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REDUCING CO2 EMMISION WITH MULTIMODAL TRANSPORT TECHNOLOGIE "A" ON SERBIAN PART OF CORRIDOR X

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Abstract *Corridor X is one of Pan-European traffic corridors that connects eight counties on main axis from Saltsburg (Austria) to Thessalonica (Greece) and six more countries with corridor branches. From total length of 2360 km, Serbian part of Corridor X is approximately 800km.*

Serbia, among many other countries is trying to find a way to reduce greenhouse gas (GHG) emission. There is an estimate that in year 2003 emission of GHG was 13 630 000 tons, which is approximately 1.81 tons per capita. By this parameter Serbia is taking a significant place in world biggest pollution countries, with constant rising emission of GHG in every year.

Because of the high number of heavy road vehicles per year on Corridor X through Serbia, there are some side effects such as emission of CO_2 gas as product of organic fuel combustion. Fossil fuels combustion causes high emission of mainly CO_2 gas and results with higher rate of dangerous substance then it can be naturally absorbed. Role of traffic in process of polluting environment is significant with big part of road traffic. Road transport is biggest polluter in traffic with 80-90% of total amount of CO_2 that is emitted by all means of traffic.

Transport affects the environment by creating a series of undesirable and harmful effects; global warming being one of the main problems the modern society is facing. Numerous studies show that the traffic significantly contributes to the environmental pollution, primarily caused by combustion of fossil fuels. In the last 15 years various studies were performed in EU about energy consumption and CO_2 emission by road and rail traffic. The results of these studies clearly indicate a significant saving in CO_2 emissions using both rail and multimodal road – rail transport compared with pure road transport. In the European Union (EU), appropriate measures in the transport sector are being implemented, significantly contributing towards enhancing the environmental protection effects. In particular, Technology "A" is heavily represented on certain routes within the EU, as a system that enables rail transport of complete road vehicles on the congested traffic routes. Its practical implementation has shown many of the benefits of faster and cheaper freight transport, resulting in the reduction of environmental pollution. Therefore, the one of the ways to reduce emission of CO_2 is to increase share of railway traffic as a ecologically clean mean of transport, because railways mainly use electrical power to operate trains. In this paper we discuss possibilities of introducing multimodal transport technology „A" (transport of heavy road vehicles by railway) on part of Corridor X thru Serbia with analysis of effects that are reflected in reduction of total GHG emission, cost-effectiveness of introducing technology „A" (adding environmental costs in the total investments), relationship between tariffs, distance and cost efficiency, etc. The key contribution of this work is in the proposal of the micro-location problem solution, as well as in the proof for the existence of the economic justification of implementing Technology "A" in Serbia.

Keywords: *freight transport, greenhouse gas, multimodal transport, ecology, corridor X.*

I. INTRODUCTION

The environment can be defined as a complex and orderly system of communities of different living organisms (flora and fauna) and the corresponding spatial elements (land, water, and air) [1]. It is governed by a system of relationships, where transport systems, due to the construction of new or modernization of existing ones, significantly contribute to the introduction of certain changes. Transport systems, as widely spread and complex structures, affect the environment both locally and globally, with the uneven spatial and functional distribution.

Transport affects the environment by creating a series of undesirable and harmful effects; global warming being one of the main problems the modern society is facing. Numerous studies show that the traffic significantly contributes to the environmental pollution, primarily caused by combustion of fossil fuels.

In the European Union (EU), appropriate measures in the transport sector are being implemented, significantly contributing towards enhancing the environmental protection effects [2]. In particular, Technology “A” is heavily represented on certain routes within the EU, as a system that enables rail transport of complete road vehicles on the congested traffic routes. Its practical implementation has shown many of the benefits of faster and cheaper freight transport, resulting in the reduction of environmental pollution.

This paper presents the financial, socio-economic and environmental effects achieved by the introduction of the multi-modal Technology “A.” A considerable number of previous studies in this field were conducted in Western Europe, as this technology has been in use in the region since 1990.

The key contribution of this work is in the proposal of the micro-location problem solution, as well as in the proof for the existence of the economic justification of implementing Technology “A” in Serbia.

