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CLIMATE CHANGE MITIGATION POTENTIAL OF THE NATIONAL TRANSPORT SECTOR

Final report

Developed by: ICEIM-MANU

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ACRONYMS

LPG	liquid petroleum gas
LDC	Least developed countries
O&M	Operation and maintenance
OECD	Organization for Economic Co-operation and Development
IPCC	Intergovernmental Panel on Climate Change
GHG	Greenhouse gas
pkm	Passenger km
CNG	Compressed Natural Gas

A. INTRODUCTION

A.1. CLIMATE CHANGE MITIGATION AND DEVELOPING COUNTRIES

In the last two decades the climate change has been a main problem which humanity faces daily. According to the IPCC [1], the global temperature is likely to rise a further 1.1 to 6.4 °C by the year 2100. In reply, many countries have developed strategy for GHG emissions reduction [2-5]. Furthermore, in many cases the GHG emissions reduction efforts have targeted specific sectors [6-8].

However, it is increasingly evident that to avoid dangerous climate change, GHG emissions need to be reduced not only in industrialized, but also in the developing world. Hence, the discussions about the future of the climate regime address enhanced national/international action, including the consideration of:

- Measurable, reportable and verifiable nationally appropriate mitigation commitments or actions by ***all developed countries***
- ***Nationally appropriate mitigation actions(NAMAs) by developing countries*** supported and enabled by technology, financing and capacity-building, in a ***measurable, reportable and verifiable(MRV)***manner
- Cooperative ***sectoral approaches*** and sector-specific mitigation actions

As of January 2012, 44 developing countries, including the major emitters, had submitted their planned mitigation actions. Most of the actions are expressed in terms of reduction of GHG emissions below the business-as-usual (Brazil, Indonesia, Israel, Kazakhstan, Korea, Mexico, Singapore, South Africa) or in terms of reduction of carbon intensity of the economy (China, India, Malaysia). Many countries submitted a list of NAMAs that were not expressed in expected GHG reductions. Some countries also indicated specific measures or sectors that would take priority. In some cases, mostly in the submissions by LDCs, countries indicated that implementation of actions would require international support in terms of finance, capacity building and technology. Many submissions have emphasized that the identified NAMAs are preliminary and further analysis would be required.

The country submitted its nationally appropriate mitigation actions of developing country Parties based on Second National Communication in terms of 20%/30% GHG emissions below the business-as-usual scenario in 2020. The focus of mitigation was energy sector, as is the case with the other developing countries, and no MRV mechanisms were considered. In line with the ongoing negotiations at international, but also at European level, regarding the quantified emission limitation or reduction objectives (QELROs), ***a participatory process*** should be initiated ***for all sectors*** – identified as potential targets of the mitigation efforts, aimed at analyses and setting of appropriate and feasible emission reduction/limitation targets. Specifically,

- analytical work should be carried out in order to identify the mitigation potential of the sector, considering all relevant aspects – technical (how the emissions can be reduced?), environmental (how much emissions can be reduced?) and economic (at what price the emissions can be reduced?);
- appropriate criteria for prioritization of the mitigation measures should be adopted
- the mitigation measures should be evaluated against the adopted criteria
- National Appropriate Mitigation Actions (NAMAs) should be developed
- Mechanisms for Measuring, Reporting and Verification (MRV) should be developed as means for tracking the progress of NAMAs

The results will facilitate the national mitigation action and planning, will enable ***recognition of the mitigation efforts of the country***, as well as will ***link the national mitigation action to international support***. Moreover, the results would support competent and wise policy making in the field of climate change and will enhance the positions of the country in the climate change negotiation process at international, as well as at European level.

A.2. CLIMATE CHANGE MITIGATION IN TRANSPORT SECTOR

Worldwide, transport sector is one of the sector s that vastly contributes to GHG emissions increase [9]. In 2005, the transport sector contributed with 23% in world GHG emissions, while the share in the OECD countries amounted 30% [10]. Therefore, ***the transport sector progressively reaches the top of mitigation agenda in Europe, as well as worldwide***.

As developing country, according to Second National Communication for Climate Changes [5], the transport sector contributed with 7% in the total national GHG emissions for the period 1990-2002 and in 2009 contributed with 10%. The increasing of GHG emissions in the transport sector is a result of increased number of vehicles, although still modest compared to developed countries - 130 vehicles per 1000 inhabitants in 2006 year, 170 in 2010 and according to the National Strategy for Energy Development [11], 260 and 400 are expected numbers of the vehicles per 1000 inhabitants in 2020 and 2030, respectively. Therefore, ***the transport sector also should be given a well deserved focus in the mitigation efforts***.

Finally, in a country with predominant fossil fuel energy generation it is clear that energy sector has the largest room for emissions reduction, and therefore needs more complex modeling and in-depth analyses. However, many other sectors (so called non-energy sectors) have been recognized as potential target of the mitigation efforts. In national context, ***the transport sector takes the lead among the non-energy sectors, and could serve as a pilot sector for assessment of climate change mitigation potential***.

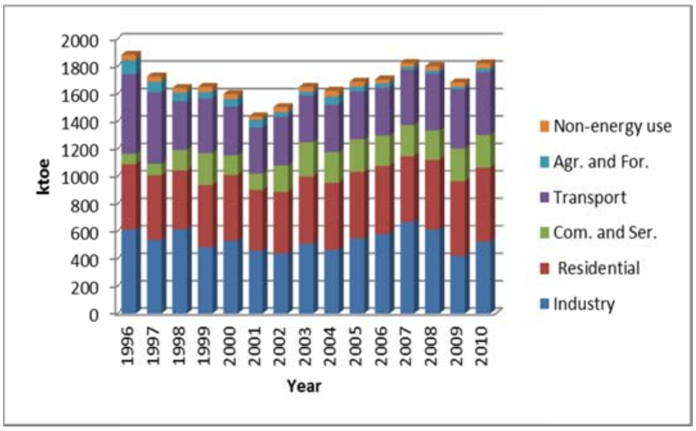
The main goal of this study is to conduct comprehensive assessment of climate change mitigation potential of the national transport sector applying ***bottom-up approach*** and evaluating the appropriate mitigation options in terms of their ***environmental effectiveness*** (volume of GHG emissions reduction) and ***economic effectiveness*** (specific cost of reduction). Furthermore, a ***participatory process*** was initiated in order to reflect the country specifics into prioritization of the mitigation strategies in national transport sector.

Including the necessary analytical work and participatory prioritization of the mitigation actions, this study is a first step in developing national NAMAs in transport sector. The next phase should include developing MRV mechanisms for the identified mitigation actions. The results will contribute towards formulation of wise and well-informed transport sector policies reflecting also the commitment for climate change mitigation.

B. AN OVERVIEW OF NATIONAL TRANSPORT SECTOR

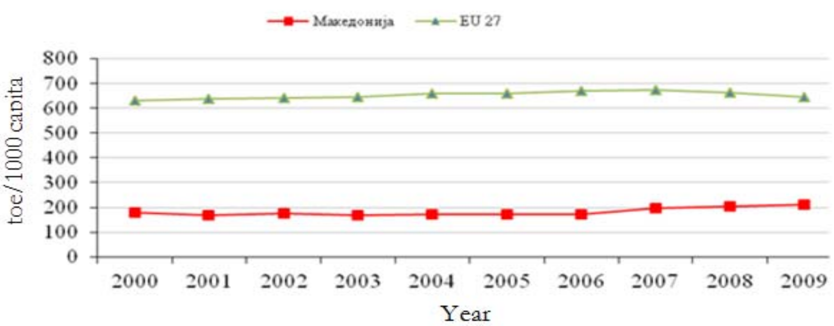
The transport sector has had a considerable share in the national energy balance, 20.2% in 2006 and 25.3% in 2010 (Figure 1).

