CASE STUDY OF LIFE CYCLE ASSESSMENT OF DIESEL AND CNG TRUCKS

[1]David STAŠ, [2]Dorota BURCHART-KOROL, [1]Radim LENORT, [1]Pavel WICHER, [1]David HOLMAN

[1]*SKODA AUTO University, Mladá Boleslav, Czech Republic, EU, david.stas@savs.cz*

[2]*Silesian University of Technology, Faculty of Transport, Poland, EU, dorota.burchart-korol@polsl.pl*

Abstract

Life Cycle Assessment (LCA) is an analytical method for assessing the potential environmental impacts generated by product manufacturing, use and disposal. LCA in transport area most often concerns the analysis of alternative fuels based on Well-to-Wheel (WTW) approach. WTW is a special type of LCA because it focuses on the fuel life cycle and its impact on greenhouse gas emissions. The aim of this paper is to compare GHG emissions from diesel and CNG fueled trucks according to WTW analysis and to identify the main sources of GHG emissions.

Keyword: Life Cycle Assessment, Well-to-Wheel, CNG, diesel, truck

1. INTRODUCTION

Nowadays, logistics processes must meet sustainable standards driven mainly by investment to modern technical features and technologies, which usually generates also energy savings. It is primarily a transport that causes a heavy environmental burden and key global players are publicly claiming that they are already working with a zero-emission vision. Can be these optimistic visions realistic in the foreseeable future? Perhaps in the case of local environmental impacts, but on a global scale, from the whole life cycle perspective, the vision of zero emissions generated by transport is only a dreamed idea.

Each car must be made from materials that need to be extracted, processed or recycled, and each type of fuel or energy to be used for propulsion must be first obtained and distributed. The acquisition, processing and distribution of all these sources will always generate a significant amount of emissions, even thousands of kilometers from the area where is the transport operated.

Unless we deal with global influences together with local environmental influences, all efforts to save our planet from total ecological disposal will be useless. Therefore, we should learn to use tools and methods that will reveal other environmental influences than just emissions produced during transport, when assessing the effects generated by the implemented practices. One of such suitable tools is LCA (Life Cycle Assessment) methodology.

The environmental impact assessment of products within the LCA methodology takes into account not only the direct impacts of a product use on the environment, but also the impacts associated with its production and disposal.

Environmental analysis in transport most often concerns the analysis of alternative fuels based on Well-to-Wheel (WTW) approach. WTW is a special type of LCA because it only focuses on the fuel life cycle and its impact on greenhouse gas (GHG) emissions. The aim of this paper is to compare GHG emissions from diesel and CNG fueled trucks according to WTW analysis and to identify the main sources of GHG emissions.

2. LITERATURE REVIEW

The idea of the LCA was conceived in the 1960s when the public began to worry about the deteriorating state of the environment and, moreover, the human population was much more aware of the problem of limited access to exhaustible resources. Life cycle methods, which were the predecessors of today's LCA, have been developed in collaboration between universities and industry. At the beginning, it was an analysis of resources and environmental profiles [1], or a description and quantification of ecological equilibrium.

A framework for LCA, as it is known today, was created especially by two organizations: Society for Environmental Toxicology and Chemistry (SETAC) in August 1990 [2] and International Organization for Standardization (ISO) in June 1997 [3]. The term LCA is firmly established and standardized in the 1990s. The development of the LCA methodology, which began in the United States, was subsequently significantly involved in North European countries as well. These methods can be characterized as a systematic concept of measuring material and energy consumption within the material flows under investigation and including focusing on the consumption of basic raw materials, materials and energy (oil, steel, water, etc.), production of emissions and waste generation in industrial processes and throughout the lifecycle of product systems. Since the comprehensive results of the evaluation of the monitored material inventories were extremely comprehensible to the public, the initial focus on material flow assessment in the life cycle of the product was gradually extended by assessing possible environmental impacts [4]. These methods for assessing environmental impacts should soon tend to present evaluated emissions to quantify the volumes of clean air or water required to eliminate emissions to a safe level or below the regulatory limits. That was the case for the Swiss method ecopoints in the eighties of the last century [5]. The first environmental impact assessment methodology covering a complex set of medium impact categories (as explained below), similar to what we know today, was CML92. This classification method was based on the method published by the University of Leiden in October 1992 [4]. Modelling of increasingly sophisticated product systems for impact assessment methodologies using Life Cycle Inventory (LCI - Life Cycle Inventory) data led to the need for specialized LCA software. The first two software tools were SimaPro and GaBi. These programs were developed and launched around 1990 [6]. In accordance with the principles of sustainability, the social dimension emerges and the initiative has also strengthened efforts to develop methods for social LCAs to quantify the social impacts of the product lifecycle. Currently, the Life Cycle Sustainability Assessment (LCSA) aims to take into account the environmental, social and economic dimension of sustainable development [7].