II. CO_2 EMMISIONS IN SERBIA

Industry and transport are the main producers of carbon dioxide (CO_2) emissions, creating greenhouse gases. Road traffic is the key contributor in the pollution, compared to other modes of transport, as road vehicles are powered by synthetic liquid fuels, obtained by processing primary fossil fuels, i.e. crude oil. The basic crude oil composition includes alkanes, alkenes and cyclic hydrocarbons (with over 80% participation) [3].

The methane combustion process, as the simplest hydrocarbon in the alkane order, can be represented by the chemical reaction equation:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \qquad (1)$$

where the atomic mass of hydrogen is 1, carbon 12 and oxygen 16, yielding the following proportions:

$$(12+1*4)_{\text{methane}(16)} + 2*(16*2)_{\text{oxygen}(64)} \rightarrow$$
$$\rightarrow (12+16*2)_{\text{carbon dioxide}(44)} + 2*(1*2+16)_{\text{water}(36)} \qquad (2)$$

Equation (2) leads to the conclusions [4]:

- combustion of 1 kg of methane requires 4 kg of oxygen and
- combustion of 1 kg of methane emits 2.75 kg of CO_2.

Combustion of the simplest hydrocarbon, methane, 75% of which is carbon, yields the ratio of oxygen consumption to carbon dioxide emission. As carbon contributes to the composition of liquid fuel materials by 87%, the CO_2 emissions in internal combustion engines (ICE) are even higher. Furthermore, in addition to the above components, fuel composition includes other impurities, emitted by internal combustion engines in the form of other oxides. Exhaust gases from ICE engines contain significant levels of soot-a hard filtrate comprised of carbon particles. In addition to reduced visibility, soot has a detrimental effect on public health, as it contains carcinogenic hydrocarbons.

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In terms of total CO_2 emissions, Serbia, with 13,630,000 tons, occupies 56th position in the world [5]. However, with 7,498,001 inhabitants, the average emission is 1.81 tons per capita, which would be even higher, if population density was taken into account. Based on these parameters, it can be unambiguously concluded that Serbia, by the per capita and spatial distribution of CO_2 emissions, occupies one of the top positions in the world. Clearly, Serbia is not one of the states that implemented the CO_2 emissions reduction measures.

All major sources of CO_2 in Serbia are clustered in a relatively small geographical area. Transport, especially road traffic, as the largest emitter of CO_2, is a major problem. The road transport participation in the environmental pollution is significant, primarily due to the fuel combustion byproducts. Significant emissions, CO_2 in particular, are generated by burning fossil fuels, whereby hazardous materials-in quantities greater than can be naturally degraded-are emitted into the atmosphere, with harmful environmental effects.

The first source of the problem is the widespread use of a large number of units of emission sources that are, compared to the industry, relatively small emitters. Small vehicle dimensions make the installation of known technologies for CO_2 separation from car exhaust fumes impractical and largely ineffective. Hence, this issue primarily relates to the prevention of CO_2 emissions into the atmosphere. Another problem is lack of concentration of emissions, i.e. the sources are distributed over the entire transport network. For this reason, technology for the separation of CO_2 produced by different modes of transport does not yield sufficient energy efficiency. Efficiency coefficient of the isolated CO_2 mass, its compression, transport, storage and further use is extremely small.

Clearly, within the transport system, the key issue is in capturing CO_2 before and after its release into the atmosphere.

III. MARKAL MODEL

The application of this model is confirmed by over 80 users in 40 countries worldwide. The outcome of its implementation is energy economy [6].

The model results analysis is presented in this paper, as none of the extant traditional models are able to provide precise answers with respect to the fundamental issues of the Kyoto Protocol [7]. For the calculations of these requirements, the part of the MARKAL model had to be extended, as related to the change in the fundamentals of economic and energy efficiency, specifically in relation to the need for additional remediation costs related to CO_2 emissions. The expanded model, based on the current information, introduced the following methods for CO_2 reduction: forestation, development of carbon-based products, energy source substitution, substitution of traditional materials the production of which is based on technologies that require CO_2 emissions, and energy restoration from unnecessary products.

Previous studies reported on indirect costs, through the tax on CO_2 emissions in different sectors of the economy, whereby the generated financial resources were used for the reduction of CO_2 emissions.

A significant result of the MARKAL model is that the increase in emissions leads to the exponentially higher taxes. In relation to the taxation system implemented in certain industries, the model clearly indicated that some previous estimates were unrealistic. Thus, it can be expected that, in many cases, CO_2 remediation costs will exceed the profits.

