Tools for calculating the emission of pollutants in transport

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Abstract: *Increasing the volume of transport requirements increases the consumption of propellants and emissions of pollutants. Calculation and monitoring of pollutant emissions and energy consumption with the aim of reducing the negative impact on the environment and thus choosing the best transport route and means of transport for a particular transport task is a step towards a solution that can be applied to reduce emissions. The development of software tools for calculating energy consumption and pollutant emissions is conditioned by the precision of the defined methodology used for the calculation. This paper presents the possibilities of using tools for calculating pollutant emissions in transport.*

***Keywords**: POLLUTANT EMISSION, ENERGY CONSUMPTION, TRANSPORT*

1. Introduction

In December 2019, The European Administration presented the "European Green Deal" – a new development strategy aimed at transforming the European Union into a fair and prosperous society, with a modern, resource-efficient and competitive economy, which will contribute to the total reduction of greenhouse gas emissions by 2050 and where economic growth is not linked to resource exploitation [1].

The European Green Deal predicts that Europe will become the first climate-neutral continent by 2050. Accordingly, concrete measures related to climate, energy, circular economy, construction, mobility, agriculture, sustainable food chains, biodiversity and pollution naturalization have been proposed accordingly. The first initiative covered by the Green Deal is the Fit for 55 package, which transposes the Ambitions of the Green Deal into legislation. It consists of a set of proposals to revise legislation in the fields of climate, energy and transport, and to introduce new legislative initiatives to align EU regulations with its climate objectives [2].

The Initiative for the Introduction of the Carbon Boarder Adjustment Mechanism (CBAM) is a key element of the European Union's package of instruments that will aim to reduce the risk of carbon „leakage“ stemming from the Union's greater climate ambitions. This will be achieved primarily by limiting the redistribution of EU-based industries to countries with less stringent climate regulations.

This mechanism is primarily oriented towards companies, not countries, because companies are the ones that are subject to cross-border adjustment only on the basis of their merits. In the first phase, it will apply to industries where a high risk of carbon leakage (high emissions and high levels of trade) is recognised, these are the industries of cement, iron and steel, aluminium, fertilizer and electricity, while later it is planned to be applied to other industries – primarily products of the chemical industry.

The CBAM will start rolling out as early as 2023, when it will start monitoring and reporting on actual carbon dioxide equivalent emissions. In this transitional phase, which will last until 2025, great work awaits both the state and manufacturers from these sectors. In the process of monitoring and reporting, the role of verifiers is important. From 2026, importers must declare the amount of embedded emissions in the total goods they have imported and then pay the CBAM liability or so-called adjustment [3].

Transport, which includes the transport of goods to the production plant, transport within the production unit itself, as well as the transport of the finished product to the final consumer (the same for services) has an extremely large impact on the carbon footprint of the product.. It is one of the factors of indirect emissions of greenhouse gases (which are generally far greater than direct ones).

It is common knowledge that the means of transport for propulsion are mostly used by fossil fuels. As the volume of transport requirements grows, so does the need for propulsion energy, which directly conditions the increase in emissions of harmful gases. Just because the world is not yet able to switch to using zero-emission vehicles, i.e. using only energy derived from renewable sources, it is necessary to find other solutions to reduce greenhouse gas emissions.

The use of modern software packages in order to monitor emissions of harmful gases by modes of transport depending on the transport route in order to choose the optimal solution is one of the solutions to the aforementioned problem.

Determining the methodology for calculating energy consumption and emissions of harmful gases by mode of transport is very important, because depending on the mode of transport, different parameters are taken for the calculation itself. In addition to the methodology for calculating energy consumption and emissions that occur during the exploitation of means of transport, it is very important to define the methodology for the calculation of emissions that occur in the process of production, processing and distribution of goods, because here, depending on the construction solutions of certain modes of transport, the methodology itself differs.

2. Limiting greenhouse gas emissions

Energy consumption and greenhouse gas emissions in freight transport activities can be reduced by two main groups of actors in the transport market [4]:

- shippers and logistics service providers arranging transport with carriers (foreign demand),
- carriers performing transport activities (foreign offers).