The SETAC report summarizes the current status of the field and outlines the technical basis for life cycle studies. LCA definition according to SETAC seas that LCA is a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and materials used and releases to the environment; and to identify and evaluate opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing, extracting and processing raw materials; manufacturing, transportation and distribution; use, re-use, maintenance; recycling, and final disposal [7]. This definition is adopted by wide spectrum of other authors (see e.g. [8], [9], [10], [11]).

In the literature is presented a lot of results of LCA for passenger cars, however, there is very few publications of environmental assessment taking into account GHG emission of alternative fuels for trucks.

3. EXPERIMENTAL PART

3.1. Materials and methods

The aim of the study was to perform LCA of trucks, taking into account two kind of fuels - diesel and CNG (Compressed Natural Gas). The analysis was done using IPCC 2013 method. IPCC 2013 method is the successor of the IPCC 2007 method, which was developed by the Intergovernmental Panel on Climate Change. It contains the climate change factors of IPCC with a timeframe of 100 years. Total amount of GHG emissions produced to directly and indirectly support human activities is expressed using the reference unit, kg of CO_2. The GHG emissions are calculated based on the Global Warming Potential (GWP) [12]. The IPCC method is useful for assessment the most important impact category - GHG emission according.

The comparative analysis is based on WTW approach. The WTW analysis allows assessment of the environmental aspect and identification of this aspect related, both directly and indirectly to the life cycle of a vehicle, taking into account fuels life cycle. The analysis was conducted in accordance with the ISO 14040:2006 [13] and 14044:2006 [14] guidelines. The scope of the analysis, the functional unit, system boundary and basic assumptions were defined. Analysis was made using the SimaPro v. 8.5 with Ecoinvent 3 database [15]. All analyses were referred to the same functional unit - one ton-kilometer (1 tkm). The system boundary includes fuel life cycle with two phases: fuel production (Well-to-Tank, WTT) and fuel exploitation (Tank-to-Wheel, TTW), see **Figure 1**.

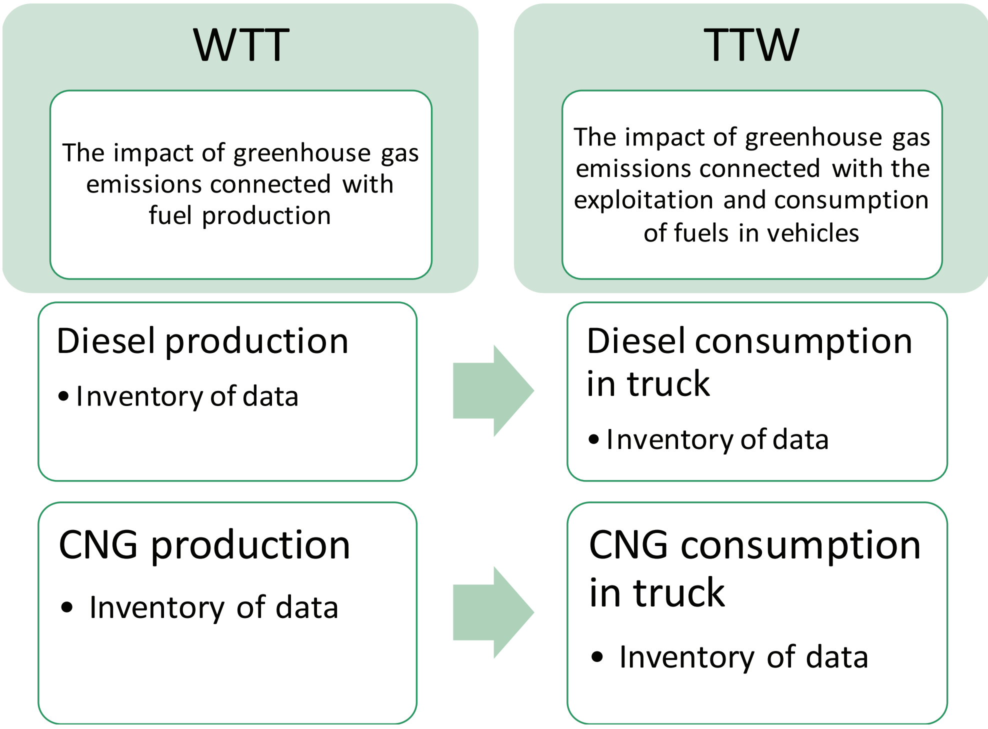

Figure 1 System boundary of the analysis

The analysis involved inventory of data and environmental assessment based on IPCC 2013 method. The main data source used for analysis was the Ecoinvent database and literature review. The dataset was parametrized with respect to the trucks which was analyzed.