Figure 1.Final energy consumption by sectors



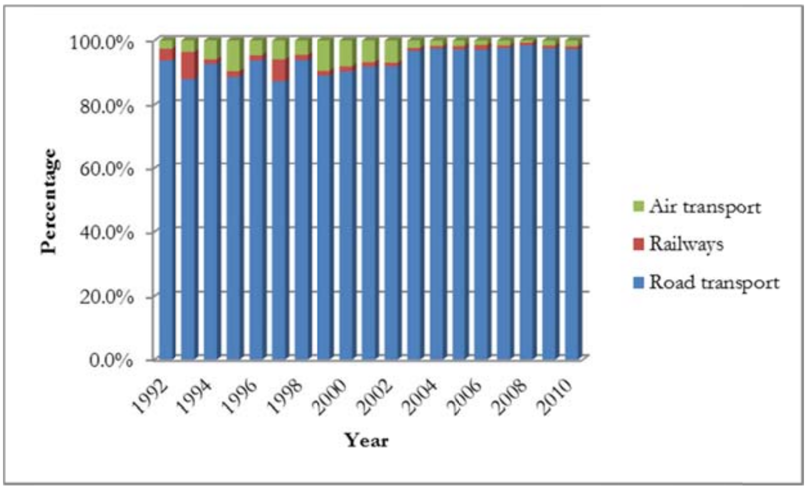
Compared to the EU-27 countries, the energy consumption per capita in the transportation sector is significantly smaller (Figure 2). The average for EU-27 is around 650 toe per 1000 inhabitants, and in the country this value is 200 toe per 1000 inhabitants. In the last five years there has been a slight increase, but still national figures considerably lag behind European ones.

Figure 2. Energy consumption in the transportation sector in the country and in EU-27



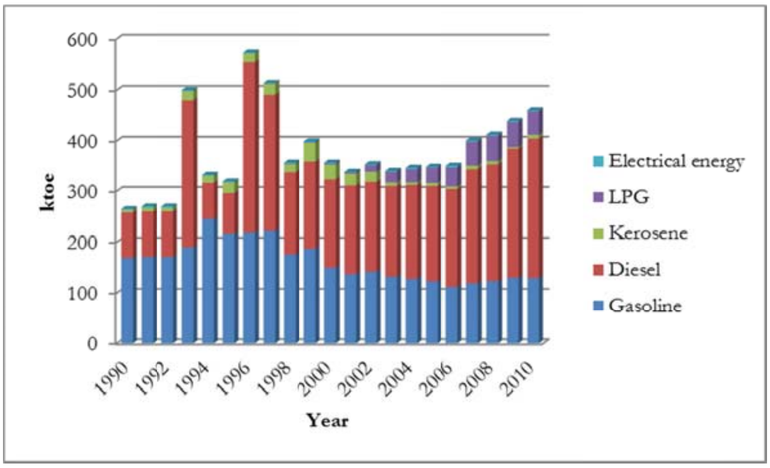
Within the transport sector, the road transport has the highest share in the energy consumption (98%) (Figure 3). Therefore, the analyses within this study are focused on road transport only.

Figure 3. Consumption of energy per type of transport



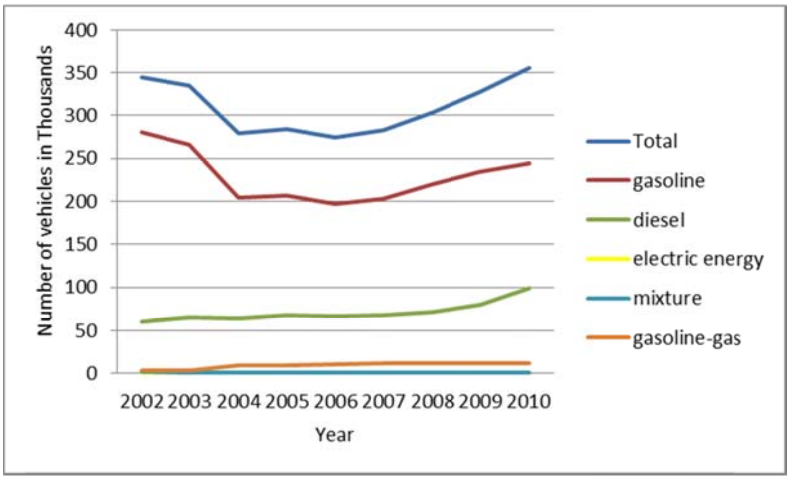
As to the energy mix, the fuels that are used in the road transport sector (gasoline and diesel) have had a dominant role (Figure 4). After 2000, there has been a significant drop in gasoline consumption on one hand, and on the other hand a significant increase in diesel consumption, since the diesel vehicles have becoming more attractive. The LPG was introduced after 2000.

Figure 4. Energy consumption in the transportation sector



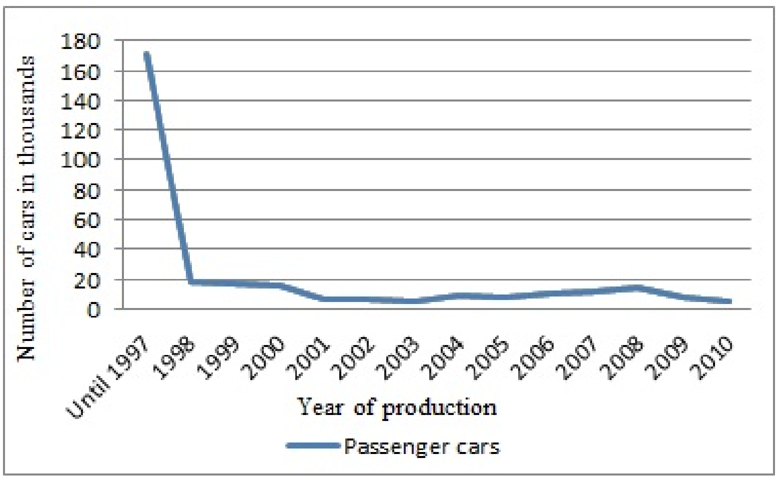
The total number of the vehicles in the country for the period 2002-2010 is shown in Figure 5[12]. Most vehicles run on gasoline, followed by diesel vehicles and mix gasoline-LPG vehicles. The share of the mixture vehicles decreased from 0.5% in 2002 to 0.1% in 2010 and the share of electricity vehicles is around 0.02%. Cars dominate with 90%, the share of buses amounts around 1%, the share of the goods vehicles decreased from 6.4% in 2002 to 3.9% in 2010, while the share of the special vehicles increased from 1.8% in 2002to 4.2% in 2010 and the share of the rest is around 1%.

Figure 5. Total number of vehicles in the road transport



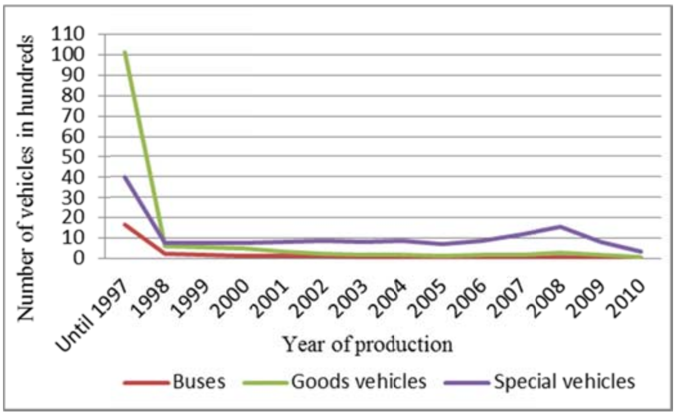
The country has had very old fleet, more than fifteen years. 55% of the cars are older than fifteen years and 71% of the cars are older than thirteen years (Figure 6).

