

Calculation of Selected Emissions from Transport Services in Road Public Transport

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Abstract. The article deals with road public transport and its impact on the environment. According to the methodology given in EN 16258, CO₂ emission value has been calculated. The input data for the calculation and the results are shown in the tables. The declaration is created according to STN CEN / TR 14310, which contains recommendations for compiling environmental reports. Finally, the comparison of the environmental impact of a bus and a passenger car, when converted to one passenger, bus has a lower CO₂ emission than a passenger car in that section.

1 Introduction

In 2012 the European standard EN 16258 Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers) was approved by the European Committee for Standardisation (CEN).

The purpose of this standard is to make it widely applicable across the transport sector and accessible to a very diverse user group. The use of standards provides a common approach to the calculation and declaration of energy consumption and emissions for transport services, irrespective of the difficulty of transportation technology and transportation process. The standard ensures that the declarations have greater consistency and transparency, and that the energy consumed and emissions produced correspond to the load, respectively occupancy of vehicles.

2 Way of expressing quantity of GHG emissions

For the calculation of greenhouse gas emissions standard considers, the unit of CO₂e (carbon dioxide equivalent) as carbon dioxide represents the largest share of the production of greenhouse gases. CO₂e value indicates the influence of each greenhouse gas on global warming using the conversion amount or concentration of CO₂, which would have similar effects. Compared with the current approach, to reporting greenhouse gas emissions standard provides:

- unification of the calculation methodology used uniform emission factors (unified emission factors are given in table 1) [1]

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- calculation of the production of all greenhouse gas emissions, calculated per unit of **CO₂e**
- taking into account both direct and indirect emissions and energy consumption of vehicle operation, allowing an objective comparison of their energy consumption and environmental impact

3 The principles of calculations of energy consumption and greenhouse gas emissions

For the calculation, it is necessary to know the operational characteristics of vehicles and transport services, such as fuel consumption of vehicles, transport distance, number of km of non-loaded vehicle, number of passengers, vehicles capacity.

3.1 Calculations for the vehicle operation system

If the transport service consists of several sections, it is necessary to identify the operation system of the vehicle (Vehicle Operation System - VOS) for individual sections, namely a number of categories, including working hours of the vehicle.

The calculation is based on the identification of a vehicle's consumption of a particular vehicle operation system (VOS). Conversion from total fuel consumption for the VOS into quantities of energy consumption and GHG emissions shall be made using following formulas:

- for well-to-wheels energy consumption of the VOS:

$$E_w(VOS) = F(VOS) \times e_w \tag{1}$$

- for well-to-wheels GHG emissions of the VOS:

$$G_w(VOS) = F(VOS) \times g_w \tag{2}$$

- for tank-to-wheels energy consumption of the VOS:

$$E_t(VOS) = F(VOS) \times e_t \tag{3}$$

- for tank-to-wheels GHG emissions of the VOS:

$$G_t(VOS) = F(VOS) \times g_t \tag{4}$$

where:

F(VOS) is the total fuel consumption used for the VOS (examples: F(VOS) equals five thousand litres of diesel; or F(VOS) equals thirty thousand kilowatt hours);

e_w is the well-to-wheels energy factor for the fuel used (example: for diesel, e_w = 42.7 MJ/l);

g_w is the well-to-wheels GHG emission factor for the fuel used (example: for diesel, g_w = 3.24 kgCO₂e/l);

e_t is the tank-to-wheels energy factor for the fuel used (example: for diesel, e_t = 35.9 MJ/l);

g_t is the tank-to-wheels GHG emission factor for the fuel used (example: for diesel, g_t = 2.67 kgCO₂e/l).

Values for energy and GHG emission factors shall be selected in accordance with Annex A., see tables 1 and 2 in EN 16258:2012 *Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)* [1].

