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Energy efficiency in the transport sector in the EU-27: A dynamic dematerialization analysis

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ABSTRACT

Energy use in the European Union's (EU) transport sector amounted to 340 Mtoe[1] in 1999 with the following increasing trend up to 379 Mtoe in 2007 and a decrease from 2008 on, down to 365 Mtoe in 2010. This changing pattern posed several fundamental questions and uncertainties regarding the broader picture of energy efficiency and environmental protection. One of them refers to absolute changes in energy use efficiency in the transport sector over time and the ways of measuring efficiency. Traditional scientific approaches conceptualized to measure efficiency of energy use do not address annual dynamics of changes in the energy use in a given sector per capita. Thus, they are not precise enough for political and methodological purposes as they do not reflect the exact amount of energy consumed in the respective countries and societies.

This paper shows a possible solution to this problem and a new perspective on measuring energy efficiency by using the product generational dematerialization (PGD) indicator. The PGD indicator allows for measuring energy efficiency as a dynamic change of consumption and population occurring simultaneously. Thus, it provides an extension to the traditional methodology commonly used for measuring efficiency. To visualize a practical application of this approach, the paper provides an example of evaluating energy efficiency in the transport sector in the EU-27 in 2000–2010. The results of the analysis show a clear materialization tendency in the transport sector (the energy consumption change exceeded the population growth) until 2007 and a reverse tendency (dematerialization) between 2008 and 2010.

As energy consumption has a direct impact on environmental quality and exhaustion of natural resources, the paper points out the necessity of extending sustainable resource management policies by new methodologies and providing more efficient solutions for energy consumption in the transport sector.

1. Introduction

According to the European Commission (2013), the share of the energy sector in the total gross domestic product (GDP) of the EU economy has been increasing since 2010 and has amounted to more than 2.5% in recent years. In 2010, the total primary energy production[2] in the EU amounted to more than 830 Mtoe, while the final energy consumption[3] amounted to 1153 Mtoe. With 365 Mtoe energy consumption, the transport sector has the highest share in the total energy use in the EU economy (31.7%), followed by energy consumption in the residential sector (26.6%) and the industry sector (25.3%) (Eurostat Pocketbooks, 2012). Although the transport sector in the EU is growing fast and indicates the highest rates of energy use, it is mostly dependent on fossil fuels. In addition, the sector takes second place in the total greenhouse gas (GHG) emission generation (20%), compared to all other sectors (i.e.: energy, agricultural processing, waste, solvent and other product industries). It is only outranked by the energy sector (60% of GHG emissions) (Eurostat Pocketbooks, 2012).

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[1] Mtoe = megatoe (one million toe). Toe — ton of oil equivalent.

[2] Primary energy production is defined as: 'energy in the form that it is first accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy'. An example of primary energy production can be coal converted to synthetic gas, which can further be converted to electricity. Thus, coal would be a primary energy source, synthetic gas would represent secondary energy, and electricity would be tertiary energy (Indexmundi, 2013).

[3] Final energy consumption is defined as total energy consumed by all end users, such as households, public administration, services, industry, agriculture and fisheries. It encompasses energy delivered to the final consumers, while it excludes energy used by the energy sector (e.g., for deliveries and transformation). It also excludes fuel transformed in the electrical power stations of industrial automobile producers and coal transformed into blast-furnace gas (Eurostat, 2013).

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Energy production and consumption are important aspects in the current EU climate policy that strives for a 'zero carbon economy'. As the 'zero carbon economy' idea and renewable energy policies are currently subject to *ex-ante* evaluations, it is important to implement a sustainable management strategy also for the currently used traditional energy sources (fossil fuels) in order to meet environmental standards and prepare the ground for future policy changes. If the EU follows the idea of the 'zero carbon economy', considerable changes will have to be implemented in terms of energy efficiency, especially in the transport sector (European Commission, 2007). In order to assess efficient energy solutions, a viable, consistent and uniform methodology is necessary to be applied in all EU Member Countries, also to ensure comparability of the results at the EU level.

According to the Organization for Economic Cooperation and Development (OECD, 2008), the process of designing and implementing energy policies in the EU is challenging, mainly due to limited methodology evaluating sustainability issues, e.g., indicators measuring energy efficiency and sustainable development in the energy sector. The commonly known and well-established indicators (e.g., Eco-index, Environment Sustainability Index, FTSE Good Index, Composite sustainable development index, ecological rucksack, and other indicators) are considered to be insufficient in measuring the real (i.e., generational[4]) energy consumption, especially at the sector level (Labuschagne et al, 2005). Those indicators address only static efficiency (and the final energy consumption, for example, in a given year), while they do not assess the dynamics of the energy consumption per capita (International Energy Agency, 2006). By contrast, the PGD indicator applied in this paper evaluates the rate of change in consumption considering a simultaneous population change. By measuring two simultaneously occurring dynamic changes, the indicator is distinct from other traditional indicators, and it allows for determining dematerialization/materialization as well as their extent and range. Traditional dematerialization indicators (even when assessed per capita) do not offer this applied methodological advantage. They depict the level of consumption, however without addressing the direction of the change or its degree over time (Ziolkowska and Ziolkowski, 2010).