The MARKAL test is aimed for the analysis of economic and energy efficiency, as well as the calculation of the CO_2 remediation costs, in all industries for the next 20 years. The MARKAL test adopts this approach due to the issues related to the reduction of CO_2 emissions originating from road traffic (large spatial dispersion of pollution sources), as well as due to the role of transport in the production and distribution. It was noted that the remediation cost of one ton of CO_2 emissions from transport is higher than for the industry sector.

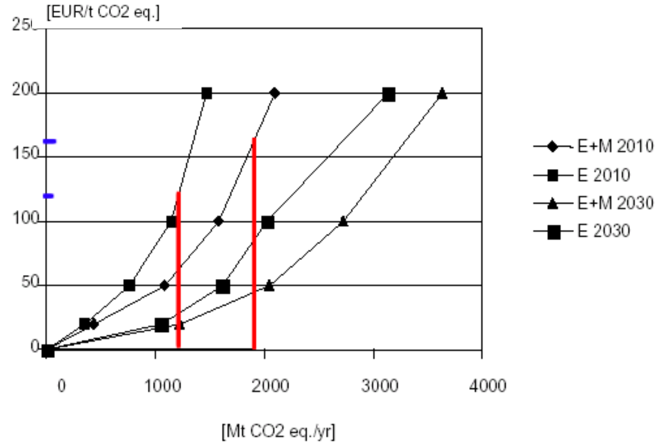

Figure 1. MARKAL CO_2 remediation cost calculation [7]

The calculated scenario applies to the total emissions in the range 1200 – 1900 Mt CO_2 in 2010, for different measurement systems that are specific to energy (E) and the energy and materials (E + M) [6]. In Figure 1, the emission intervals (1200 – 1900 Mt CO_2) and their corresponding remediation costs (120 – 160 Euro per ton of CO_2, for 2010) are highlighted.

It is assumed that the minimum remediation cost, based on the MARKAL model, is 120 Euro per ton of CO_2.

IV. TECHNOLOGY "A"

Technology "A" refers to the transport of complete road vehicles on specialized railway carriages [8]. The transport carriages within this technology are constructed with extremely low loading surface, and are interconnected to form a platform for the movement of road vehicles during loading and unloading. For this reason, the technology is named mobile highway, and is referred to in the literature as "Rollende Landstrasse − Ro-La", "Rolling Motorway − Ro-Mo", "Rolling Highway", "Rolling Road" or "Route Roulante".

During the railway transport, the road vehicle drivers, can sleep or rest in the passenger carriages, which are an integral part of the train (accompanied transport), as shown in Fig. 2. At the station, they can reclaim their vehicles and transport them to the destination of their choice. However, this technology, as many others, enables transport of road vehicles without drivers (unattended vehicles). In this case, at the station, the vehicle is delivered to a road transport company representative for further transit.

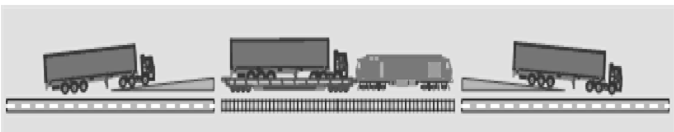

Figure 2. Accompanied transport

Reloading operations required by auto transporters and saddle vehicles can be accomplished without any special reloading facilities or equipment. These vehicles can be self-loaded onto the train over the frontal ramp and later unloaded in the same manner. Compared to the vertical cargo unit reloading, the railway company implementing Technology "A" can achieve substantial savings that can be reinvested into reloading equipment and other resources [9].

Technology "A" advantages:

- Traffic, transport, economic and social benefits;
- Reduction in road traffic volume;

- Environmental protection by reducing emissions and noise;
- Much shorter reloading time, compared to other huckepack technologies (about 20 minutes for a train weighing 1.250 tons);
- Potential for transporting all types of road freight vehicles with no adaptation;
- No expensive reloading machinery is required, as only reloading ramps are used in this process;
- High road vehicle productivity (faster delivery and longer driver operating time).

Technology “A” drawbacks:

- The unfavorable ratio of useful vs. redundant mass, due to the need to transport road haulage vehicles;
- Significant fixed capital expenditure, as the haulage vehicles cannot be used in other capacity during the rail transport;
- High rail carriage costs;
- High low-floor carriage maintenance costs.

