THE COST OF CO2 EMISSIONS ACCORDING TO THE TRANSPORT IN SLOVENIA

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Abstract

Transport is one of the human activities that increases the amount of greenhouse gases in the air. CO2 is the main cause of global warming and contribute for around 80% of all greenhouse gas emissions. Approximately 40% of CO2 emissions from transport is produced only from urban mobility.

The paper presents review of CO2 production based on the amount of sold fuel, number of registered vehicles, busses, trucks and motor cycles (in relation to the population). Research involves 7 major cities in Slovenia: Ljubljana, Maribor, Celje, Koper, Novo Mesto, Kranj and Murska Sobota. Based on the obtained data, we made calculations about the production of Co2 according to the type of fuel. We captured the percentage of consumed gasoline and diesel fuels in each city. According to these findings, we found out the value of Co2 emissions from transport. The purpose of this article is to show possible improvements that would reduce the production of CO2 emissions from transport. There are numerous ways to decrease CO2 emissions in cities not just in transport but mostly with smarter industry. The conducted research has focused on the issue of traffic congestion in cities and to reduce CO2 emissions by 15% in total by 2030, as Slovenia concluded an agreement with other EU members in 2009**.** We found out that with implementation of wiser traffic management and reduction of traffic in cities there would be a remarkable change in the amount of CO2 emissions produced from transport.

Keywords: CO2 emissions, the cost of CO2 from transport, traffic congestions, traffic management, transport

1. INTRODUCTION

Globalization is the main reason for increasing mobility in the world, thus also result in significant costs. Next to all the impacts on the environment and human health, that was the main reason for the formation of our article.

The increase in transport has many negative impacts on the environment like air pollution problems that are caused by Burning of Fossil Fuels, Agricultural activities, Exhaust from factories and industries and some other activities. Global climate changing has become a severe problem in the world nowadays. The temperature of the atmosphere is increasing because the heat waves are becoming more intense and more frequent. Global warming and air pollution are largely caused by greenhouse gas emissions from traffic and Fossil Fuels (Kakouei et. al., 2012).

A Stanford scientist details how each increase of 1 degree Celsius caused by CO2 would annually lead up to upward of 20000 air-pollution-related deaths (Whitty, 2008). GHG include Fluorinated gases, Nitrous oxide (N2O), Methane (CH4) and the most problematic Carbon dioxide (CO2). Carbon emissions are the most significant of greenhouse gas emissions that cause global warming (Dosio et. al., 2018). Increased concentration of CO2 can lead to various health problems, these are: headache, dizziness, restlessness, difficulty breathing, sweating, fatigue, high blood pressure, suffocation and other (Department of Health Services). The effects of CO2 on an individual are dependent on the concentration and duration of exposure. At the same time, other factors have influence on this, those are: age, health, physiological composition, lifestyle and others (Rice, 2003).

Carbon dioxide is a colorless and non-combustible gas at room temperature. It is naturally present in the air, so it is inhaled at a concentration of about 0.037% (Health and Safety Executive).

Levels of CO2 emissions in the air are:

a) 250-300 ppm - normal amount of exterior spaces;
b) 350-1000 ppm - normal amount of indoor spaces;
c) 1000-2000 ppm - rate associated with fatigue;
d) 2000-5000 ppm - rate associated with headaches, poor concentration and increased heart rate;
e) > 5000 ppm - unusual air conditions (Department of Health Services).

The industrial revolution has caused a significant increase in CO2 emissions. CO2 accounts for 72% of all greenhouse gases. It is the main cause in addition to PM particles for global warming. It takes 100-200 years for CO2 to decompose from the atmosphere, due to this fact, because of that CO2 accumulates in the atmosphere, which leads to an increase in surface temperatures and increasing fluctuations in weather. For this reason, the European Union has made a directive that the atmosphere should not be heated by more than 2 degrees Celsius, which on the other hand means a significant reduction in CO2 emissions. Transport planners and founders of transit and real estate were from the very beginning interested in those markets, which were supportive of transit services, especially in the field of public transport. The expansion of the automotive industry between and after industrial revolution, almost broke the development of the railways with the comfort and ease of a car (Feigon et.al., 2003)

Many organizations strive for efficient supply chains because of enormous mass production of raw materials, goods and products for the customers' needs. Today's production of goods is formed based on customer satisfaction (Jereb et. al., 2016). To make business processes more effective and efficient we must to reduce time and costs. This is achieved by well-organized transport. Because of this reason, the increase on transport is reflected in all modes of transportation: road, rail, sea and air (Jereb et al., 2017), (Jennings, 2006).