Figure 6. Number of passenger cars by year of production



The same problem is with buses and goods vehicles. 62% of the buses,74% of the goods vehicles and only 27% of the special vehicles in 2010 are older than fifteen years (Figure 7) [12-15].

Figure 7. Number of buses, goods vehicles and special vehicles by year of production



In general, the old fleet is slowly renewed. The fleet is progressively enlarged, but the increment is mostly through used vehicles (a little newer than the previous ones). In the last four years there has been quite a big change when it comes to fleet renewal. In 2007 and 2008a significant renewal of the fleet occurred, but during 2009 and 2010 the fleet size has increased with imported used vehicles, older than 2000. This is characteristic for cars and buses (Figure 8 and Figure 9), while the number of goods vehicles older than 1997 in 2010 was dramatically reduced (Figure 10). Only the number of special vehicles has increased with new vehicles (Figure 11).[1]

The specific national figures for 2010 are: 170 passenger cars per 1000 inhabitants, average age of the passenger cars of about 15 years, 5000 new cars and 2000 cars older than 1998 were purchased.

[1]Clarification for Figures 8-11: A point *(x, y)* from the curve of the year *Z* denotes that in the year *Z*, the number of vehicles older than the year *x* changed for *y* vehicles, whereby positive *y*-values mean an increase while negative *y*-values mean decrease of the vehicle number. Example (Figure 8): In 2010 (violet curve) the number of cars older than 1998 increased for 2000 cars, and number of the new cars increased for 5000 (in 2010, 5000 new cars and 2000 cars older than 1998 were purchased). In 2007 (blue curve) more than 6000 cars older than 1995 were retired, while more than 10000 new cars were purchased.

For the sake of comparison, in 2011 in Slovenia, the number of passenger cars per 1000 inhabitants amounted 519, average age of the passenger cars was 8.4 years, 59813 new vehicles were purchased and 12665 used vehicles were purchased.

Figure 8. Renewal of cars by year of production

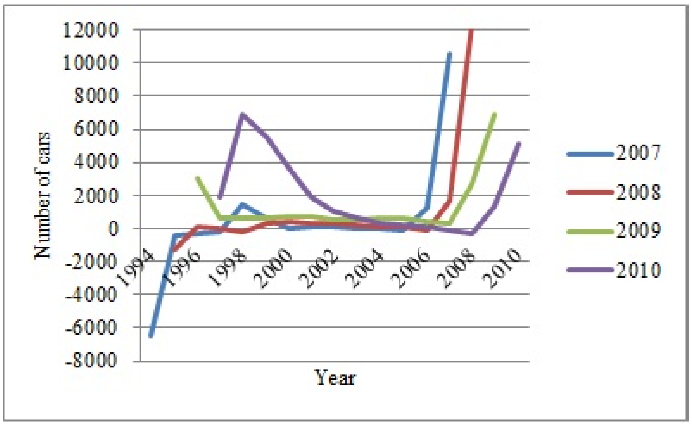


Figure 9. Renewal of buses by year of production

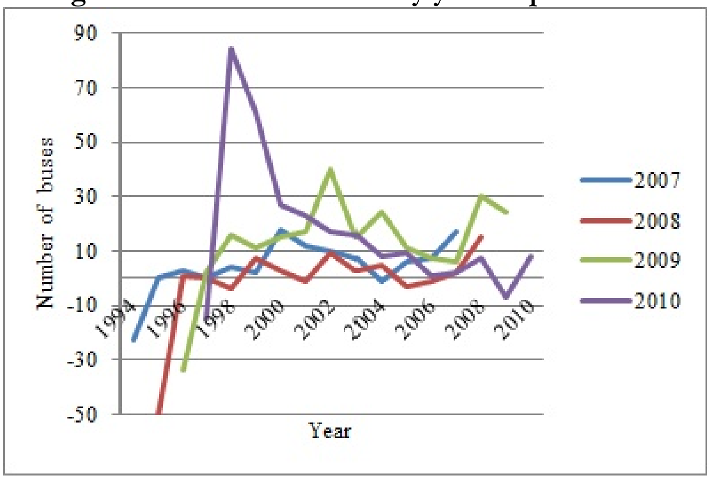


Figure 10. Renewal of goods vehicles by year of production

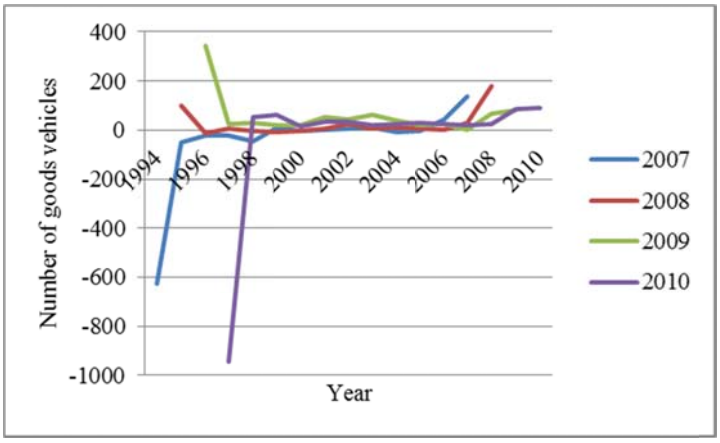
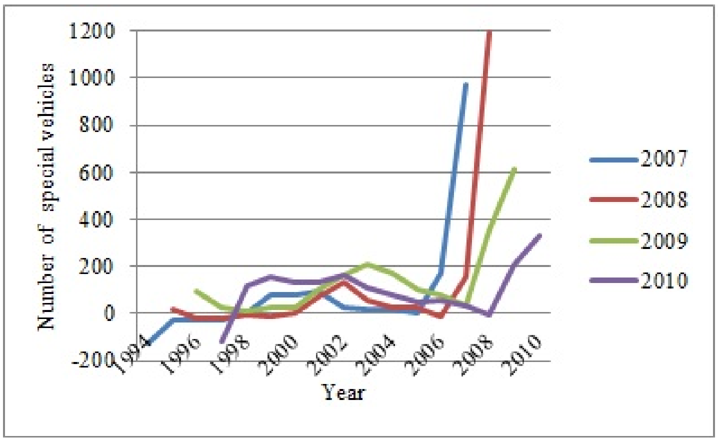


Figure 11. Renewal of special vehicles by year of production



C. NATIONAL BUSINESS-AS-USUAL TRANSPORTSECTOR PATHWAY

The annual increase of energy consumption in transport sector over the period 2010-2020, estimated to 3.6%, is higher than the annual increase of the total energy consumption in the country (3.1%), as well as much higher than the corresponding figure for developed countries (2% [16]).

The motorization level in the country follows the "S" curve. In the initial period slow growth of the motorization (beginning of motorization of the population) can be observed, followed by a period of intensive growth, and in the last part of the curve by a slower growth again, due to saturation phase. The saturation level varies among countries and is between 500 and 800 vehicles per 1000 inhabitants [11]. In the country, the expected numbers of the vehicles per 1000 inhabitants in 2020 and 2030 are 260 and 400, respectively.

If we monitor the motorization in the country in a longer period of time, we can see the growth pattern [11]. According to the data given in Figure 12we can see clearly defined curve of the motorization level growth from 1955 to 1987. After that we can see distortion of the trend and its reinstatement until 1993. In the period1993-2006 we can see distortions of the motorization level growth. It is the transition period and a period of instable economic growth which had strong influence on the traffic.

