducing greenhouse gas emissions, as well as to building the EU's position on sustainable development. The authors concluded that a unified European climate strategy is necessary in the context of new political and economic changes facing Europe and the importance of the provisions of the Paris Agreement for existing EU members, as well as for countries that aspire to become EU members.

A research by Kyzym et al. (2018) is devoted to substantiating the priority areas of structural and technological modernization of the Ukrainian electricity sector, taking into account changes in the national economy and the development trends of modern energy and restoration energy in the world.

Khaustova et al. (2018) investigate the problem of forming an energy policy based on the concept of energy security. The authors proposing to consider the energy supply, energy conversion and energy consumption subsystems as components of the energy security system, the assessment of the quality for functioning of which is advised to be carried out by using system indicators of energy dependence, energy efficiency and energy saving. The research is also proving that the constant existence of the energy system is ensured by such a component of energy security as energy resistance. Particular attention is paid to the need to reduce the negative impact of energy on the environment (Lisin et al. 2014; Gryshova et al. 2017)

At the same time, the problem of reducing greenhouse gas emissions in the world remains open and extremely urgent. With regard to Ukraine, a number of issues remains particularly for reduction of carbon dioxide emissions through decarbonization of the electric power industry.

Thus, the purpose of this research is to analyze the state and dynamics of greenhouse gas emissions by world leading countries and Ukraine, and their impact on the environment.

2. Materials and methods of research

The statistical sources used in this study include the data from the International Energy Agency (hereinafter called "IEA"), data from the State Statistics Service of Ukraine on the state of the environment and emissions of pollutants and greenhouse gases into the atmosphere from stationary sources of emissions, as well as some novel analytical data from national research centers. Taking into account the goal in the study the used methods of analysis and comparisons, as well as groupings, were used.

3. Results and discussions

In accordance with its international obligations, Ukraine conducts statistical observations and systematic monitoring of greenhouse gas emissions and prepares reports in accordance with the requirements of the UN Framework Convention on Climate Changes.

Statistical reporting on environmental pollution (Ukrstat 2017; Rada 2018) contains information on atmospheric emissions of a wide range of pollutants, but the greenhouse gases are not displayed separately. Only in 2018, carbon dioxide emissions began to be separately identified in the statistical reporting (Rada 2018).

The latest statistical research on the emissions of the State Statistics Service of Ukraine was published in the form of the statistical collection "Environment of Ukraine" for 2017 (Ukrstat 2017). In this study carbon dioxide emissions are recorded only from stationary sources of pollution since 2016 (combustion plants, contactless technological furnaces, contact processes, etc.) and emissions from mobile sources (internal combustion engines of vehicles) are not taken into account (see Table 1).

Table 1. Carbon dioxide emissions in 2010-2017 by source, thousand tons

Sources	Years				
	2010	2014	2015	2016	2017
Stationary	165041,8	166926,7	138932,1	150581,0	124217,9
Mobile	33188,9	27813,1	23139,8	…	…
Total	198230,7	194739,8	162071,9	…	…

Source: Ukrstat (2017)

National inventory of anthropogenic emissions which forms periodically for international obligation fulfilment, also has information about Ukrainian greenhouse gas emission

Last National inventory of anthropogenic emissions was developed as a result of 2011 (SEIA 2019). Official website IEA (Official Website of the International Energy Agency) contains more accurate datas about greenhouse gas emissions.

Data analysis shows that main greenhouse gas in Ukraine is carbon dioxide, which specific weight in general emissions in 1990-2011 fluctuated between 77,7 % (in 2011) to 85,1 % (in 200). Data comparisons of carbon dioxide emissions in 2010 shows the disparity of this datas. Significant difference between IEA and national statistical observations data (Ukrstat 2017) is explained below.

Firstly, national statistical reporting captures only stationary sources of emissions, while in IEA international statistics consider the wider circle of pollutants (except energetics and industry also include emissions from all modes of transport, emissions from agriculture, emissions from waste management, etc.)

Secondly, data discrepancy explained by different approaches in identification of pollution load. National statistical surveys are carried out on data reported in polluting enterprise statistics. Such a report is based on output and approved specific emission standards on unit of production.