On the other hand, we have a smart traffic management in the transport field, where users can choose new and more clever ways of transport such as public transport, car sharing, hybrid vehicles, electrical vehicles, etc. On the side of the member states of the EU is to regulate the legislation in the field of transport, or just to implement the smart traffic management such as green waves. By implementation of such management we decrease fuel consumption, emissions of CO2 and the impact on the environment. The correlation is always proportional, as the fuel consumption increases, so do emissions and the impact on the environment (Jereb & Čeh, 2017).

The European Union wants to reduce the amount of greenhouse gas emissions by 20% (European Commission)[1]. They want to reach a reduction with the strategy called European 20/20/20 objectives. The strategy was set by EU leaders in 2007 and has three targets to achieve: 20% increase in energy efficiency, 20% reduction of CO2 emissions and 20% renewables by 2020. Whit this set of binding legislation, they want to ensure improvements on climate and energy sets (Lodi et. al., 2018), (Erixon, 2010).

The first clear EU demand of emission trading was in 2000 when the EU issued a Green Paper on greenhouse gas emissions trading. Such a system of restriction and trading of emission credits (A "cap and trade" system) was established in the EU in 2005, primarily for the achievement of the Kyoto Protocol of 1997 when it was signed (A. D. Ellerman et al., 2015). The Kyoto Protocol was signed by industrialized nations and stipulates that greenhouse gas emissions will be reduced by 5% between 2008 and 2012 compared to 1990. The second target period was adopted in 2012, known as the modification of the Doha Convention Protocol (CNN Library, 2018).

The objective of establishing an emission trading scheme is to allow market mechanisms to drive industrial and commercial processes towards lower emissions of carbon dioxide and other greenhouse gases, as in the case of processes where the price for discharges is not determined. It is a trading that represents the right to release 1 ton of CO2 or any other gas of the same weight. Limiting the amount of greenhouse gases is determined by the installations that are covered by the system. Within these limits, such companies may receive or buy these credits. If the company reduces emissions during the year, it can maintain or sell the reserve emission credits (European Commission)[2].This way of an emission trading is then reflected in the prices. We can check it with the financial models, such as the OMEGA, where the basic information about the vehicle such as weight, aerodynamic drag, map engine, etc. It is used to predict fuel consumption and CO2 emissions within a specific driving cycle. OMEGA was developed to correspond requirements of the manufacturers:

a) cost of the technology paid by the consumer,

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[1] 2020 climate & energy package
[2] EU Emissions Trading System (EU ETS)

b) the value which the consumer is likely this place on improved fuel economy,

c) the degree to which manufacturers are prepared to go to meet the co2 emission target (EPA, 2009).

The EU framework by 2030 contains the targets for reducing CO2 emissions by at least 40% since 1990, which will allow the EU to take cost-effective steps towards achieving long-term targets (2050) for reducing CO2 emissions by 80-95% within the framework of emergency reductions based on the Paris agreement (European Commission)[3]. The European Union dictates that CO2 emissions should be reduced to 20 gigatons of CO2 by the year 2050 (Rohrer, 2007).

Low carbon economy of the EU suggests:

- The EU must reduce GHG by 80% of the values measured in 1990 by 2050,
- 40% by 2030 and 60% by 2040,
- all sectors must be included, - low-carbon transition is feasible and at the same time accessible (European Commission)[4].

These regulations are covered by the White Paper, which also lists several other measures to reduce traffic in the EU. Among them are introduction of more integrated and efficient transport system, accelerated introduction of modern technologies for vehicles and fuel, promoting the use of cleaner modes of transport (European Commission)[5].

