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Analysis of greenhouse gas emissions in the European Union member states with the use of an agglomeration algorithm

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A B S T R A C T

The use of fossil fuels as sources of energy is related to the emission of pollutants into the atmosphere. The implementation of international commitments on reducing emissions requires their continuous monitoring. The main energy resources for electricity production in the world include fossil fuels, i.e. oil, coal and natural gas, and according to projections their dominant role in the market of energy resources will persist for at least the next two decades. The aim of this article is to analyse the level of differentiation of European Union member states in terms of emissions of four greenhouse gases and to identify groups of similar countries based on these criteria. Such studies will provide information that will enrich our knowledge about the contribution of each European Union country to the emissions of greenhouse gases. This article uses a taxonomic method - cluster analysis, namely the agglomerative algorithm, which enables the extraction of objects that are similar to each other from the data and then to merge them into groups. In this way, a number of homogeneous subsets can be obtained from one heterogeneous set of objects. European Union countries make up the objects of segmentation. Each of them are described by their level of greenhouse gas emissions, such as carbon dioxide, methane, nitrogen oxides and nitrous oxides. Groups of homogeneous countries are distinguished due to total emissions and due to the level of their emissions per capita. Analysis is based on annual Eurostat reports concerning greenhouse gas emissions.

1. Introduction

The concept of sustainable development is now having increasing impact on the economic situation of European Union countries. The assumptions of sustainable development relate to the combined economic, social and environmental spheres, and are directed at the maintenance and stimulation of economic growth whilst taking into consideration social welfare, as well as the quality of the environment as being of utmost importance. Unfortunately, for several decades, a sharp increase in greenhouse gas (GHG) emissions throughout the world has been observed. According to the Kyoto Protocol, greenhouse gases include seven gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and four fluorinated gases (F-gases). Different GHGs stay in the atmosphere for different lengths of time. Carbon dioxide is the most common GHG emitted by human activities. In 2014, in EU countries CO_2 emission accounted for 81% of total emissions, methane for 10.6%, N_2O for 5.6%, and F-gases for 2.9% (EEA, 2016). The main emission sources in EU countries are: fuel combustion 55.1%, transport 23.2%, industrial processes and product use 8.5%, agriculture 9.9%, and waste management 3.3% (Eurostat, 2016).

A comparison of emission sources in 1990 and 2014 is shown in Fig. 1.

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To meet its commitments to the 2005 Kyoto Protocol, the European Union created a system of measurement and limits for emissions of GHGs (UNFCCC, 2008). With the objective of reducing emissions of GHGs, the EU introduced three flexible systems: emission trading system (ETS), join implementations (JI) and clean development mechanism (CDM) (Ranosz, 2008). The EU Emissions Trading System (EU ETS) is Europe's flagship tool to meet its carbon mitigation objectives. It remains the largest example of emissions trading in operation today, encompassing over 11 500 installations

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across 30 countries and covering approximately 40% of total EU emissions. The three most challenging key areas of evaluation are emissions abatement in relation to the balance with economic objectives, investment and innovation impacts, and profits and price impacts. These are presented in (Laing, Sato, Grubb & Comberti, 2013).

The dynamic development of the economy and the growth of the human population is closely related to the continuing growth in demand for electricity. Oil and coal represent a significant share in the global supply of primary energy sources, as in 2014 they contributed 31% and 29% respectively. The emission of CO_2 from coal is greater than the emission from other fuels such as oil or natural gas, and accounted for 46% of the global CO_2 emissions, although coal only represented 29% of the world TPES (Total primary energy supply) in 2014 (Fig. 2). For Poland, the mining industry is a strategic sector of the economy and coal accounts for nearly 90% of electricity generation and for many years it has remained the primary source of energy in Poland (Dubiński & Turek, 2014).

Discussions are continuously ongoing regarding the impact of GHG emissions from human activities, in particular CO_2 emissions, that are dangerous for climate change. Since the Industrial Revolution, the annual CO_2 emissions from fuel combustion increased from approximately 40 Mt of CO_2 in 1813 to more than 35.85 Gt of CO_2 in 2013 (Fig. 3). The Intergovernmental Panel on Climate Change (IPCC) concluded that most of the observed increase in global average temperatures since the mid-twentieth century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations (Pachauri & Meyer, 2014). Different opinions are presented by the Nongovernmental International Panel on Climate Change (NIPCC), which represent arguments that it is nature, not human activity that governs climate (Idso, Carter, Singer, & Soon, 2013).