Figure 3. Frontal ramp for reloading road freight vehicles

Technical Technology “A” characteristics include [8]:

a) Road transport vehicles,

b) Specialized railway carriages, and

c) Terminals with facilities and equipment for horizontal loading of road freight vehicles (Fig. 3).

Based on the evidence from other European countries, and the goal to implement more effective transport systems-including increasing environmental protection measures-Technology “A” has been used on many routes within EU. This transport method, whereby complete road vehicles are transported by rail, in particular on congested routes, has shown many advantages in practice, such as faster and cheaper transport of goods, as well as reduction of environmental pollution.

V. COST-BENEFIT ANALYSIS OF FEASIBILITY AND JUSTIFIABILITY OF INTRODUCING TECHNOLOGY "A"

In order to provide an adequate economic and financial justification of introducing Technology "A" in the Serbian Railways system, a cost-benefit analysis was carried out. The costs include all the investments and operating costs of railway assets, whilst financial effects are reported as profits.

In the process of investment efficiency evaluation, all effects are classified as [10]:

- Effects on the railway system, or
- Effects on economy and society.

The effects on the railways are the direct effects that are manifested as immediate and visible results of the introduction of this technology, directly affecting the railway operations (revenues and costs).

The societal and economic effects are the indirect effects that result from investment activities, which are not manifested within the railway system, but within its environment, i.e. economy and society.

The above effects clearly indicate the demand for two assessment measures:

- Financial assessment − assessment of efficiency from the standpoint of the Serbian Railways, as investors, and
- Socio-economic evaluation – assessment of efficiency from the perspective of transport users and society as a whole.

The present efficiency assessment places special emphasis on the issue of environmental pollution, which is why the socio-economic evaluation will, for the first time, include the CO_2 emissions reduction cost.

A. Financial Assessment

The paper discusses two potential applications of Technology "A" in Serbia [11]:

- The introduction on the route Zemun Polje – Subotica, with the investment into two terminals, located in these cities (Variant A),
- The introduction on the route Zemun Polje – Budapest, with the construction of the terminal station in Zemun Polje (Variant B).

In the first case, a closed system is considered, i.e. transport is performed within the Serbian borders, in which case two terminals are required. The second option connects Serbia with Hungary, whereby only one terminal in Zemun Polje is needed.

The cost of capital investment for both variants (A and B) is estimated to 2,000,000 Euro, based on the studies conducted by the Traffic Institute CIP [10].

The basic costs of introducing Technology "A" are calculated as follows:

- Freight vehicle maintenance costs are calculated based the projected number of actual vehicle kilometers and average maintenance costs, whereby the amount of 0.06 Euro/vehicle km is adopted.
- Locomotive maintenance costs were calculated as above, yielding a value of 0.47 Euro/locomotive km.
- Energy costs are calculated for consumption of 23 kWh/103 BRTKM, at 0.04 Euro/kW.

Although both versions are unacceptable for the tariff of 0.5 Euro/km, as the internal rate of return (IRR) is about 10%, further analysis of the impact of increasing transportation costs to the feasibility of introducing this technology was carried out.

As the tariffs for the transport of complete heavy road vehicles varies in the range of 0.5 to 1 Euro/truck km, a further analysis incorporated the increase from 0.5 to 0.59 Euro/truck km.

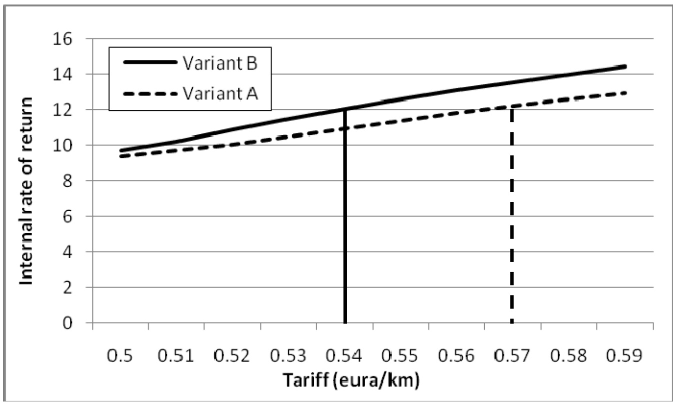

Figure 4. Change in the internal rate of return (IRR) with the tariff increase

The first Variant A - the construction of a closed system (within Serbia) - becomes profitable when the tariff exceeds 0.57 Euro/truck km, which is, for this route, equivalent to 102.6 Euro per truck. The second Variant B that connects Serbia with Hungary becomes profitable for tariffs above 0.54 Euro/km.