Since there are no oil deposits in Slovenia as well as refineries for the processing of crude oil, petroleum products used as energy products, including motor fuels, we import them into the territory of Slovenia or acquisition petroleum products from any country, regardless of whether it is a member of the European Union or a third country. Gasoline and diesel are imported from abroad. Due to the geographical location of Slovenia and especially access to the sea, imports from abroad do not represent major obstacles and related costs. Imports into Slovenia are done through wholesalers selling to different customers who sell motor fuels to end users or other market participants through various sales channels (Javna uprava Republike Slovenije za varstvo konkurence, 2017).

In 2016, we sold 1.651.977.401,13 liters of diesel in Slovenia and 566.994.926,89 liters of unleaded 95 octane fuel, or so-called petrol (Statistični urad RS: Bilanca trdnih, tekočih in plinastih goriv, Slovenija, letno, 2017).

Subsequently, this data was used in calculating CO2 emissions and the related value of co2 emissions arising from traffic in Slovenia, which were calculated in relation to year 2017, when the average price of the emission credit in Slovenia was € 5,76 (Ministrstvo za okolje in proctor: Register emisijskih kuponov, 2017). To calculate the emissions of co2 from the quantity of sold fuel it is necessary to know the amount of CO2 emissions that are dropped into the atmosphere when consuming 1 liter of diesel and 1 liter of petrol. So, if you use a liter of diesel, it will produce 2.6 kg of carbon dioxide. Petrol has a lower carbon content and thus produces 2.30 kg of CO2 (Comcar, 2018).

The Kyoto Protocol was ratified by Slovenia in 2002. The Kyoto Protocol's goal says that by 2030 Slovenia should reduce emissions by 15 percent compared to 2005.

[3] 2030 climate & energy framework
[4] 2050 low-carbon economy
[5] Transport: EU transport white paper

Of importance is the action to reduce emissions from the household and services sector and limiting emissions from the transport sector, in which, to attain objectives, it is first necessary to further increase the use of public passenger transport. The most unpredictable are the emissions from the transport sector, which represents 50 percent of all emissions (Senica, 2018).Reduction of GHG emissions by 15 percent will be mainly possible with a smarter and cleaner industry, which will consequently allow emissions reduction in transport as well. Transport itself will not contribute to the results. Car manufacturers will need to invest in cleaner engines, and electric cars will have to be powered by renewable energy, to achieve a 15 percent reduction by 2030. Also, the percentage of vehicles on other fuels like hybrid, electric and LPG vehicles, which now represent 1.1%, must be increased (Ministrstvo za okolje in prostor, 2014).

2. RESEARCH MODEL

To start the survey, we needed the exact number of registered vehicles in 2016 (Statistical Office of Slovenia), which we distributed to passenger cars, buses, trucks and motorcycles. According to the previously presented correlation between 1 litter fuel (gasoline or diesel), a division of vehicles was made according to diesel and petrol. Based on literature from Introduction, we researched the external costs of CO2 emissions in Slovenia from transport. As is clearly seen from Figure 2, we distinguish 3 major parts in our research, Part A, Part B and Part C.

Part A was basic part, where the data was set up for further emission calculations and costing. Part B is so called connecting part which connected the basic data with fuel litters and then the litters of spent fuel in Slovenia, with emissions. Part C or final part represents the calculation of external costs of CO2 emissions in Slovenia from transport.