For international statistics purposes emissions are determined by special calculation methods, which developed for different types of economic activities and different types of fuel based on its used amount. Carbon balance (different uses of different types of organic fuel) appeared as a basis of calculations of international statistics. Besides, GHG emissions are calculated separately of non-fuel related activities (waste management, agriculture, etc.). Thence, in the national statistical observations, the amount of emissions is determined based on volume of production, when in international statistics determine the amount of fuel used. With regard to the aboe, it could be concluded that the IEA data are more representative than the statistics. In addition, these data are used by international organizations to assess Ukraine's compliance with international climate protection commitments and to ensure low carbon development. It is the foundation to further analysis to be done on the basis of data from the National Inventory and other documents established under the international obligations.

According to IEA data (IEA 2020) in Table 2, total datas of greenhouse gas emissions provided in individual sectors.

Table 2. Dynamics of CO2 Emissions in Ukraine by Economic Sectors, million tons

Economy sector	Years							
	1990	1995	2000	2005	2010	2015	2016	2017
Production of electricity and heat	333	191	133	129	123	90	101	83
Industry	195	98	81	75	61	42	38	31
Transport	55	33	27	31	34	23	24	25
Household sector	52	52	41	37	35	23	23	22
Agriculture	22	5	3	8	4	4	5	4
Other energy industries	24	13	7	9	7	4	4	3
Total	689	396	295	291	267	188	198	171

Source: IEA (2020)

As evidenced by the data given in Table 2, for all sectors in Ukraine, a steady reduction in emissions is observed in dynamics. Thus, in the energy and industrial processes, the level of greenhouse gas emissions in 2011 amounted to 24.9% and 15.9% of its level in 1990. In general, greenhouse gas emissions in 2017 amounted to 24.8% of its level in 1990. But such a reduction in emissions is explained as due an inefficient environmental policy of the country, and a significant decrease in production capacity, that happened after independence.

According to the research of the Scientific and Design Center for the Development of the United Energy System of Ukraine SE “Ukrenergo” (hereinafter - SDCD) (Ministry of Energy of Ukraine 2018), which includes World Bank data, from 1990 to 2014. Real GDP of Ukraine declined by 39 % that is more than all countries of the world, against the background of almost doubling world GDP. According to the same study, the fate of the service sector in GDP grew from 29.8% in 1990 and up to 62.8% in 2014. In another study of the SDCD, it is noted that at the same time the real GDP of the industrial sector since 1990 decreased almost 3 times, which was not observed in any country in the world. That is in the context of such processes, the observed decrease in energy intensity (and, accordingly, carbon dioxide) of Ukraine’s GDP was determined mainly by structural and resource factors rather than technological factors (Ukraine and Climate Change Policy 2016).

At the same time, the energy intensity of the GDP of the industrial sector of Ukraine is more than four times higher than the average European indicator. Since 1990 the value of this indicator has only increased, taking into

account structural changes within the sector itself, that indicates on the almost complete absence of any technological improvements in production processes (Ukraine and Climate Change Policy 2016).

The technical and technological backwardness of many industries has a definite effect on the carbon content of GDP. For example, in 2013 the indicator of energy use for the production of one ton of steel in Ukraine was 50% higher than the world average. In particular, extremely energy-intensive open-hearth steel production technologies are still actively used in Ukraine: for example, in the world there was only 7,6 miotons of steel produced this way in 2014, of which 5,6 mio tons (or 74%) in Ukraine (Ukraine and Climate Change Policy 2016).

On the other hand, in agriculture, the level of specific energy consumption per unit of GDP created is even lower than the European average, given the high share of manual labor in agriculture and the significant contribution of the household sector for creation of products of this type of economic activity, particularly in the process of self-procurement and farming (Ukraine and Climate Change Policy 2016). Table 2 is showing dynamics of emissions which in uninformative without comparison with data from other countries of the world.

It is possible to assess the impact of Ukraine in global air pollution by comparing the total greenhouse gas emissions of "Ukrainian origin" with emissions from other countries. Table 3 shows the dynamics of carbon dioxide emissions in 1990-2015.