In the baseline scenario from the National Strategy for Energy Development [11]a stable economic growth and return of the trend of the motorization starting from 2010is assumed. According to the baseline scenario, the motorization level in 2020 will reach 260 vehicles per 1000 inhabitants. This scenario is a starting point for the analyses made in this study. However, due to the government policy for allowance of import of used vehicles in the recent couple of years, certain adjustments should be made for the projections for the share of vehicles by fuel type. Hence the curve "new projection" is created according to which, at the beginning of the considered period, the number of vehicles per 1000 inhabitants will be higher than projected in the Strategy (baseline scenario), but at the end of the considered period the number of vehicles per 1000 inhabitants will converge to the projections from the

Strategy (baseline scenario). The new data for 2011 obtained from the State Statistical Office [17] show that our projection for 2011 is in line with these data. In 2011, the number of vehicles in the country is almost the same as in 2010 (only 3000 vehicles more than in 2010).Furthermore, the number of LPG vehicles is decreasing, so in the reference scenario we assume that the share of LPG vehicles in 2020 will be the same as in 2010. As to the diesel vehicles, the number in 2011 is higher than projection in the Strategy, so the necessary adjustment was made. The share of gasoline vehicles follows the projection from the Strategy (Figure 13).

Figure 12. Curve of development of the motorization level in the country and forecast of the development of the motorization level

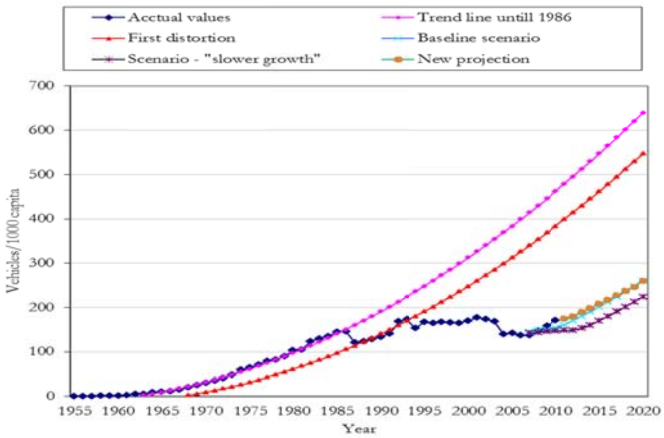
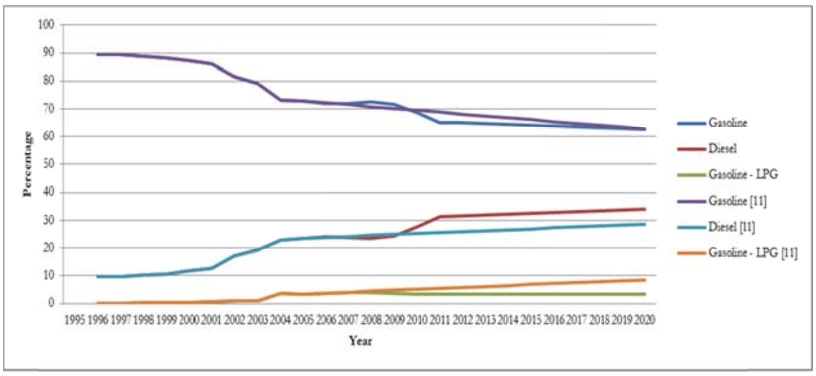


Figure 13.Projected share of vehicles by fuel in percentage (adjusted projections vs projections under Baseline scenario of Energy strategy [11])



According to projections of the baseline scenario in [11], the consumption of diesel in 2020 will be 403 ktoe, the consumption of gasoline will be 188 ktoe and the consumption of LPG will be 45 ktoe.

These numbers are obtained taking into account the fuel economy of the vehicles (Table 1) and the fact that since the early 1980s the fuel efficiency of the vehicles is improving, averagely by 1.4% per year in global proportions.

Table 1. Fuel economy [l/100km] of the vehicles in 2020 as projected in the Strategy [11]

Year/Vehicles	Gasoline car	Diesel car	Gasoline – LPG car (gasoline run)	Gasoline – LPG car (LPG run)	Diesel Goods vehicles	Gasoline motorbike
2007	8.5	7.5	8	10	37	5
2020	6.8	5.8	6	8.3	27.4	3.8

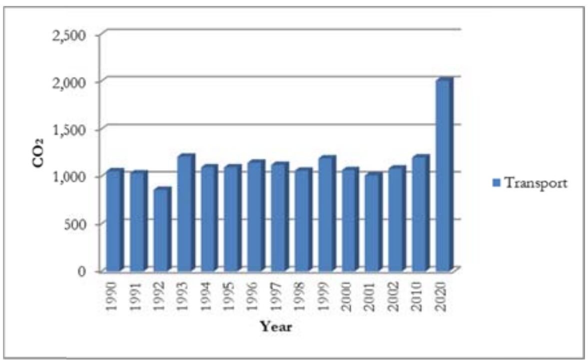
However in the country, since 2007 there have been deviations from the projections in the Strategy [11] (there was no improvement in car efficiency in the period from 2007 to 2011 for 1.4%), so we have to adjust the projections assuming that the fuel efficiency of the vehicles is improving, averagely by 1.1% per year (Table 2). Accordingly, the consumption of diesel in 2020 will be 427ktoe, the consumption of gasoline will be 207 ktoe and the consumption of LPG will be 18 ktoe.

Table 2. Fuel economy [l/100km] of the vehicles in 2020 (new projections adjusted to national conditions)

Year/Vehicles	Gasoline car	Diesel car	Gasoline – LPG car (gasoline run)	Gasoline – LPG car (LPG run)	Diesel Goods vehicles	Gasoline motorbike
2010	8.3	7.5	8	10	35	4.7
2020	7.4	6.7	7	8.9	27.4	3.8

Taking into account these figures ***the baseline GHG emissions for 2020 in the amount 2 MtCO_2*** are calculated using the software package GHG protocol [18].***Compared to the emissions from 1990 to 2010 (1.2 Mt CO_2 in average), the 2020 emissions are doubled*** (Figure 14).

Figure 14.Baseline CO_2emissions [kt]



D. CLIMATE CHANGE MITIGATION OPTIONS FOR TRANSPORT SECTOR

The measures that can be applied in order to reduce GHG emission can be divided into two categories: technical and non-technical measures (first group) and policy measures (second group). The first group involves measures that directly or physically help to reduce GHG emissions, while the second group involves measures that promote and facilitate the application of such physical measures [19]. In this study, the mitigation measures are selected following five strategies:

(1) Improvement of vehicle fleet

(2) Introduction of low carbon fuels

(3) Improvement of travel behavior

(4) Advance vehicle equipment

(5) Campaigns for awareness rising

D.1. IMPROVEMENT OF VEHICLE FLEET

The considered measures under this mitigation strategy include:

1. Replacement of diesel car with new diesel car
2. Replacement of gasoline car with new diesel car
3. Replacement of gasoline car with new gasoline car
4. Replacement of gasoline car with new hybrid car
5. Replacement of gasoline car with new LPG car
6. Replacement of diesel car with new LPG car
7. Replacement of city bus with new one

8. Replacement of city bus with used bus

9. Replacement of intercity bus with used bus

10. Replacement of intercity bus diesel engines

11. Replacement of company bus diesel engines

We are a country with old fleet (cars and buses). Namely, according to the data from State Statistical Office for 2010 [12], 72% from the vehicles are older than 2000 (Figure 6and Figure 7), with quite large consumption, and thus, potential polluters that contribute to increased GHG emissions. To reduce GHG emission in road transport it is assumed that people whose vehicles are older than 2000, will replace them by 2020. Due to relatively low living standard there is a historical practice in the country to buy quite old used vehicles. An economic analysis of what is better to buy, new or used vehicle, is also included. Thereby, a new car means a car from middle class with advanced technology (Euro 4 (2008), Euro 5 and Euro 6) (gasoline, diesel and LPG), produced according to latest EU standards(by 2015 manufacturers should produce cars with exhaust gases up to 130 gCO_2/km, and in 2020 to achieve 95 gCO_2/km [20] and a hybrid car, while used car means a car older than 2008 (Euro 1, Euro 2, Euro 3 and Euro 4 till 2008) (gasoline, diesel and LPG) with standard technology. New bus is the same like new car (Euro 5 and Euro 6) and used bus means 4-5 year old bus, but with advanced technology (Euro 4).