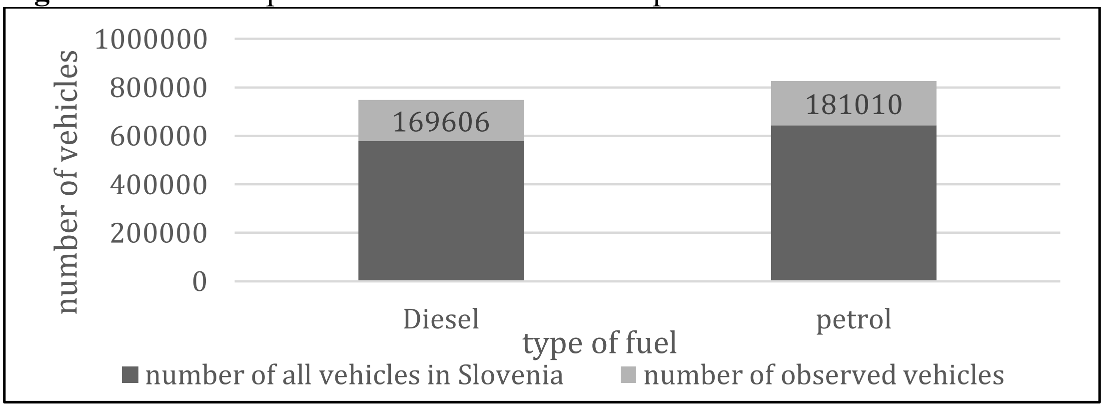
Tabel 1. Research model description

Parts of research model	Characteristics
A	Based on the previous division of registered vehicles in Slovenia by selected cities (Lj, Mb, Ce, Nm, Kp, Kr, MS), where we recalculated the percentage of registered vehicles in Slovenia, we later carried out a division of vehicles according to the motor fuel. For the subsequent calculations of CO2 emissions, we divided gasoline driven vehicles (cars and motorcycles) and diesel driven vehicles (buses and trucks). In Ljubljana there was 13,08% of registered vehicles with **petrol engine** according to whole Slovenia, in Maribor 4,73%, in Celje 2,24%, in Koper 2,73%, in Kranj 2,63%, in Novo mesto 1,78% and in Murska Sobota 0,87%. This represents

	28.06% of all registered petrol vehicles in Slovenia as is represented in Figure 1. There was 13,81% of registered vehicles **with diesel engine** in Ljubljana, 5% in Maribor, 2,41% in Celje, 2,69% in Koper, 2,65% in Kranj, 0,89 in Murska Sobota and 1,84% in Novo mesto. Discussed cities together, represent 29,29% of diesel vehicles according to whole country as represented Figure 1.
B	According to the final fuel consumption data in Slovenia, separated into 95 octane unleaded petrol and diesel, we calculated the CO2 emissions by cities based on the calculated percentages in Part A. There is 2,6 kg of CO2 emissions from 1 litter of diesel and 2,3 kg of CO2 emissions from 1 litter of gasoline. The difference between emissions of CO2 from 1 litter of diesel and 1 litter of gasoline is 0,3 kg.
C	Based on the calculated emission quantities of CO2 and the fuel used litters separated on gasoline and diesel from Part B, we calculated how much money is charged on the CO_2 emissions from petrol and from diesel fuel. Formula, which we considered for the calculation was: $t(CO2) * Price of 1 emission credit = X[€]$

Source: own study

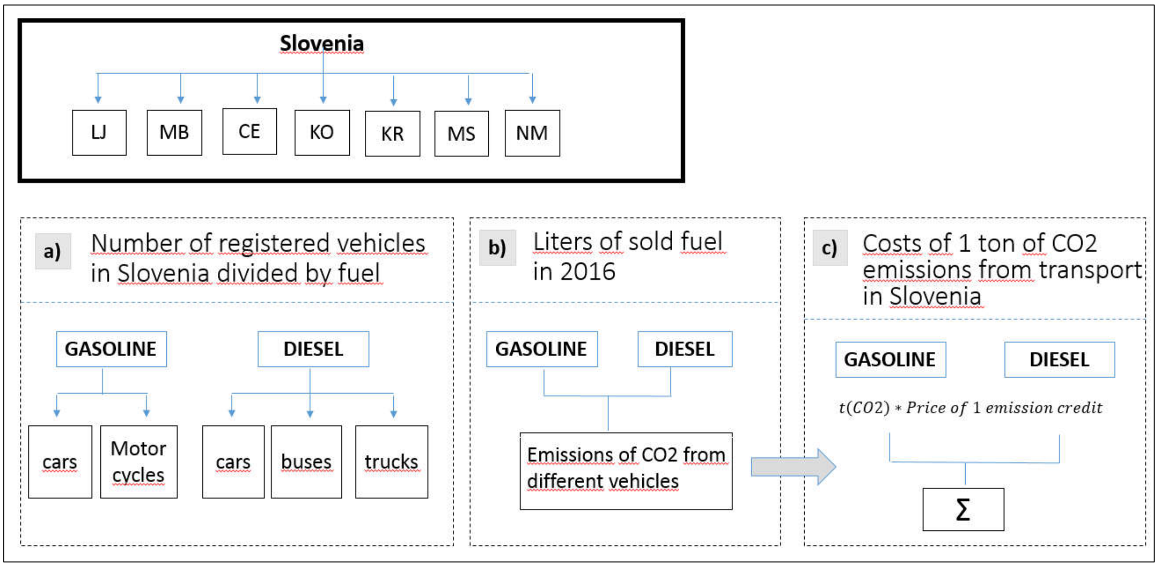
Figure 1. Research pattern divided on diesel and petrol