The groups of measures to reduce emissions of harmful gases that can be used are:

1. greater use of rail and water transport, from the demand side;
2. improving the planning of transport routes of means of transport, from the side and demand and supply;
3. improving the utilization of means of transport (reducing the number of rides without cargo, better use of cargo space), from the aspect of the offer;
4. improving the efficiency of the use of propellants (using low rolling resistance tyres, economical driving, choice of alternative propellants) on the offer side.
5. selection of alternative raw material suppliers / alternative customers (for industries) located in logistically better locations from the aspect of total cost, from the moment of more rigorous collection of total emissions to manufacturers and distributors of products.

Senders can directly influence the first measure by choosing the mode of transport. They can also encourage or oblige the carrier to apply the other three measures. In the end, senders can completely change the raw material market and customers because it is expected that with the implementation of CBAM and other carbon footprint collection mechanisms, manufacturers will review the most profitable options for themselves, which can have a significant impact on the required routes to transporters [5].

The calculation of emissions of carbon dioxide and other components converted to the amount of carbon dioxide allows the establishment of a system of comparison of different transport systems that create greenhouse gases. Reporting such information can encourage a change in the behavior of senders and carriers.

With more widespread use of carbon dioxide emissions calculations for different types of activities, and when reported greenhouse gas emissions are assumed to be a realistic picture, senders can assess different modes of transport and carriers, as well as their emissions of carbon dioxide and other carbon-based components. In addition, determining the amount of carbon dioxide in transport services can provide an incentive for carriers to change their own behavior in order to reduce carbon dioxide emissions and outperform their competitors. Arguments for changing behavior may include the need to increase income, reduce costs, and limit risks (legal requirements and work permits), as well as care for the well-being of others.

Therefore, emissions of carbon dioxide and other carbon-based components is an instrument that targets the decision-making process of the transport contracting authority or transport intermediary when purchasing transport services and encourages carriers to improve their performance. This limits the efficiency of the instrument in two ways:

- emissions of carbon dioxide and other carbon-based components are generally effective when purchasing a transport service from another participant. In the freight transport market, the largest share of transported quantities is achieved by carriers working at the request of transport intermediaries;

- The efficiency of the use of calculations depends largely on the number of alternatives available and whether the sender gives importance to the performance of greenhouse gas emissions. Logically, carriers uninterested in greenhouse gas emissions are unlikely to change their behaviour, although they have the ability to compare different carbon dioxide emissions. However, for those interested in reducing the impact of greenhouse gas emissions, the availability of these alternatives is an important prerequisite to becoming energy efficient.

Calculating carbon dioxide emissions is one of the options available to improve the efficiency of greenhouse gas emissions generated in transport. However, the calculation of carbon dioxide emissions is not enough on its own; there are many other factors that lead to improved energy efficiency in passenger and freight traffic [6]. Therefore, information on ensuring energy efficiency is particularly effective when supported by other policies, such as standards or prices. For example, this has proven itself well with CO_2 labeling for cars and vans, which is also a means of providing information to consumers. Evaluation studies have shown that this instrument is particularly effective as an additional measure to other policies such as CO_2 standards for new cars and vehicles up to 3.5t of maximum permissible mass (both in perspective, potentially for heavy goods vehicles).

With these combinations, different standards provide incentives for manufacturers to improve the average fuel efficiency of new vehicles, while CO_2 labeling helps them identify vehicles with the highest fuel consumption, in order to provide incentives for consumers to include energy efficiency criteria when buying a car. According to a similar logic, providing information can also support the prices of certain legal regulations, such as, for example, differentiated vehicle tax. Standards and pricing measures have proven to be effective instruments for improving the energy efficiency of transport. Many other instruments can reduce greenhouse gas emissions from transport, such as green public procurement or sustainable procurement, infrastructure subsidies, speed policies, traffic management, etc. Openly providing information about such measures will increase consumers' awareness and ability to take greenhouse gas emissions into account when making decisions about choosing a mode of transport.

Carbon dioxide emissions from transport services can be seen as a complementary measure for the organisation of EU environmental initiatives: Product Environmental Footprint - POF and Organisation Environmental Footprint – OEF.