Thus, the above analysis has proven that the introduction of Technology "A", from the perspective of the railway, is a profitable enterprise. Fig. 4 shows an overview of both versions, with the variations in IRR resulting from increases in tariffs for the heavy vehicle rail transport.

B. Socio-economic Assessment

In the socio-economic assessment, the main costs include maintenance of freight vehicles and locomotives and energy costs, calculated in the same way as in the previous case.

The analysis of cost-effectiveness of introducing this technology in terms of society as a whole should include revenues that will not directly affect the railways, but will benefit the society [12]. This paper specifically considers the savings in:

- Highway maintenance,
- Reduction in greenhouse gas emissions (CO_2), and
- Reduction in heavy road vehicle depreciation and maintenance costs.

However, the above analysis must include all the losses the state will incur by investing in Technology "A". These are:

- Losses incurred due to unpaid tolls, and
- Losses arising due to uncollected excise taxes.

Clearly, from the socio-economic perspective, Technology "A" is fully viable, although CO_2 remediation costs are not included in the above analysis.

Variant A (closed system, with the construction of two terminals in Serbia) has IRR of 13.15%, whereas it is 14.80% for Variant B (connection with Hungary).

C. Analysis of the Environmental Effects

In order to determine the economic and societal effects of the introduction of Technology "A", the next section presents a socio-economic evaluation, which includes income resulting from the reduction of CO_2 emissions.

Diversion of road traffic (heavy freight vehicles) onto the railway will result in reduced exhaust emissions, providing income due to much lower environmental pollution [13].

The Markal test determined the amount of compensation for emitting a ton of CO_2 as approximately 120 Euro.

Fig. 5 gives an overview of the socio-economic assessment for the Variant A. The lower curve is a graphical representation of the IRR for the Variant A when environmental costs are excluded, and the upper curve includes these costs. The difference between the two curves appears negligible (2.55%), as it is based on the comparison between the two IRR estimates - inclusive and exclusive of environmental costs - at 15.70% and 13.15%, respectively.

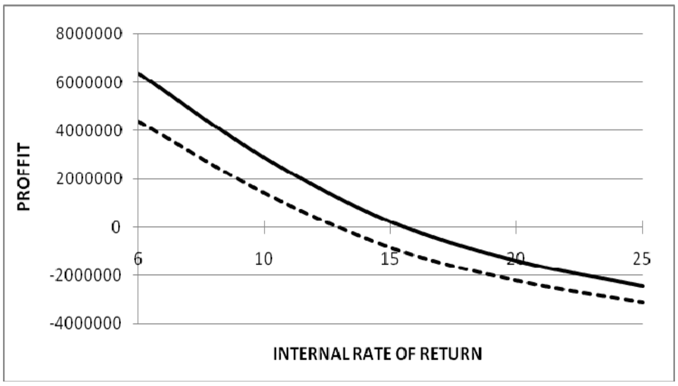

Figure 5. Variant A

Fig. 6 shows the socio-economic evaluation for Variant B, where the IRR inclusive of the environmental costs is 19.25% (the upper curve), and 14.80% with the costs excluded (the lower curve).

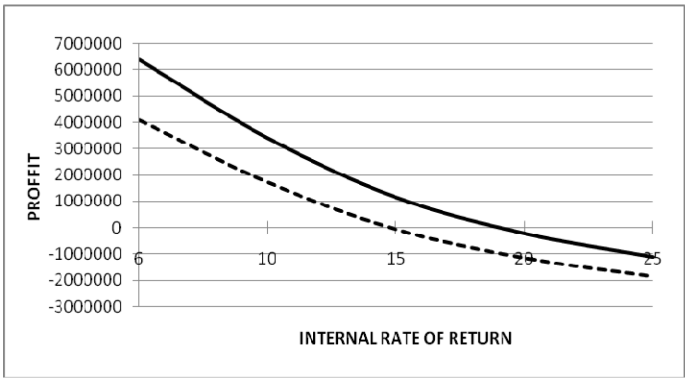

Figure 6. Variant B

Although the differences for both variants are relatively low, they can have a significant impact on the return on investment period, which will be shown in the next section.