Source: own study

As we already said in part A, we divided vehicles according to the whole of Slovenia and separately according to fuel. As can be seen from Figure 1, diesel vehicles are approximately 1,23% more than petrol. Hybrid vehicles, gas-powered vehicles and LPG vehicles have been excluded from our research due to a negligible number of them in 2016.

Figure 2. Calculating model of research



Source: own study

3. ANALYSIS OF RESULTS

The research was carried out on the basis of the oversaturation of cities with vehicles and, consequently, of the emissions of co2 in Slovenia. From the sample of 7 biggest cities in Slovenia, we calculated the amount of co2 emissions from transport (passenger cars, buses, trucks and motorcycles) and later the costs associated with emissions. Based on the data from the literature on the reduction of Co2 emissions by 15 % in Slovenia by year 2030, we calculated what a reduction in external costs would be achieved with implementation of the smart industry and using cleaner energy sources. The costs shown below are external costs from Co2 emissions and are not tied to individuals.

In the research, we had to conclude from the sample of 7 major cities in Slovenia to the whole country, we also didn't consider those vehicles on other motor fuels, because they represented a negligible percentage of all vehicles and that was 1.1%.

From the Statistical Office of the Republic of Slovenia we obtained data on the liters of fuel consumed in Slovenia, which are shown in Table 2.

Table 2. Liters of fuel consumed in Slovenia

L (diesel)	L (gasoline)
1.651.977.401,13	566.994.926,89

Source: own study

Based on the percentage of vehicle numbers, the fuel consumption was based on the fuel consumption calculation separately for cities. Table 3 and 4 integrates the whole part A and half of Part B from the research model.

The table 3 shows the calculations of consumption of liters of diesel fuel by observed cities in Slovenia. This information includes personal vehicles, buses and lorries. These data are calculated for the following sites: MB, CE, NM, LJ, KP, MS, KR. For the entire calculation, only 29.29% of diesel vehicles were considered for the whole Slovenia.

Table 3. Liters of diesel fuel consumed by cities

	Number of all diesel driven vehicles (cars, busses, trucks)	Percentages	L (diesel)
SLO	578.944	100%	1.651.977.401,13
LJ	79.983	13,81%	228.138.079,10
MB	28.935	5,00%	82.598.870,06
CE	13.930	2,41%	39.812.655,37
NM	10.633	1,84%	30.396.384,18
KP	15.584	2,69%	44.438.192,09
MS	5173	0,89%	14.702.598,87
KR	15.368	2,65%	43.777.401,13
Σ	169.606	29,29%	483.864.180,80

Source: own study

The table below shows the calculations of fuel consumption per city in Slovenia for petrol vehicles. This information includes personal vehicles and motorcycles. These data are calculated for the following sites: MB, CE, NM, LJ, KP, MS, KR. For the entire calculation, 28.06% of petrol vehicles were used according to whole Slovenia.