3. Approaches for calculating CO_2 emissions

There are more methodologies for calculating greenhouse gas emissions resulting from transport services, each with different levels of accuracy and detail. "Strategy for increasing energy efficiency in road transport" distinguishes three methods for transport carbon footprint calculations with different levels of accuracy, required data and possible changes [4]:

1. Basic emission factors according to the volume of transport (g/tkm)

Required data:
- Transport volume (tkm)
- Type of vehicle
- Basic values (g GHG/tkm) specific to the vehicle class

Possible changes:
- Change of mode of transport
- Reducing the volume of transport (tkm).

2. Basic emission factors of the vehicle (g/vkm)

Required data:
- Road travelled (km)
- Type of vehicle
- Vehicle load capacity (kg)
- Basic values of emission factors for each type of vehicle

Possible changes:
- Reduction of vehicle distance travelled (with cargo and without cargo)
- Change of mode of transport
- Increase the level of utilization of cargo space.

3. Measured energy consumption of the vehicle (l, kg, kWh)

Required data:
- Road travelled (km)
- Type of vehicle
- Measured energy consumption (MJ/km) of the appropriate type of vehicle with an appropriate degree of utilization of load capacity
- Quantity of cargo transported

Possible changes:
- Increasing the energy efficiency of vehicles
- Reduced fuel consumption
- Reduction of vehicle distance travelled (with cargo and without cargo)
- Change of mode of transport
- Increase the level of utilization of cargo space.

It is important to note that although a high level of precision and detail (Level 3) results in more reliable estimates of emissions of greenhouse gases, it also requires a significant amount of real data. So there is a trade-off between the accuracy of measurement methods and the simplicity of their use.

3.1. Basic emission factors according to the volume of transport – Level 1

Calculating greenhouse gas emissions based on emission factors is relatively simple and requires a limited set of data. Emissions for the transport service are calculated according to the following formula:

$$F = W \cdot D \cdot E$$

where is:

F - greenhouse gas emissions [g]

W - real mass of cargo [t]

D - the actual distance of transport [km]

E - specific emissions of greenhouse gases [g CO_2 eq./tkm].

When using this method, carriers and contracting authorities should provide information relating to their part of the work, i.e. to the distance of transport for a certain mass of cargo. Specific factors of greenhouse gas emissions are obtained from public or licensed databases or studies. The accuracy of the calculation depends on the quality of these databases.

3.2. 2. Basic emission factors of the vehicle – Level 2

The calculation of carbon dioxide emissions with vehicle emission factors also uses core values. However, while the Level 1 method uses one emission factor (g/tkm) per vehicle type, Level 2 calculation uses two (g/km of an empty vehicle and a g/km- loaded vehicle). This method requires more data than in the Level 1 Method, but also generates a more accurate result because it requires the degree of utilization of payload. The formula used with this method is as follows:

$$F_{vehicle} = D \cdot [(E_{max} - E_{empty}) \cdot W\% + E_{empty}]$$

where is:

$F_{vehicle}$ - greenhouse gas emissions from vehicles [g]

D - the actual distance of transport [km] (kilometers with cargo, empty kilometers)

E_{max} - specific greenhouse gas emissions of vehicles with full payload [g GHG/km]

E_{empty} - specific emissions of greenhouse gases of an empty vehicle [g GHG/km]

W% - The actual level of utilization of the vehicle's payload.

Normal values based on the vehicle's energy consumption (litre or MJ/km) instead of the vehicle's emission factor (in gCO2 per km) are considered correct. An example of a commonly used database for such emission factors for road vehicles is the Handbook for Road Transport Emission Factors (HBEFA).

3.3. Measured energy consumption of the vehicle (Level 3)

The third method uses the individual measured energy consumption of an individual vehicle. There are differences in the energy efficiency of different vehicles, which are also affected by the driving style of the driver. This method is quite accurate, given that the measured data that companies can collect is used. Unlike level 1 or 2 calculations, this method also includes measures to reduce GHG emissions by carriers. As such, this method encourages energy-efficient driving and the adoption of technology to reduce fuel consumption.