Data for all vehicles categories are shown in Table 3. Most of the input data are taken from the State Statistical Office [12], annual report of the Public Transport Enterprise JSP Skopje for 2010 [21] and national Energy Regulatory Commission [22]. Prices of new vehicles and their consumption are taken from the official websites [23-26], for cars Toyota (model Yaris, Auris and Prius), Skoda (model Fabia), Fiat (model Punto and Linea) and Kia (model Ceed) are considered, for buses models are taken from [27] and [28]. Prices for used cars are taken from official website [29], while the fuel consumption of used cars is taken from [30].

Table 3. Input data for cars and buses

Vehicle category		average km	average consumption (liter/100km)	Emissions (g/km)	Project life (year)	Investment (US$)
Existing car	gasoline	9000	10	228		
	diesel	9000	8	214		
Used car	gasoline	9000	8	183	5	4011
	diesel	9000	6.5	187	5	5348
New car	gasoline	9000	5.5	126	15	14707
	diesel	9000	4.5	120	15	17380
	LPG	9000	7	112	15	13370
	Hybrid	9000	3.9	89	15	34761
Current city bus	diesel	41072	39.3	1052		
Used city bus	diesel	41072	30	803	15	50000
New city bus	diesel	41072	25	669	20	170000
Current intercity bus	diesel	53948	30	803		
Used intercity bus	diesel	53948	22	589	15	80217
Current intercity bus with new engine	diesel	53948	25	669	10	17000
Current company bus	diesel	17000	30	803		
Current company bus with new engine	diesel	17000	25	669	10	17000

Additional parameters are annual fuel cost, annual operation and maintenance costs (registration, insurance, annual service cost and spares) and level of investment(Figure 15 and Figure 16). Level of investment or annual investment parameter depends on the investment cost, projected vehicle lifetime and interest rate. For example, if investment in new vehicle is 17380 US$, projected lifetime is 15 years and interest rate is 6%, than level of investment or annual investment in that vehicle is 1790 US$ (We have to pay 1790 US$ every year to return the investment (loan) of 17380 US$).

Total annual cost is sum of annual fuel cost, annual operation and maintenance cost and level of investment. For example, if we buya new diesel car with fuel consumption of 4.5 liter per 100 km we have to pay 17380 US$ (money that we took from the bank as loan). The level of investment for this car is 1790 US$. If we pass 9000 km a year, we have to pay 638 US$ for fuel and 413 US$ for operation and maintainence (without spares). Annualy we have to spend 2841 US$. If we buy used diesel car with fuel consumtion of 6.5 liters per 100 km, we have to pay 5348 US$ (1270 US$ is the level of investment, with 5 years projected life and 6% interest rate).If we pass 9000 km a year (same as in the previous case), we have to pay 922 US$ for fuel and 543 US$ for operation and maintainence (including spares). Annualy we have to spend 2735 US$ or around 100 US$ less than in the previous case (new diesel car).

Figure 15. Annul car costs

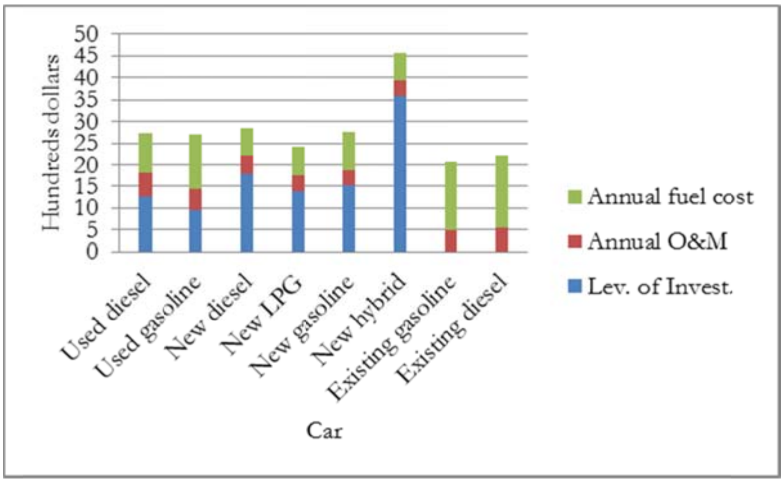
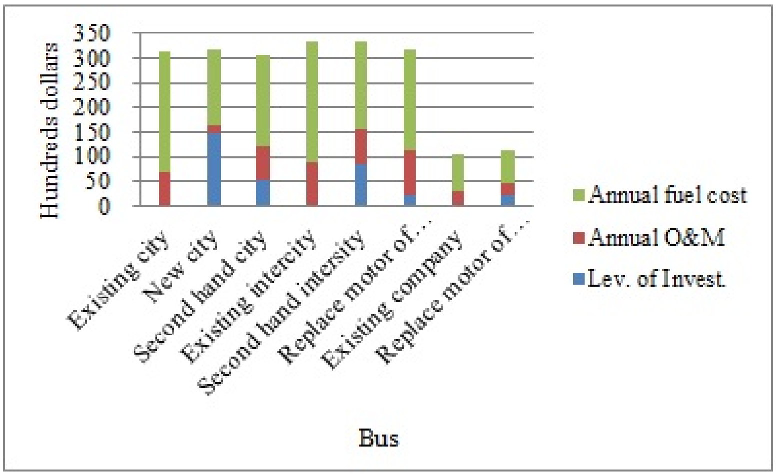


Figure 16. Annual bus costs



Assumptions for the year 2020:

45 000 diesel cars will be replaced with new diesel cars

60 000 gasoline cars will be replaced with new diesel cars

70 000 gasoline cars will be replaced with new gasoline cars

5 000 gasoline cars will be replaced with hybrid cars

20 000 gasoline cars will be replaced with new LPG cars

15 000 diesel cars will be replaced with new LPG cars

100 city buses will be replaced with new ones

350 city buses will be replaced with used buses

200 intercity buses will be replaced with used buses

250 diesel engines of intercity buses will be replaced with better performance diesel engines

300 diesel engines of company buses will be replaced with better performance diesel engines

It should be noted that all these assumptions are made on basis of the following:

- The current purchasing trends, which are in favor of diesel cars due to their lower fuel consumption
- Emerging market of LPG cars as a cheaper option, by technology but also by fuel
- The current trend in the country of replacement of old city buses with new buses (Public transport company JSP), as well as replacement of old city buses with newer used buses (Private sector)
- The company buses (used for transport of employers) will be replaced by used buses or their engines will be replaced with better performance diesel engines. The replacement with new buses is not economically viable due to low number of kilometers the company buses pass.