Table 4. Liters of petrol fuel consumed by cities

	Number of all petrol driven vehicles (cars and motorcycles)	Percentages	L (petrol)
SLO	64.4968	100 %	566.994.926,89
LJ	84.369	13,08 %	74.162.936,44
MB	30.477	4,73 %	26.818.860,04
CE	14.469	2,24 %	12.700.686,36
NM	11.523	1,78 %	10.092.509,70
KP	17.619	2,73 %	15.478.961,50
MS	5.593	0,87 %	4.932.855,86
KR	16.960	2,63 %	14.911.966,58
Σ	181.010	28,06 %	159.098.776,5

Source: own study

CO2 emissions are divided into those derived from gasoline and diesel. From 1 liter of petrol, 2.3 liters of CO2 emissions from 1 liter of diesel fuel and 2.6 kg of CO2 emissions are released into the atmosphere. With these data, data from Table 3 and Table 4, we got the amount of CO2 emissions per city which are shown in Table 5 and Table 6.

First are shown CO2 emissions from diesel driven vehicles and then from petrol driven vehicles.

Table 5. CO2 emissions from diesel driven vehicles by cities

	CO2 [t]
SLO	4.295.141,24
LJ	593.159,00
MB	214.757,06
CE	103.512,90
NM	79.030,60
KP	115.539,30
MS	38.226,76
KR	113.821,24
Σ	1.258.046,87

Source: own study

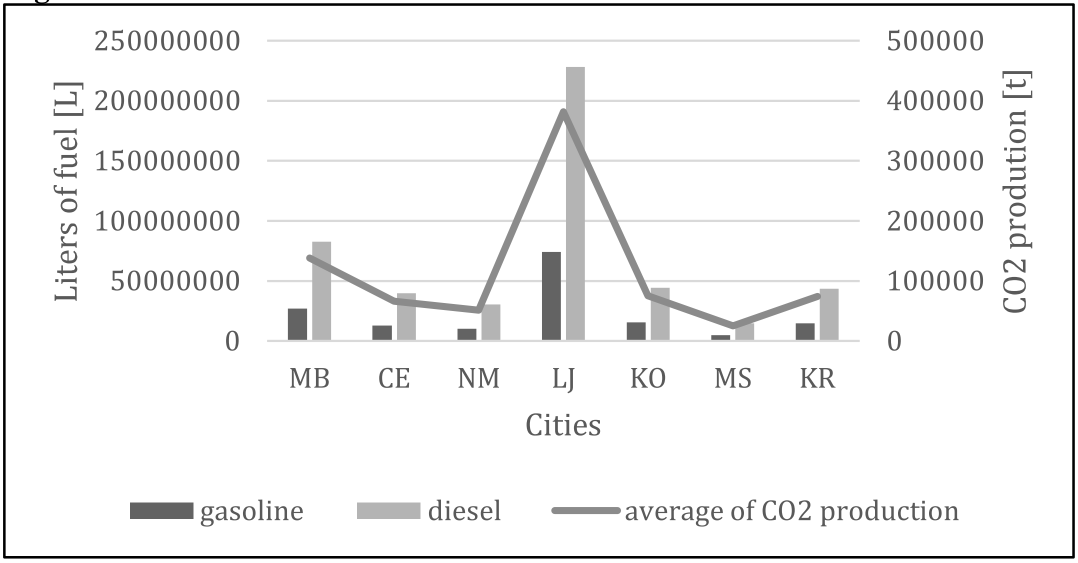
Table 6. CO2 emissions from petrol driven vehicles by cities

	CO2 [t]
SLO	1.304.088,33
LJ	170.574,75
MB	61.683,38
CE	29.211,58
NM	23.212,77
KP	35.601,61
MS	11.345,57
KR	34.297,52
Σ	365.927,19

Source: own study

Calculated in tonnes, CO2 emissions from diesel and petrol together amount 1.623.974,06 t, where 80% of emissions are produced by diesel vehicles and 20% by gasoline.

Figure 3. Production of CO2



Source: own study

The price of 1 emission credit that was used in the research was 5.76 €. As already stated in the methodology, the calculation was made using the following formula:

$$t(CO2) * Priceof1emissioncredit = X[€]$$

The results are shown in Table 7, where it is very clear that costs are higher for CO2 emissions, produced from diesel fuel.

