Spatial analysis of carbon dioxide emission processes from cement production and iron and steel production in Ukraine

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Abstract—**Carbon dioxide is the most significant greenhouse gas with the longest lifespan in the atmosphere. Nowadays it is extremely important to work on finding strategies to reduce carbon dioxide emissions. Due to this, we need to develop advanced monitoring methods that will help us to make better decisions and track both positive and negative trends in carbon dioxide emissions. This study is devoted to spatial analysis of emission processes from cement, iron and steel production in Ukraine.**

Keywords—mathematical modeling; carbon dioxide emission; cement production; iron and steel production.

I. INTRODUCTION

Ukraine is a participant of two the most famous international treaties aimed at controlling and reducing greenhouse gas emissions: the Kyoto Protocol and the Paris Agreement. According to these agreements, the country estimates GHG emissions in each sector every year. The disadvantage of this approach is the lack of spatial reference of the obtained results, which makes it impossible to understand the GHG emissions dynamics by regions and complicates the development of localized methods of GHG emissions reduction.

The aim of this study is to perform a spatial and temporal estimation of carbon dioxide emissions from industrial processes in two developed sectors of Ukraine: Cement production and Iron and Steel production (categories 2A1 and 2C1 according to IPCC Guidelines).

II. IPUT DATA COLLECTING AND PREPROCESSING

Our first step was to determine locations of cement and metallurgical plants. After that, analyzing various available sources of information such as official websites, plants reports and media, we collected data on the product capacity of the enterprises, which were used as disaggregating factor/proxy for statistical data on manufactured industrial products. In addition, we paid a lot of attention to information about occupied plants and based on it we made our own estimates about the volume of products produced by each plant.

Since, carbon dioxide in cement production sector emits only during calcination of carbonate materials, we used information from open sources to determine plants that actually product clinker and statistical data on country level about clinker production that were provided by the State Statistics Service of Ukraine [1]. The statistical data were disaggregated in proportion to the previously collected production capacity of the plants that produce clinker.

In Iron and Steel production sector, we estimated carbon dioxide emissions from iron, steel and sinter production. Many plants in this sector published accurate amount of manufactured products. For those who did not, we disaggregated the difference between statistical data and known production volumes proportionally to production capacity.

Carbon dioxide emissions from clinker production depend on calcium oxide and magnesium oxide content from carbonate source in clinker. Ukraine publish average CaO and MgO content from carbonate source in clinker for each year since 1990 in National Inventory Submission [2]. These data were used for emission factors calculation for different years for Cement production sector.

Carbon dioxide emission factors in Iron and Steel production sector depend on type of equipment used in the plant. We managed to collect information about furnace type for most plants. For those with unknown equipment type we used Global Average Factor published in [3].
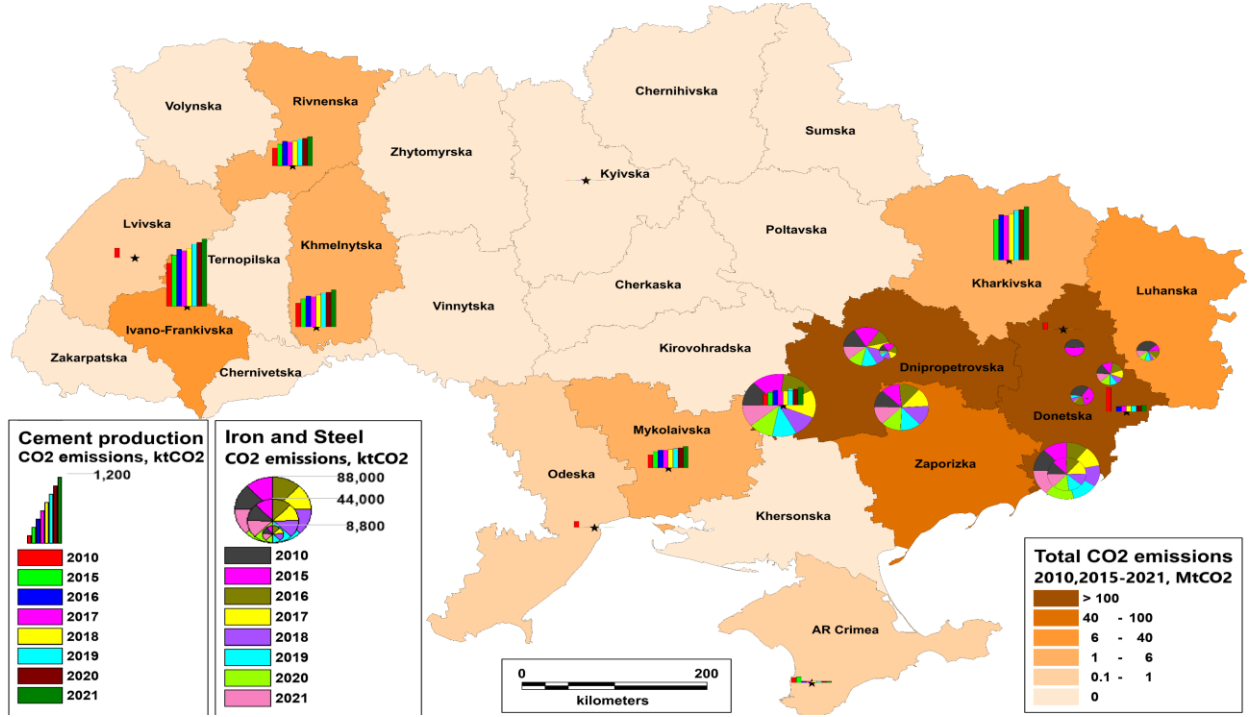
Figure 1. Spatial and temporal distribution of carbon dioxide emissions