Thus, the methodological and scientific added value of the PGD indicator applied here is underscored with its ability to evaluate both changes in resource production/consumption and changes in the population consuming these resources. The indicator facilitates social comprehension of generational dematerialization and materialization, as the indicator values denote not only changes in social behavior, but also effectiveness of implemented policies and the potential to compare different materials used in an economy. As the indicator provides one numeric value, it can be useful for trend visualizations with time series analyses. To emphasize practical applications of this approach, the PGD indicator was applied to evaluate for the first time energy efficiency in the transport sector at the EU-27 level in the time span 2000–2010.

The paper is structured as follows. Section two describes challenges in the EU transport sector and introduces the concept of dematerialization and the related product generational dematerialization (PGD) indicator. In section three, methodology and data are presented. Section four discusses the research results, while conclusions are presented in section five.

2. Dematerialization in the transport sector and the PGD indicator

Sustainable management policy in the European Union encompasses policy intervention measures fostering sustainable development in each sector, also in the transport sector. One of the main documents underpinning this concept is the Sustainable Development Strategy (SDS) that describes the process of establishing sustainability in the transport sector as one of the most challenging goals. To reach this goal and to decrease negative impacts of the transport sector on the environment and society, in 2006 the SDS introduced general and operational policy objectives including, among others, the modernization of the EU framework for public passenger transport services with the aim of encouraging higher efficiency and a better sector performance by 2010 (Council of the European Union, 2006). The strategy includes, for instance, the following actions:

- Improvement of economic and environmental performance of all modes of transport and measures to affect a shift from road to rail.
- Improvement of water and public passenger transport including lower transport intensity through production and logistic processes and reengineering.
- Behavioral change combined with a better connection of the different transport modes.
- Improvement of energy efficiency in the transport sector by means of cost-effective measures.

Despite the precise definition of necessary policy actions, the outcomes of implementing this strategy in the last 10 years have not been satisfactory. Recent reports by the Commission of the European Communities (2007), European Environment Agency (2010) and Greenpeace et al. (2013) evaluating the process of improving efficiency and sustainability in the transport sector indicate that the European transport system is not sustainable yet. Although there is a recognizable pattern of increasing energy efficiency in the transport sector, the efficiency gains have not been entirely utilized to reduce the overall fuel consumption, and further, they have not been large enough to outweigh the increasing transport volumes (European Communities, 2009). Despite missing efficiency of policy actions, some scientists predict that the future (Sathaye et al., 2006) and the 21st century (Rondinelli and Berry, 2000) will impose multiple pressures to manage environmental impacts of logistics and transportation systems in a proactive way. Proactive environmental management is defined by Rondinelli and Berry (2000) as a measure to prevent pollution and eliminate sources of environmental degradation. A proactive environmental management system can help design comprehensive policies and frameworks for effective and efficient planning, action and improvement (Rondinelli and Berry, 2000).

The energy consumption in the EU-27 transport sector (assuming the *business-as-usual* scenario) has been estimated to amount to 405 Mtoe in 2020 (European Commission, 2007). This estimation of the absolute energy consumption allows only for a comparative-static analysis, while it overlooks an important aspect of population changes occurring simultaneously with the energy consumption changes.

In this paper, a new scientific concept of the product generational dematerialization (PGD) indicator – introduced previously by Ziolkowska and Ziolkowski (2010) – is applied for analyzing the transport sector in the EU-27. The PGD indicator depicts a change in population related to the change in energy used by this specific population group. It extends the traditional per capita calculations that omit annually occurring population and energy changes. The indicator belongs to the group of sustainability indicators, but it provides a more extensive analysis than other traditional sustainability indicators. It can be used either independently or as a complementary instrument in a bigger indicator framework. The PGD indicator can reveal and evaluate two types of situations, either materialization or dematerialization of resource use.

The term 'dematerialization/materialization' has many definitions. An extensive elaboration on different aspects and perspectives of this terminology can be found in Ziolkowska and Ziolkowski (2010). In this paper, the definition by Sun (2001) is applied, according to which

[4] The term 'generational' refers to the word 'generation' and emphasizes the relevance of population in measuring resource efficiency.