The projected term for return on investment in Variant B is 8 and 11 years, when the environmental protection costs are included or excluded, respectively.

The difference of 3 years is not negligible, especially when the environmental costs and benefits are considered (in this case, reduction of CO_2 emissions).

The above results classify the environmental costs as the most important. Given this information, all subsequent economic analyses will favor the use of multimodal technologies, due to their high rates of return.

We expect that, in the future analyses, the inclusion of environmental factors will become the norm, whereby meeting environmental standards would be a requirement for integration into modern European trends.

VI. CONCLUSION

The analysis conducted in this study highlights the necessity of initiating concrete activities on the development of multimodal technologies in Serbia (primarily Technology “A”). The findings indicate that the construction of terminals in Serbia must commence in order for the country to integrate into the in international flows of intermodal units.

The profitability of the Technology “A” application is fully proven, with the IRR for the Variant A at 12%, based on the tariff of 0.57 Euro/km. For Variant B, the corresponding values are 12% and 0.54 Euro/km.

A relatively high IRR of was obtained due to the inclusion environmental costs, i.e. the costs incurred by environmental pollution.

Environmental effects outlined in this paper are based on the analysis of a single part of Corridor X in Serbia. The environmental costs are classified as the most important part of the analysis. Given this information, all subsequent economic analyses will favor the use of multimodal technologies, due to their high rates of return. It should be noted that the funds required for building roads and the implementation of multimodal technology are invested only once, whilst yielding permanent environmental protection. Finally, the environment is currently the most important economic parameter, as it has no alternative and its degradation cannot be compensated for by other resources.

The role of government in designing a national strategy for the development of combined transport is extremely important. The prerequisites for the implementation and development of combined transport in Serbia are adopting the concept of the development of combined transport, identification and tracking of goods flows, construction of terminals for combined transport, improving tariff system, identifying bottlenecks in the transport infrastructure, adopting appropriate measures towards reducing delays at border crossings, and shorter transit time through Serbia.

The necessity of introducing Technology “A” in Serbia is obvious, as it is one of the fundamental environmental protection measures and a precondition for EU membership. The significance of the environment is yet to be recognized; however, the emphasis on its societal effects can contribute to the development of the aforementioned and other technologies that will improve the quality of living conditions and preserving non-renewable natural resources.

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НАМАЛЯВАНЕ НА ЕМИСИИТЕ НА CO2 ПРИ МУЛТИМОДАЛНА ТРАНСПОРТНА ТЕХНОЛИГИЯ "А" В СРЪБСКАТА ЧАСТ НА КОРИДОР X

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Ключови думи: *товарен транспорт, газ с парников ефект, мултимодален транспорт, екология, Коридор X.*

Резюме: *Коридор X е един от пан-европейските пътни коридори, който свързва осем страни по главната ос от Залцбург (Австрия) до Солун (Гърция) и още шест страни с клонове на коридора. От обща дължина 2360 км сръбска част на Коридор X е около 800 км.*

Сърбия, наред с много други страни се опитва да намери начин за намаляване на емисиите на газове с пярников ификт. Налице е оценка, че през 2003 г. емисиите на парникови газове е 13 630 000 тона, което е приблизително 1,81 тона на глава от населението. По този параметър Сърбия заема значително място в света сред страните с най-голямо замърсяване, с постоянно нарастващите емисии на парникови газове всяка година.

Поради големия брой на тежки превозни средства, преминаващи годишно по Коридор X през Сърбия, има някои странични ефекти, като например емисиите на CO_2 като продукт на биологично изгаряне на горивото. Изгарянето на изкопаемите горива води до високи емисии на основно на CO_2 и резултати с по-висок процент на опасни вещества, отколкото може да се абсорбиращ естествено. Ролята на трафика в процеса на замърсяване на околната среда е значително голяма. Автомобилният транспорт е най-големият замърсител в транспорта – 80-90% от общата сума на CO_2, който се излъчва от всички средства в транспорта.