D.2. INTRODUCTION OF LOW CARBON FUELS

The considered measures under this mitigation strategy include:

1. Introduction of 10% biodiesel
2. Introduction of 10% ethanol

The introduction of low carbon fuels is considered as a key measure for GHG emission reduction, which in case of diesel fuel is implemented with introduction of biodiesel, while in the case of gasoline the biofuel is ethanol. The fuels prices used as input data are shown in Table 4. For biodiesel the current price of biodiesel with 8% share is taken and for the bio gasoline (gasoline+10% ethanol) it is assumed that the price is higher than gasoline price for 2% because ethanol is not currently on the market in the country.

Table 4. Fuel prices

Fuel	Price	Unit
Diesel oil	1.58	US$/l
Gasoline	1.77	US$/l
LPG	1.02	US$/l
Biodiesel	1.60	US$/l
Bio gasoline	1.81	US$/l

Assumption for the year 2020:

In line with the EU RES directive (Directive 2009/28/EC [31]) it is assumed that that in 2020, the biofuel share will be 10% of the total fuel consumption in the transport sector, resulting in 42.7ktoe biodiesel and20.7ktoe ethanol.

D.2.1. INTRODUCTION OF CNG

Due to the fact that the production of ethanol is resource intensive and can affect other types of products, the Compressed Natural Gas (CNG) can be used to support decarbonization in the case of gasoline. The utilization of CNG considerably varies among EU countries, (Figure 17[32]). Italy and Bulgaria are with highest CNG share in road transport fuel consumption of around 2.5%. During the period from 2000 to 2010 the number of CNG vehicles in Italy increased from 320000 to 730 000 vehicles, while in Spain from 912 to 2539 vehicles [33].

At the moment, in the country there are only three CNG stations - one located on the Corridor 10, near Kumanovo (MAKPETROL “mother” station), other in Skopje (settlement Vlae) (MAKPETROL “daughter” station), and the third one belongs to the Public Transport Enterprise JSP. The current price of CNG is 1.35 US$/kg and the cost of installation of CNG system ranges from 1800 to 2070 US$, which makes CNG option very attractive from economic point of view. Although relatively cheap fuel, the main problem hindering the higher utilization of CNG is the coverage of the territory with CNG stations. The development of the CNG infrastructure is strongly related to the availability of the natural gas, so in the situation when natural gas transmission and distribution network is undeveloped, the penetration of CNG is uncertain and difficult to predict. Therefore, for the time being, we just emphasize the potential of CNG for achieving GHG reductions at low price, which can be harnessed once the availability of natural gas is ensured.

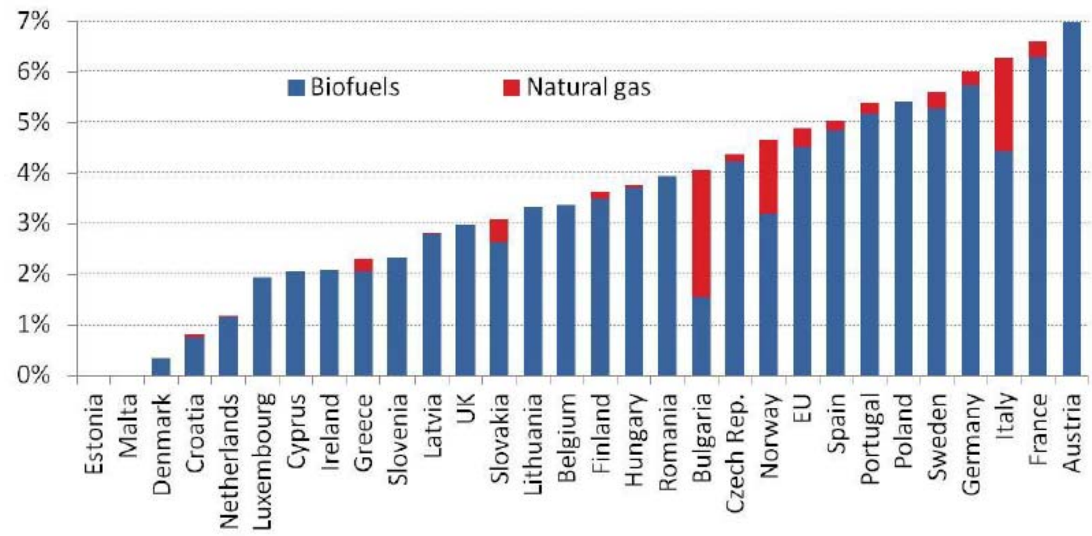


Figure 17.Share of biofuels and natural gas in road transport (2010) [32]

D.3. IMPROVEMENT OF TRAVEL BEHAVIOR

The considered measures under this mitigation strategy include:

1. Use of public transport (instead of private cars)

2. Walking or biking instead of short distance driving

In the first measure it is assumed that a person daily passes 10 km to and from office, which makes annually 2000 km (200 working days x 10 km). The total annual costs if a private car is used would amount 544 US$ (280 US$ fuel costs and 264 US$ parking costs). If a public bus is used the total annual costs is 217 US$ (40 tickets for 10 drives x 5.4 US$) for bus tickets. The annual saving would be 327 US$. If the car is shared by two persons, the annual saving would be 110 US$, the travelled kilometers would amount 2000 (2 persons x 2000 km / 2 car occupancy), against 134 travelled kilometers when public bus is used (2 persons x 2000 km / 30 bus occupancy).

In the second measure it is assumed that instead of car for short distance (2 km), the person would walk or bike [34]. With this measure the annual saving is 72 US$(mainly fuel cost savings). This measure is more applicable in the small cities where people use their car for short distances.

Assumption for the year 2020:

The number of people using public transport will increase for 40 000

The number of people walking or biking instead of short distance driving will increase for 30 000

D.4. ADVANCED VEHICLES EQUIPMENT

The considered measures under this mitigation strategy include:

1. Low viscosity lubricant vs. conventional lubricant

2. Low rolling resistance tires vs. conventional tires

To use an advanced equipment means to use low resistance tires and low viscosity lubricant.

Input data for these two measures are shown in Table 5. Michelin and Goodyear tires with low resistance and Shell low viscosity lubricant fuel oil are considered. The tires reduce fuel consumption for 1.6% and the lubricant for 4.6%.

Table 5. Input data for tires and fuel oil

Measure	Investment(US$)
Conventional lubricant	12.2
Low viscosity lubricant	60.9
Conventional tires	438.3
Low rolling resistance tires	534.8

Assumption for the year 2020:

300 000 cars will use low resistance tires

300 000 cars will use low viscosity lubricant

D.5. CAMPAIGNS FOR AWARENESS RISING

This strategy includes awareness rising campaigns, promoting the following facts:

- Air condition in vehicles can reduce fuel consumption for 8%
- Quick acceleration and heavy braking can worsen reduce fuel economy by up to 33 percent on the highway and 5 percent around town
- Idling consumes fuel, so if you wait more than one minute is better to turn off your engine. This can reduce the consumption for 3%
- Driving with 80 km/h instead of 110 km/h can reduce fuel consumption for 30%. Fuel consumption in terms of speed or in terms of CO_2 emissions is shown in Figure 18[35]
- Driving on tires with air pressure at 50kPA (0.5kg/cm²) below the recommended pressure decreases fuel efficiency by 2% and 4% in urban and suburban areas respectively (Figure 19)[35]

Figure 18.Average CO_2 emission factors on motorways for trucks and passenger vehicle (Euro 4and 5)