Table 3. Dynamics of CO2 Emissions by Selected Countries of the World in 1990 – 2017

Country	Years							
	1990	1995	2000	2005	2010	2015	2016	2017
China	2122	2937	3140	5449	7875	9145	9109	9302
USA	4803	5074	5730	5703	5352	4929	4838	4761
EU-28	4024	3812	3786	3923	3613	3216	3202	3209
India	529	703	885	1074	1583	2027	2058	2162
Russia	2164	1548	1474	1482	1529	1534	1511	1537
Japan	1042	1118	1136	1167	1127	1156	1147	1132
Ukraine	689	396	295	291	267	188	198	171
World	20521	21387	23240	27075	30571	32431	32414	32840

Source: IEA (2020)

The data in Table 3 indicates that, compared with the most powerful economies in the world, the share of Ukrainian emissions in global volumes for the period 1990-2017. Decreased from 3.4% in 1990 up to 0.5% in 2017, almost by 7 times. At the same time, the mass of global emissions over this period increased by 1.6 times while the mass of Ukrainian emissions decreased by 4 times. Such dynamics is explained first of all by the growth of the world economy, the contraction of the national economy and changes in its structure.

The analysis of the absolute indicators of greenhouse gas emissions (including carbon dioxide) does not completely characterize the economy of Ukraine in view of its carbon dioxide content. More informative is the use of relative indicators, then it is possible to compare the size of emissions with the size of the economy (energy intensity and grossness of GDP, specific emissions per capita, etc.).

Energy intensity of the economy (an indicator that shows how much energy is spent on creating a unit of GDP) in dynamics over 2010-2015. It is characterized by the data given in Table 4.

Table 4. Key Energy Indicators of Ukraine in 1990 – 2017

Indicator	Years							
	1990	1995	2000	2005	2010	2015	2016	2017
GDP energy intensity by GCS, t / USD USA	0,5	0,6	0,6	0,4	0,4	0,3	0,3	0,3
Carbon intensity of GDP per SCC, kg CO2 / USD. USA	1,3	1,6	1,3	0,9	0,8	0,6	0,6	0,5
CO2 emission rate per tonne of primary energy supply, kg CO2 / tonne	2,7	2,4	2,2	2,1	2,0	2,0	2,2	1,9
Primary energy consumption per capita, ie / person	4,9	3,2	2,7	3,0	2,9	2,1	2,0	2,0
CO2 emissions per capita, ie / person	13,3	7,7	6,0	6,2	5,8	4,2	4,4	3,8

Source: Ukrstat (2017)

The decrease in energy intensity of GDP is explained by the crisis phenomena and by a significant decrease in the demand for energy resources from the most energy-intensive sectors of production. Overall, with a reduction in the country's purchasing power parity (PPS) by 40% in 2017 (compared to 1990), the intensity of CO2 emissions per tonne of primary energy supply has decreased by 30%.

The carbon intensity of Ukraine's GDP remains one of the highest in the world (Table 5). However, the gap of the country from the world average level has significantly decreased. When in 1990 the indicator in Ukraine exceeded the world average by 2.6 times, then in 2017 this excess was 1.7 times.

Table 5. Dynamics of carbon intensity of GDP by PCA in selected countries in 1990 – 2017

Country	Years							
	1990	1995	2000	2005	2010	2015	2016	2017
China	1,2	0,9	0,7	0,7	0,6	0,5	0,5	0,4
USA	0,5	0,5	0,5	0,4	0,4	0,3	0,3	0,3
EU-28	0,4	0,3	0,3	0,3	0,2	0,2	0,2	0,2
including								
Germany	0,4	0,3	0,3	0,3	0,2	0,2	0,2	0,2
France	0,2	0,2	0,2	0,2	0,2	0,1	0,1	0,1
Poland	0,9	0,8	0,5	0,5	0,4	0,3	0,3	0,3
Hungary	0,4	0,4	0,3	0,3	0,2	0,2	0,2	0,2
Slovakia	0,7	0,6	0,4	0,4	0,3	0,3	0,2	0,2
India	0,4	0,4	0,3	0,3	0,3	0,3	0,3	0,3
Russia	0,8	0,9	0,8	0,6	0,5	0,5	0,5	0,5
Japan	0,3	0,3	0,3	0,3	0,3	0,3	0,2	0,2
Ukraine	1,3	1,6	1,3	0,9	0,8	0,6	0,6	0,5
Belarus	1,2	1,0	0,8	0,5	0,5	0,3	0,3	0,3
World	0,5	0,4	0,4	0,4	0,3	0,3	0,3	0,3

Source: Ukraine and Climate Change Policy (2016)

Statistics of the level of environmental pollution is also carried out using an indicator, the volume of emissions of harmful substances per capita (ratio of mass emissions to the population of the country). In the table 6 showed carbon dioxide emissions per capita by country.