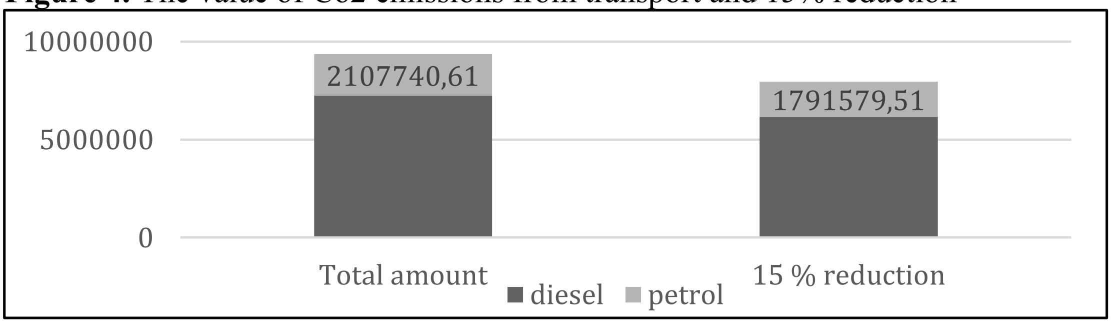
Table 7. External costs from transport according to the amount of co2 produced in selected cities

	Petrol	Diesel	Σ
External costs	2.107.740,61 €	7.246.349,97 €	9.354.090,58 €

Source: own study

Figure 4 shows the total value of Co2 emissions in Slovenia based on a sample of 7 places. The graph also shows the reduced value of the external costs of Co2 emissions from transport by 15% in the case of reaching the set goals of Slovenia until 2030.

Figure 4. The value of Co2 emissions from transport and 15% reduction



Source: own source

4. CONCLUSION

CO2 is one of the main causes of global warming, which is a major problem in today's world. A substantial proportion of the CO2 is produced because of exhaust gases in traffic.

In 2016, on the whole territory of Slovenia, it was sold 566. 994. 926,89 L of petrol and 1.651.997.401,13 L of diesel fuel. On the basis of this data, we calculated that from this quantity, 1.623.974, 06 tons of CO2 were produced. It is known that the amount of sold fuel is increasing every year, so the question is, what number of CO2 production, we will achieve in the next 10 years?

It is known that CO_2 causes many health problems in humans, so we need to be aware of their consequences. How big will these problems be, if the production of co2 continues to increase in the coming years.

The results show that Slovenia produces 1,623,974.06 tons of Co2 emissions from transport annually. In the context of the Kyoto Protocol, which was adopted in 1997 with a view to reducing emissions, Slovenia started trading in emission credits in 2003. In 2017, the average price of the emission loan was 5, 76 €, but it changed drastically from year to year. On the basis of this data, the total value of Co2 emissions for the sample of 7 cities in Slovenia amounted to 9,354,090.58 €. Due to the need to reduce emissions, Slovenia has committed itself to reducing Co2 emissions by 15% by 2030. For the state of Slovenia, this would in practice amount to 1,403,113.58 € less on an annual basis. But the question is how to achieve this reduction? Here, the state plays a big role, to achieve these figures by means of smart traffic management and better links of public transport. In addition to transport measures, it will also be necessary to promote the transition to a low-carbon economy using renewable energy sources, with measures to promote the green growth of the economy and sustainable consumption and production. Some companies have already found out that they can make money from CO2 emissions. Climeworks, for example, is the first company that started collecting CO2 and selling it for use in greenhouses (McGrath, 2017). This is also an excellent opportunity to reduce the amount of greenhouse gases from the atmosphere. In addition to the already existing measures in the field of reducing Co2 emissions in transport, we see an exceptional opportunity also in Audi's production of EV with solar cells integrated into the car's glass, which operates according to the zero-waste concept.

However, since Slovenians are probably not going to massively drive cars to solar cells by 2030, we may at least increase the current percentage of other alternative forms of power, which now represents only 1,1 %.

So, we can see that CO2 hides a lot of business opportunities, but how we will use it, depends of the country.We have to be aware that Slovenia is a small country with about 2 million inhabitants, and therefore the quantity of produced CO2 emissions is much lower than in the larger countries of the European Union, and nevertheless 7 cities in Slovenia produces 1.623.974,06 tonnes of CO2 emissions from transport at an annual level.

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