III. MATHEMATICAL MODELS

For carbon dioxide emissions estimation for each plant in each study year in Cement production sector we built the following model:

$$E_i^{CO_2} = M_i^{cl} \times EF^{cl} \times CF^{ckd} ,$$

where $E_i^{CO_2}$ is the annual carbon dioxide emissions produced by i-th cement plant; M_i^{cl} is the mass of clinker produced by i-th cement plant; EF^{cl} is the annual emission factor for clinker based on average CaO and MgO content; and CF^{ckd} is the emission correction factor for cement kiln dust, equals to 1.02.

Carbon dioxide emissions in Iron and Steel production sector for each plant in each year were estimated using the next model:

$$E_i^{CO_2} = M_i^{stl} \times EF_i^{stl} + M_i^{irn} \times CF^{irn} \times EF^{stl} + M_i^{sint} \times EF^{sint} ,$$

where $E_i^{CO_2}$ is the annual carbon dioxide emissions produced by i-th metal plant; M_i^{stl} is the mass of steel produced by i-th metal plant; EF_i^{stl} is the emission factor for i-th steel plant based on furnace type; M_i^{irn} is the mass of iron produced by i-th metal plant; CF^{irn} is the percentage of iron that were not processed into steel, equals to 10%; EF^{irn} is the emission factor for iron that was taken from [3]; M_i^{sint} is the mass of iron produced by i-th metal plant; EF^{sint} is the emission factor for sinter that was taken from [3].
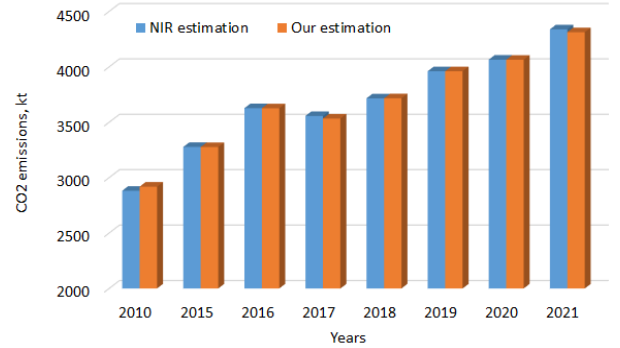

Figure 2. Comparison of National Inventory Report data and our estimations

IV. RESULTS

Based on our estimations we produced a dataset that gives a comprehensive understanding of emission dynamic of carbon dioxide over a time in different regions of Ukraine. Fig. 1 shows spatial and temporal distribution of calculated emissions. Comparison of our results and National Inventory Submissions data in Cement production sector is shown in Fig. 2.

Retrieved dataset can be useful for building and monitoring region-level strategies for sustainable development, air quality analysis, climate change modeling and many other purposes. The data also reflect economic and political changing in a country. Fig. 3 shows carbon dioxide emissions trend over a time for occupied after 2014 territories and territories controlled by Ukraine.
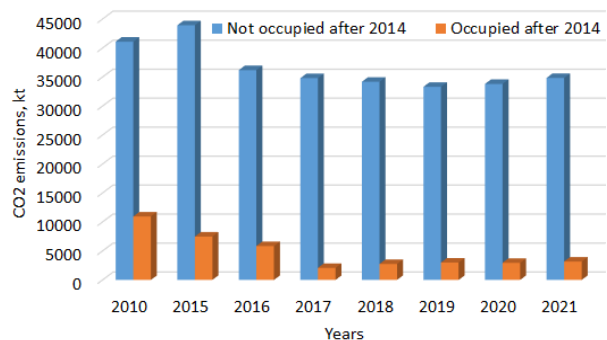
Figure 3. Comparison of emissions from occupied and not occupied after 2014 territories

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