3.1 Calculations for the vehicle operation system

If the realized transport service consists of several sections (different customers, different numbers of passengers carried, the distance traveled with loaded and an empty vehicle and so on.), It is necessary to implement the conversion of energy consumption and emissions to stretch. The calculation is performed as follows:

- Identifies the VOS used to implement transport service on the field in question
- To quantify the total consumption of VOS
- Calculate the total energy consumption and emission levels for VOS according to formula (1), (2), (3) and (4)
- Calculate the share of energy consumption and emissions attributable to address segment of transport services (a dimensionless number) as the ratio of power attributable to the segment of transport services and power system operation of the vehicle:

$$S(\text{leg}) = T(\text{leg}) \div T(\text{VOS}) \tag{5}$$

Subsequently, this proportion will be used to calculate energy consumption and greenhouse gas emissions for solving section of transportation services:

$$E_w(\text{leg}) = E_w(\text{VOS}) \times S(\text{leg}) \tag{6}$$

$$G_w(\text{leg}) = G_w(\text{VOS}) \times S(\text{leg}) \tag{7}$$

$$E_i(\text{leg}) = E_i(\text{VOS}) \times S(\text{leg}) \tag{8}$$

$$G_i(\text{leg}) = G_i(\text{VOS}) \times S(\text{leg}) \tag{9}$$

where:

S(leg) is the factor used to calculate the share of the VOS’s energy and emissions which is allocated to a transport service for the leg. This share is based on relative proportions of transport activity for the leg and for the associated VOS;

T(leg) is the transport service’s transport activity for the leg;

T(VOS) is the transport activity of the VOS which is related to the leg;

Performance of vehicle operation system (T (VOS)) and the power of stretch of transport services (T (leg)) must be in the same unit terms. The standard recommended for freight and passenger traffic to use transport capacity. That means multiplying the number of passengers and the actual transport distance in terms of passenger kilometers in passenger transport, freight transport multiplying the quantity of transported goods and the actual transport distance in terms of tonne-kilometers.

4 The structure and content of the declaration of energy consumption and GHG emissions

The standard does not prescribe the form of the declaration, it only defines the requirements for their content. For declaring the recipient declaration standard user can use any medium that provides unambiguous results and related documents for the calculation such as web site. Declarations on energy consumption and GHG emissions of a transport service shall include:

- a) *four results* (E_w, G_w, E_i, G_i) calculated according to previous clauses (when the energy in units of J, or MJ or GJ in CO₂e emissions in g or kg or t)
- b) *supporting information*, which, among other things contain:

- transparent description of the method used, in case other factors of energy consumption and emission factors as listed in Annex A standards, they need to give reasons to justify the need to also use predefined values
- basic description of the services (source and destination of the route, the number of persons transported)
- used vehicle operation system (VOS) for each section
- the size of the vehicle fleet, vehicle categories

In formal terms, it is possible to create a declaration using the standard **STN CEN / TR 14310 freight services. Designation and reporting of environmental performance in freight transport network**. The aim of the standard is to provide guidance for preparing (creating) environmental declarations and reports. It contains recommendations on the content and structure of the documentation and evaluation of the impact of freight on the environment. It refers to road, rail and waterway does not apply to air transport [2].

5 External costs from transport services

External costs of transport are the costs associated with the negative effects of transport activities on the environment and human life, they are costs associated with deleting their effects. In particular, the pollution of air, water and soil disturbance of ecosystems, noise pollution, traffic accidents (of the damage not covered by insurance), takes up space and overloading capacity. Categories of external costs are accident costs, air pollution costs (emissions), noise costs, congestion costs [3].

The internalisation of external costs is an objectification costs and subsequently attributed to the those entities that cause them and are responsible for. Internalization is a tool to convert external effects of transport in monetary terms to those that actually cause these effects [3].

6 Case studies

The calculation for energy consumption and emissions was designed and tested in a model situation of passenger transport. Route: 21 km long and 34 stops. Vehicle: M3 category. Parameters of a vehicle: SOR BN 10.5, engine Iveco Tector (2. series), 185 kW, Euro IV, year 2007, diesel fuel, 3 doors for entry and exit, maximum occupancy 96 passengers.

The resulting calculation of greenhouse gas emissions and energy use for the direct transport are presented in tabular form in the form of output reports (table 1).

Table 1. Outputs of calculation of emission and energy consumption for route in road public transport (total). Source: authors

Indicator	Characteristic
Number of stops	34
Distance (km)	21
Vehicle, engine power, emission limit, year of production	SOR BN 10.5, Iveco Tector (2. series), 185 kW, Euro IV, 2007
Number of doors	3
Number of seats	30 + 1 (driver)
Number of places to stand	66
Tank volume (l)	180

Indicator	Result of calculations
Gross vehicle weight (t)	15
Average number of passengers	29.5
Fuel	Diesel
Fuel consumption per route (l)	5.67
Energy consumption in the transport (e_t (MJ))	203.553
Energy consumption in the transport (e_w (MJ))	242.109
CO ₂ emissions during transportation (g_t (kgCO ₂ e))	15.139
CO ₂ emissions during transportation (g_w (kgCO ₂ e))	18.371

In the next table, we can see model declaration with information about vehicle, route characteristics and final results of energy consumption and emission pollution expressed per one passenger in average.