3.2. Description of the analyzed trucks

The LCA study analyses truck transport between two production plants located 75 kilometers away. This transport is realized by diesel and CNG trucks with gross vehicle weight (GVW) of 25 metric tons. Further specific data on the analyzed trucks is available in **Table 1**.

Table 1 Specifications of analyzed trucks

Truck brand	Truck type	Fuel type	Year of production	Engine displacement (cm^3)	Number of cylinders	Engine power (kW)	Euro norm	Declared fuel consumption (litters/100 km)
MAN	TGX 500	Diesel	2017	12,419	6	368	EURO 6	34.3
Scania	N 320	CNG	2016	9,291	6	250	EURO 6	38.4

4. RESULTS

The results comparing the GHG emissions from diesel and CNG life cycle are shown in **Figure 2** and **Figure 3**. **Figure 2** presents WTW GHG emissions. It is obvious that higher GHG emissions was indicated for diesel life cycle than CNG life cycle. In both cases the TTW GHG emissions are strongly predominant. **Figure 3** shows the proportion of direct emissions in the TTW phase. On the basis of input data used, direct emissions of CO_2 and CH_4 were considered. The figure shows that CH_4 emissions are negligible compared to CO_2 emissions.

The share of main determinants of GHG emissions for CNG and diesel life cycle are presented in **Figure 4** and **Figure 5**. The core source of GHG emissions from CNG and diesel fueled trucks is direct emission of CO_2 that arise during combustion in an internal combustion engine.