This method provides the most accurate calculation of CO_2 emissions, but also requires a large amount of data. In this case, the carbon dioxide footprint is calculated using the following formula:

$$F_{vehicle} = D \cdot G \cdot Q$$

where is:

$F_{vehicle}$ - vehicle greenhouse gas emissions [g]

D - the actual distance of transport [km] (with and without cargo),

G - specific power consumption (e.g. l/km or MJ/km),

Q - conversion factor (g GHG/l diesel).

The result of this formula results in the emission of harmful gases from the vehicle. These emissions can then be assigned to different shipments or cargo quantities. Since this method does not use the default emission factors, the carrier should collect data on the energy consumption of its vehicles. This can be achieved in two ways: by using data from on-board computers and processing data on the records of refuelling in vehicles.

4. The complexity of the calculation of the total emissions CO_2

There are several complex problems with calculating total CO2 emissions, especially when total emissions need to be distributed by type of services.

Calculating CO_2 emissions at the service level requires a specific allocation of emissions from vehicles (e.g. emissions per ride with cargo, per transport customer or per passenger), because only this approach can be useful for decision-makers when comparing the amount of CO_2 per type of service. Therefore, in the case of group transport, where multiple shipments are transported at once, the sender is not interested in the total emissions generated by this operation, but only in the emissions that can be assigned to his shipment. In the case of a relatively imprecise Level 1 approach, this is irrelevant, since the emission of gases is already expressed per unit of transport. However, if more accurate and reliable data is required, and carbon dioxide emissions are calculated with Level 2 or Level 3 methodology, greenhouse gas emissions will be determined at the level of the means of transport. In this case, the allocation of emissions to services or customers becomes an important and complex issue.

Likewise, sometimes it is necessary to distribute auxiliary and location processes and emissions by individual services.

There is a wide range of initiatives to determine the amount of carbon dioxide emitted into the transport and logistics markets. Looking at their type, purpose and variability, they can be divided into the following categories:

- standards for prescribing and/or harmonizing the CO_2 emission calculation methodology;
- programmes and other initiatives within the transport market to promote, support or harmonise the CO_2 emissions calculations;
- tools for calculating or comparing total CO_2 emissions in transport services.

The most important standards for the calculation of CO_2 emissions for transport services are:

- Standard EN 16258, developed by CEN, published in 2012

It is a European standard that provides a methodology for the calculation and declaration of energy consumption and greenhouse gas emissions of transport services (freight and passenger transport);

- Regulation 2011-1336, adopted by the Government of France, in 2011, with the beginning of application in 2013;

Regulations in France that oblige passenger and cargo transport providers to report greenhouse gas emissions. The regulation is based on EN 16258;

- Corporate value chain - standard of GHG protocol;

A standard for the calculation of greenhouse gas emissions developed by the Green House Gas Initiative, which is a multi-stakeholder partnership in the economic, non-governmental and administrative sectors led by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD).

In addition to standards and normative documents that were developed by standardization bodies and public institutions in the transport sector, the sector itself has also launched initiatives to support methods of calculating carbon dioxide. In order to use different methods in practice, it is necessary to determine the limitations, comparability of methods, transparency, credibility and usability.

5. Conclusion

The topic of energy efficiency, on the one hand, and the CO_2 emissions as the main greenhouse gas on the other, have resulted in a series of research aimed at finding the best solutions to environmental challenges. In the field of transport, with the aim of reducing emissions, all factors that in any way have contact with vehicles from production to the end of the operational life of a motor vehicle are included.

It has been observed that at different stages of the exploitation cycle, i.e. the life cycle of a motor vehicle, its specific and overall fuel consumption can be affected in several ways. Therefore, it has been shown that, in addition to complex and expensive constructive vehicle systems, other, by nature and cost simple, measures and techniques can also make a significant contribution to the solution of energy efficiency problems.

It is very important to emphasize that a significant number of these measures do not require large financial resources for implementation, and it is necessary to promote them through various forms of education by introducing drivers to the reasons, ways of application and finally the benefits for them and the environment.

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