Currently, the subject of GHG emissions is very important because the policy of the European Union and electricity sector laws, including those relevant to the mining industry, are focused on implementing the strategy of sustainable development, mainly through the development of technologies which use renewable energy resources and the development of associated heat and electricity production. Sustainable energy policy is aimed at

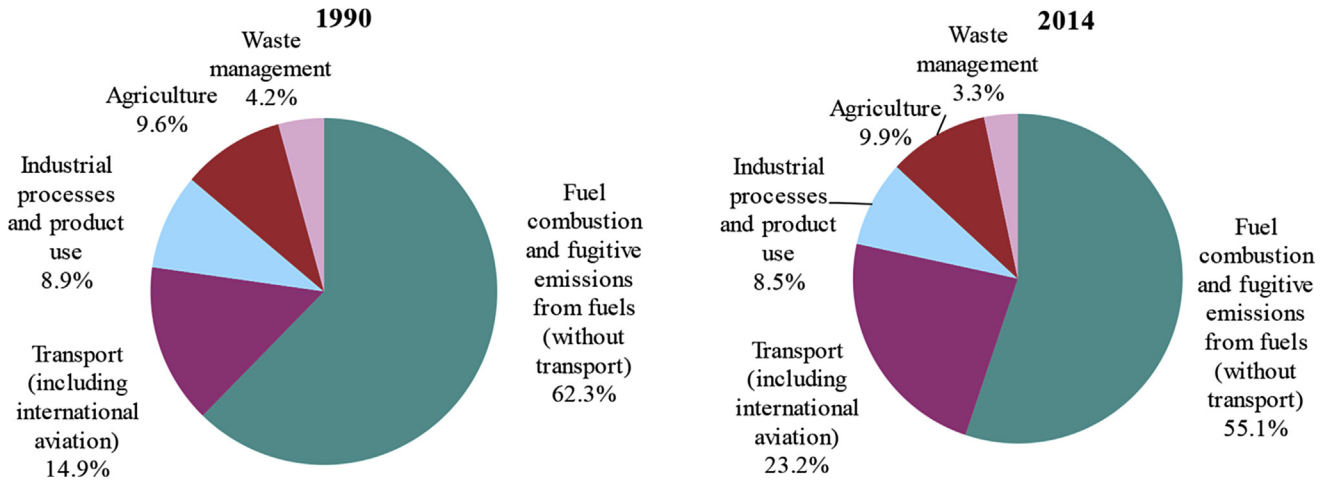

Fig. 1. The share of emissions by type of activity in 1990 and 2014 (EEA, 2016).

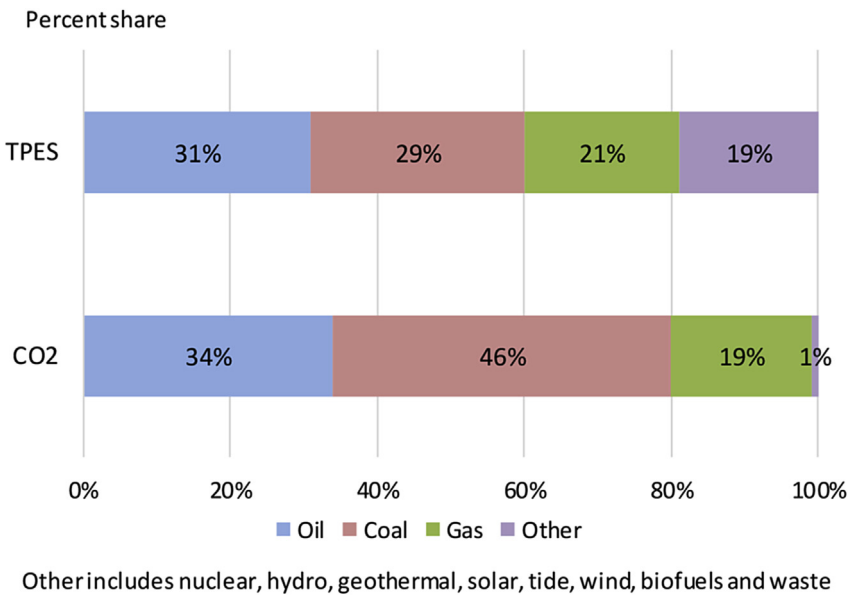

Fig. 2. World primary energy supply and CO_2 emissions: share of fuel in 2014 (IEA, 2016).

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