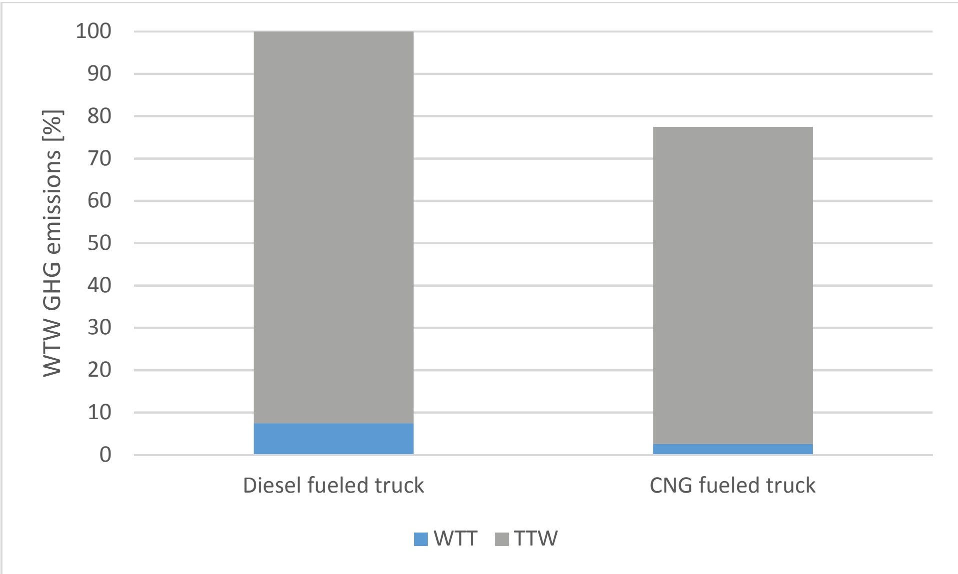

Figure 2 Comparison of WTW GHG emissions for CNG and diesel fueled trucks

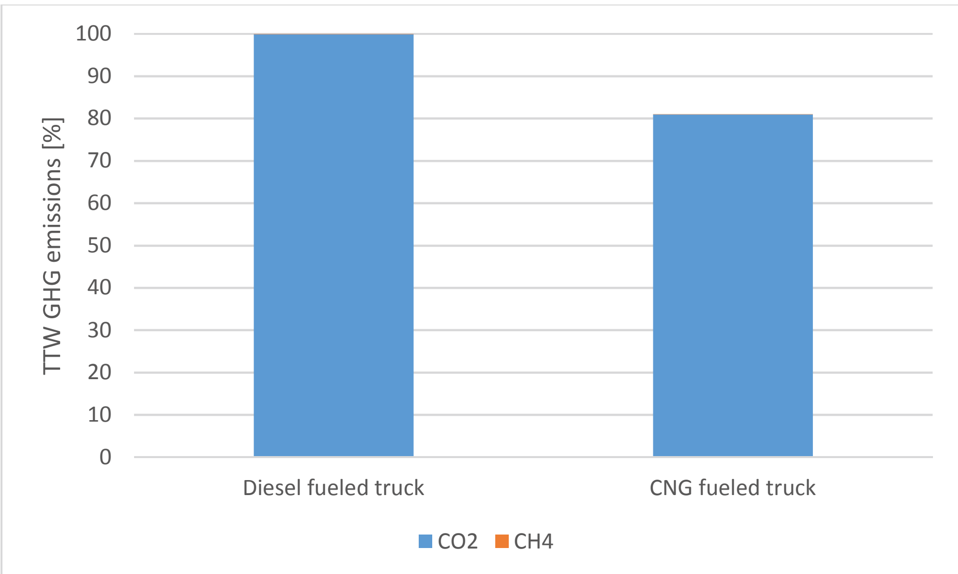

Figure 3 Comparison of TTW GHG emissions for CNG and diesel fueled trucks

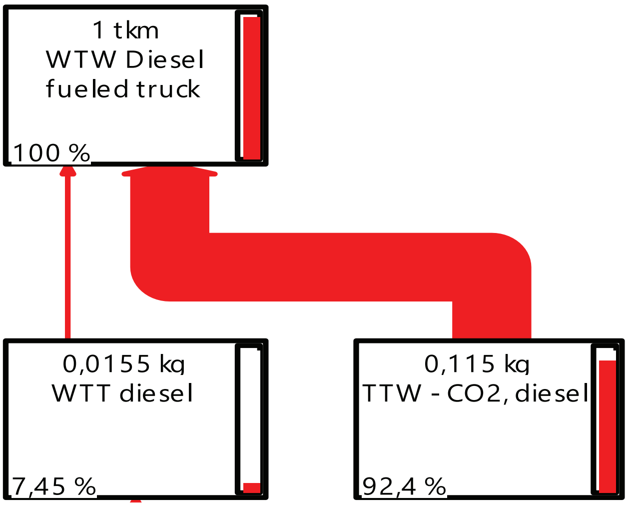

Figure 4 Determinants of GHG emissions from diesel life cycle

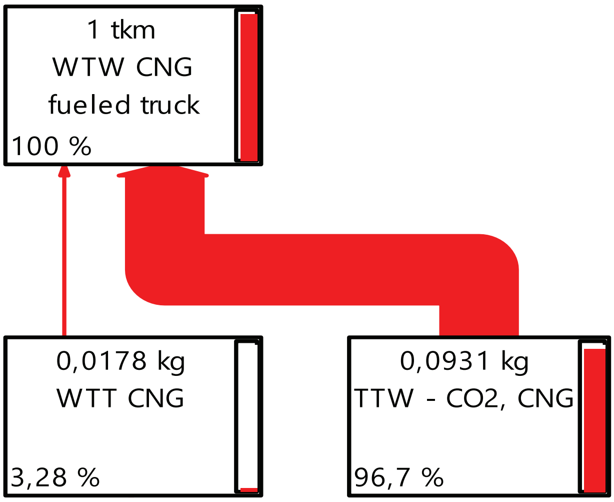

Figure 5 Determinants of GHG emissions from CNG life cycle

A deeper analysis showed that the main sources of GHG emissions in WTT phase are connected with petroleum production (53 %), heat burned in furnace (27 %) and heavy fuel oil burned in refinery furnace (14 %) in case of diesel and with natural gas production in case of CNG.

5. CONCLUSIONS

It was concluded that the GHG emissions from CNG life cycle are less than from diesel life cycle. It was also proven that direct emissions of CO2 are the most important source of GHG emissions for both analyzed trucks. In general, it can be stated that the analysis based on life cycle approach is appropriate and useful for comparison of haulage environmental impacts and can support the decision making in transport sector.

The results of this study can be used as the first step in performing LCA of trucks included all the stages of the truck life cycle and many impact categories. GHG emissions management has become important element of sustainable transport. This analysis focuses only on one impact category - GHG emissions. Next research will cover other impact and damage categories like human health, cumulative energy demand and fossil fuels demand and other environmental categories according to circular economy guidelines during the stages related to the life cycle of trucks.

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