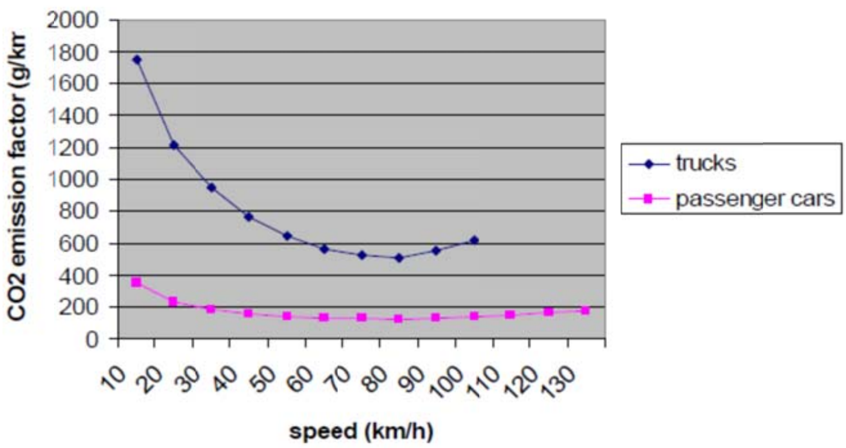
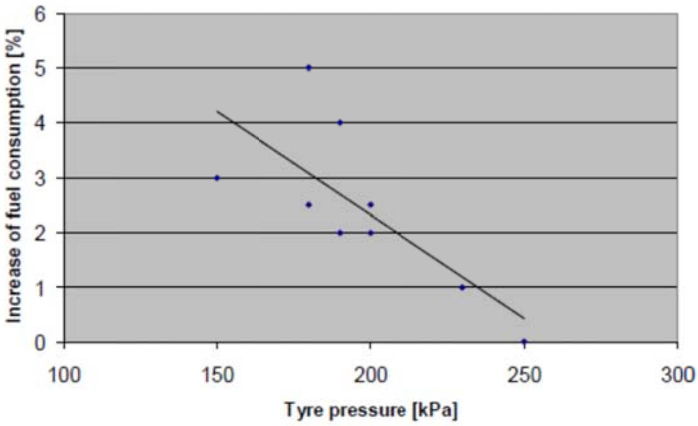


Figure 19.Effect of too low tire pressure on increase of fuel consumption



Assumption for the year 2020:

200 000 US$ will be spent every year on awareness rising campaigns. As a result of these campaigns, 1% reduction of fuel consumption will be achieved in 2020.This assumption is made on the bases of the costs for similar campaigns undertaken by the Government in the recent years.

Emission factors for all fuels are taken from IPCC [36], except for biofuels [37] and LPG. LPG emission factor depends on the propane and butane shares. The common composition of LPG contains 70% or 60% volume of butane and 30% or 40% volume of propane [38]. National country specific emission factor for LPG is not defined, so in this study an emission factor is taken relevant for countries with similar LPG related specifics [39].

E. ENVIRONMENTAL AND ECONOMIC EFFECTIVENESS OF THE MITIGATION STRATEGIES

The main goal of this study is to analyze the potential for reduction of GHG emissions of the national transport sector employing ***bottom up approach,*** including also estimation of the specific cost of the achieved emissions reduction. The findings could help setting the priorities in the national transport policy in a way that it also incorporates climate change mitigation action.

E.1. METHODOLOGY

The software tool that is used for this purpose is GACMO - GHG emission reduction strategy evaluation model developed by the UNEP [40]. GACMO can be used to rank the cost effectiveness of various GHG reduction strategies in a transparent and simple way, even when there is no detailed data available. GACMO is based on the principle of calculating the reduction costs when individual reduction strategies replace high emission technologies under the same comparative basis. It aggregates and ranks the average cost of each emission reduction option, and then draws the reduction cost curve.

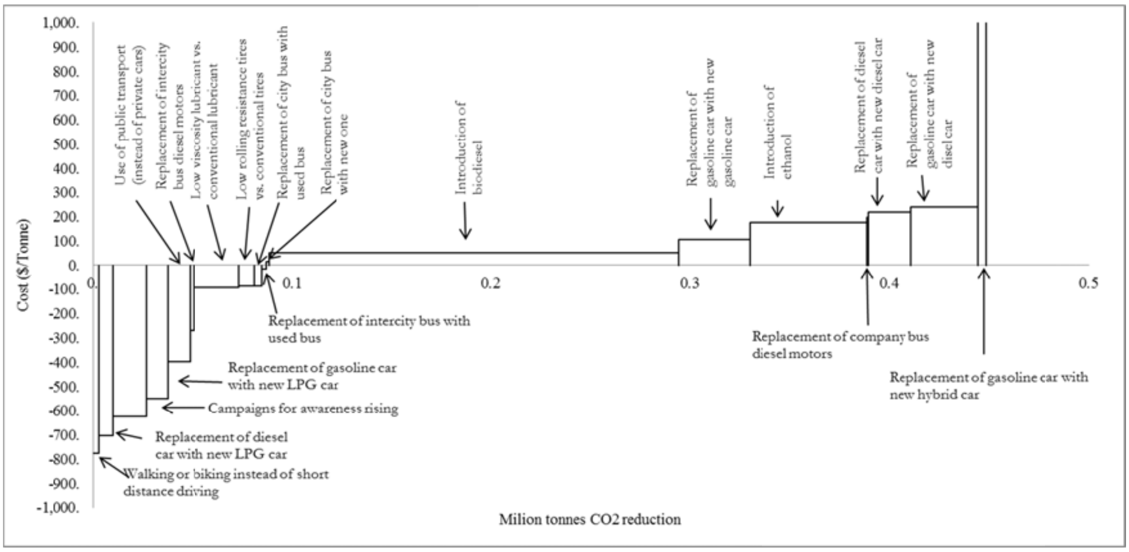
The basis for a mitigation analysis is a baseline or reference scenario for the development of the GHG emissions from the base year (in our case, 2010) until a "target" year (in our case, 2020). The mitigation scenario combines the emissions in the reference scenario with the changes (i.e. reductions) in emissions introduced by the various mitigation options being evaluated. For each mitigation option, the technologies/practices that deliver energy/transport services in the reference option are changed. A mitigation unit of emissions from these new technologies/practices offsets a unit of energy consumed in the reference scenario. A very important assumption that is made in this regard is that the level of energy/transport service delivered by the reference option and the mitigation option does not affect the demand for the energy/transport service. In other words, there is no change in the level of energy/transport service demand when the new technology/practice is introduced, e.g. the amount of person-km transported is the same. Here it can sometimes be difficult to draw the borderline between what is changed and what is unchanged. There can also be some welfare changes, e.g. usage of time, health benefits, which are difficult to quantify.

The structure of the mitigation options in the different sectors varies a lot. It is impossible to describe them all in the same standard format. Therefore, a flexible representation is used in GACMO for the selected options.

E.2. MARGINAL ABATEMENT COST (MAC) CURVES

The results obtained for specific costs and volume of reduction of the CO_2 emissions, for each of the measures is plotted as a curve, which is called marginal abatement cost (MAC) curve. This curve is shown in Figure 20. The vertical axis shows the specific costs (costs for reduction of a ton CO_2), while on the horizontal axis reduction of the CO_2 emissions is presented. The measures are introduced according to their cost-effectiveness (the option with smaller specific costs is introduced first on the left side of the curve).

Figure 20. Marginal cost curve of the transport mitigations measures for the year 2020



Although we have calculated environmental and economic effectiveness for each of the measures separately, in order to facilitate the prioritization of the mitigation efforts in a participatory manner, we present the results at the level of mitigation strategy.

Hence, in Table 6, the results including specific costs and volume of reduction of the CO_2 emissions and the assumed penetration rate of the technology/practice in 2020 for each mitigation strategy (D1-D5) are presented. The corresponding MAC curve is shown in Figure 21.