Table 6. Dynamics of CO2 emissions per capita by different countries of the world in 1990 – 2017

Country	Years							
	1990	1995	2000	2005	2010	2015	2016	2017
China	1,9	2,4	2,5	4,2	5,9	6,6	6,6	6,7
USA	19,2	19,1	20,3	19,3	17,3	15,3	15,0	14,6
EU-28	8,4	7,9	7,8	7,9	7,2	6,3	6,3	6,3
including								
Germany	11,8	10,5	10,0	9,7	9,5	8,9	8,9	8,7
France	5,9	5,8	6,0	5,9	5,2	4,5	4,5	4,6
Poland	9,1	8,7	7,9	7,8	8,0	7,4	7,6	8,0
Hungary	6,3	5,5	5,2	5,4	4,7	4,3	4,5	4,7
Slovakia	10,4	7,7	6,8	6,9	6,4	5,4	5,6	5,9
India	0,6	0,7	0,8	0,9	1,3	1,6	1,6	1,6
Russia	14,6	10,4	10,1	10,3	10,7	10,7	10,5	10,6
Japan	8,4	8,9	9,0	9,1	8,8	9,1	9,0	8,8
Ukraine	13,3	7,7	6,0	6,2	5,8	4,2	4,4	3,8
Belarus	9,8	5,6	5,2	5,7	6,3	6,5	5,6	5,7
World	3,9	3,7	3,8	4,2	4,4	4,4	4,4	4,4

Source: IEA (2020)

In according to this indicator, Ukraine also declare a tendency to improve the situation: for the period 1990-2017 carbon dioxide emissions per capita decreased by 71.4%, while world average specific emissions increased by 12.8%. Generally, in according to the table 6 and the countries therein, Ukraine shows the largest decline in

this indicator. As for 2017 specific carbon dioxide emissions in Ukraine were less than in the more developed European 28 countries. However, if we compare Ukraine with other countries that are carrying out significant industrialization of the economy (China - growth 3.5 times, India - growth 2.7 times), we can conclude that such improvement in Ukraine is most likely due to the processes of de-industrialization.

Indirectly, Ukraine's contribution to environmental pollution and its reduction potential can be estimated using the specific indicator of energy use by the population per square meter. This indicator is likely significantly higher than most EU countries and 40% higher than the European average. Henceforth, twice as many resources are used for home heating and hot water supply per square meter of living space than in Europe with a similar climate. In Ukraine, this indicator is on average 44% higher than in Germany and 56% higher than in Sweden.

4. Conclusions

Summarizing the comparisons can be made the following conclusions: First of all, during the analyzed period (1990-2017), the situation with greenhouse gas emissions in Ukraine has significantly improved. But this improvement is not the result of an effective state policy of decarbonising the economy and of the country's transition to low-carbon development. The main reason for the reduction of technogenic load on the environment in Ukraine was the world's largest economic downturn, de-industrialization and corresponding structural changes in the economy.

Second, despite this fact, the economy of Ukraine is on a number of indicators at a lower degree of decarbonisation than in the world-leading countries. At present, the GDP fall has stopped, the new structure of the national economy was formed and these factors in the future will not affect the performance of Ukraine, that characterize the decarbonisation of the economy.

According to the commitments made (submitted to the UNFCCC Secretariat), the expected level of emissions in 2030 should not exceed 60% of greenhouse gas emissions of 1990's levels. In absolute terms, this corresponds to the amount of emissions of not more than 566 mio tons of CO2 equivalent. / year, which is significantly higher than level achieved in 2011 (394 mio tons of CO2 eq. - table. 2). Eventually Ukraine has formally already fulfilled the requirements of the UN Framework Convention, however in the near future it will be necessary to develop and implement an effective state policy to decarbonize the economy. This statement is explained as follows. First of all, the requirements for the development of renewable energy and the decarbonization of the economy are contained in a number of international treaties, agreements etc. Particularly requirements related to the decarbonization of the economy are contained in the Association Agreement between Ukraine and the EU, the Memorandum of Understanding on cooperation in the energy sector between Ukraine and the EU, Energy Community agreement. Secondly, in accordance with the provisions adopted by world leaders, decarbonization of the economy is a prerequisite for the formation and implementation of a sustainable development strategy.

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