Table 2. Outputs of calculation of emission and energy consumption for route in road public transport (per one passenger). Source: authors

Indicator	Characteristic
Distance (km)	21
Vehicle, engine power, emission limit, year of production	SOR BN 10.5, Iveco Tector (2. series), 185 kW, Euro IV, 2007
Tank volume (l)	180
Indicator	Result of calculations
Average number of passengers	29.5
Fuel	Diesel
Fuel consumption per route (l)	5.67
Energy consumption in the transport (e_t (MJ))	6.90
Energy consumption in the transport (e_w (MJ))	8.21
CO ₂ emissions during transportation (g_t (kgCO ₂ e))	0.51
CO ₂ emissions during transportation (g_w (kgCO ₂ e))	0.62

6.1 Leg of a transport service

Also we made a comparison concerning a certain leg of transport service between bus vehicle and passenger car. We followed energy consumption and emission production. Leg of transport service is represented by route from one bus stop to another. Total length is 8

km. Bus vehicle technical characteristics remains the same. Chosen passenger vehicle has these parameters: Škoda Octavia II, 1.9 TDI, 77 kW, Euro IV limit, year of manufacturing 2006. Final results of this comparison are shown in tables 3 and 4. The road elevation profile of the section of the transport service is shown in figure 1.



Fig. 1. Road elevation profile. Source: GoogleMaps

Table 3. Outputs of calculation of emission and energy consumption for route in road public transport (peak hour per one passenger). Source: authors

Indicator	Characteristic
Distance (km)	8
Vehicle, engine power, emission limit, year of production	SOR BN 10.5, Iveco Tector (2. series), 185 kW, Euro IV, 2007
Tank volume (l)	180
Indicator	Result of calculations
Average number of passengers at peak	36
Fuel	Diesel
Fuel consumption per route (l)	5.67
Energy consumption in the transport (e_t (MJ))	5.65
Energy consumption in the transport (e_w (MJ))	6.73
CO ₂ emissions during transportation (g_t (kgCO ₂ e))	0.42
CO ₂ emissions during transportation (g_w (kgCO ₂ e))	0.51
Total CO ₂ external costs	0.0045 €

The Handbook of external costs was used to determine the amount of money generated for total emissions. It states that 1 tonne of CO₂ emissions are at 4.81 €. This value is multiplied by the total emissions produced, resulting in the external costs of one bus passenger amounting to 0.0045 € (see table 3). The same procedure was used to determine the amount of external costs per one passenger in car. Value is 0.046 €, see table 4.

Table 4. Outputs of calculation of emission and energy consumption for route by passenger car (in road public transport [car + driver]). Source: authors

Indicator	Characteristic
Number of stops	0
Distance (km)	8
Vehicle, engine power, emission limit, year of production	Škoda Octavia II, 1.9 TDI, 77 kW, Euro IV, 2006
Tank volume (l)	55
Indicator	Result of calculations
Average number of passengers at peak	1 (driver)
Fuel	Diesel
Fuel consumption per route (l)	1.62
Energy consumption in the transport (e_t (MJ))	58.16
Energy consumption in the transport (e_w (MJ))	69.17
CO ₂ emissions during transportation (g_t (kgCO ₂ e))	4.33
CO ₂ emissions during transportation (g_w (kgCO ₂ e))	5.25
Total CO ₂ external costs	0.046 €

7 Conclusion

Road public transport in Slovakia is less preferred and has little passenger support. The advantage of a passenger car lies in greater passenger comfort and higher transport speeds to the desired destination. The results of the model show that road public transport has one very important asset and is more environmentally friendly than a passenger car. Comparison of the bus and passenger vehicle with external costs is the difference in prices per kilogram of emissions produced up to 1050% higher than the passenger car. The results are shown in tables 3 and 4. This comparison is for the CO₂ emission component. We also know other negative components like NO_x, CO, PM, etc., which also have their monetary expression as external costs (see [3]). Better promotion and transfer of passengers to public transport would have less unacceptable emissions to the environment. It would also reduce the number of passenger cars in city centers. Passenger cars, which are capacitively used on average by 2 passengers, are among the largest environmental pollutants in cities.

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