As can be seen from Figure 21the reduction cost in 2020 varies in the range from -625to 98US$/t CO_2. The total achievable reduction (if all considered options are implemented with the assumed breakthrough rate) in 2020 is estimated to be 0.45 Mt CO_2, or 22% of the 2020 baseline emissions (2 Mt CO_2).

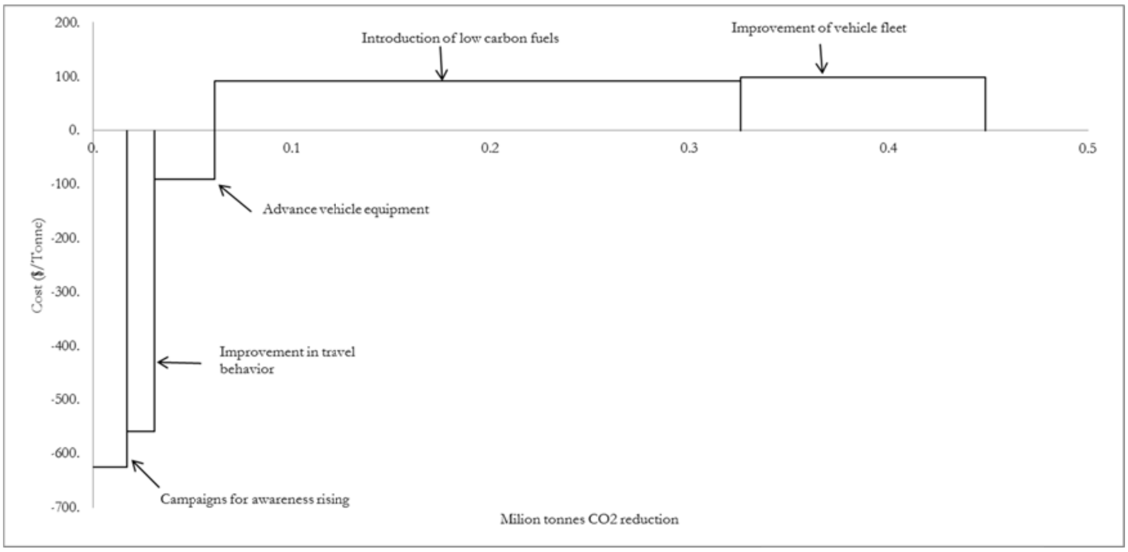
Introduction of low carbon fuels has the greatest contribution in CO_2 emission reduction with annual reduction of 0.26Mt CO_2 followed by Improvement of vehicles fleet with annual reduction of 0.12Mt CO_2.

From the economic aspect the most cost effective strategy appears to be Campaigns for awareness rising, followed by Improvement of travel behavior and Advanced vehicle equipment. These three strategies are of win-win type (with negative specific costs). On the other hand, strategies with relatively high positive marginal costs are Introduction of low carbon fuels and Improvement of vehicles fleet.

Table 6. Summary of the economic and environmental evaluation of the mitigation measures in the transport sector

Reduction option	US$/t$CO_2$	Unit Type	Emission reduction t CO_2/unit	Units penetrating in 2020	Emission reduction in 2020 Per option Mt/year	Cumulative Mt/year	Frac.of total [%]
Campaigns for awareness rising	-625	Campaigns	16762		0.02	0.02	0.01
Improvement in travel behavior	-560	Passenger	0.20	70000	0.01	0.03	0.02
Advance vehicles equipment	-91	4 tires 4l lubricant	0.05	600000	0.03	0.06	0.03
Introduction of low carbon fuels	91	26.5 PJ	264053	1.00	0.26	0.33	0.16
Improvement of vehicle fleet	98	Vehicles	0.57	216200	0.12	0.45	0.22

Figure 21. Marginal cost curve of the transport mitigations strategies for the year 2020



These results are based on current fuels prices in the country. However it should be recognized that the LPG should be reconsidered in terms of taxation and environmental impacts in line with the relevant EU approach. According to proposed EU legislation the LPG tax will increase from current 125 euro per 1000 kg to 500 euro per 1000 kg [41]. The current LPG tax in the country is 80 euro per 1000 kg [42], while the taxes for the other fuels are like in EU. We made additional analysis with the proposed highest EU tax (500 euro per 1000 kg). This assumption makes significant decrease in the economic effectiveness of the measure Improvement of vehicles fleet, since the corresponding figure rises from 98to 164 US$/t$CO_2$.

As to the CNG utilization, if examples from Bulgaria or Italy are followed, the number of CNG vehicles in 2020 will reach 20 000, which implies that 5% of ethanol will be replaced with CNG. Since introduction of CNG is win-win measure, it will considerably improve the economic effectiveness of the strategy. Introduction of low carbon fuels, reducing the specific costs from 91 to 72 US$/t$CO_2$. The total achievable emission reduction will decrease from 22% to 21%as a result of the higher CNG emission factor.

F. PRIORITIZATION OF THE MITIGATION STRATEGIES

This chapter deals with the second component of the assignment aimed at prioritization of the mitigation strategies applying participatory approach. For this purpose a thematic workshop was organized with the following items on the agenda:

- Presentation and discussion of the analytical results
- Setting and weighting of the criteria for evaluation of the transport mitigation strategies
- Evaluation of the transport mitigation strategies

The workshop created an environment of dialogue and cooperation among a range of stakeholders in the articulation of their views and perspectives about the priorities of the national transport policy accountable also for climate change mitigation. The workshop is documented in the Appendix I.

F.1. CRITERIA FOR PRIORETIZATION

The analytical work conducted under this study delivered two parameters for each mitigation strategy – environmental effectiveness and economic effectiveness, which serve well in addressing the ***environmental*** and ***economic*** aspects of the mitigation efforts. Although highly important, these two dimensions are not sufficient for comprehensive assessment. Indeed, to better inform policy and strategic action it is critical to explore and evaluate the ***feasibility*** of the mitigation strategy, since there might be cases when mitigation efforts with high economic and/or environmental performance cannot be realized due to country-specific barriers, be they financial, institutional, legislative, administrative or technical ones (infrastructures and supply chain gaps, involvement of many stakeholders with different interests, as well as, lack of relevant data, studies and knowledge in general).

Furthermore, in light of the MRV as an essential element of NAMAs, ***measurability*** of the achieved emissions reductions should act as a partial determinant of the policy decisions that are guided and bolstered by the mitigation achievements (including policy decisions for appropriate country specific emission reduction/limitation targets). Moreover, associating measurement methodologies to the mitigation action will open possibilities for linking the national mitigation actions to international support (which is among the topics of the international negotiations about the future of the climate regime).

Finally, it is becoming clear that ***co-benefits*** can help to make the economic case for climate change mitigation measures. Hence, the majority of the co-benefits associated with climate change mitigation strategies for the transport are directly related to human health, including:

- Improved air quality due to reduced emissions of air pollutants from transport
- Increases in the amount of physical exercise carried out by the population in general due to a shift to non-motorized transport modes (cycling and walking)
- Reductions in the number and/or severity of traffic accidents (e.g. through speed reduction policies)
- Reduced ambient noise levels due to quieter low-carbon vehicles (e.g. electric vehicles)
- Indirect effects related to the life cycle effects of vehicles, energy carriers or infrastructure

Other co-benefits associated with climate change mitigation strategies, particularly the reinforcement of low carbon fuels, include diversification of income in rural areas and creating of new jobs.

Accordingly, the participants of the thematic workshop were asked to present their opinion about the importance of the following criteria which are to be applied in the subsequent phase of the mitigation strategies evaluation:

- Economic effectiveness (price of reduction)
- Environmental effectiveness (volume of reduction)
- Feasibility (difficulty of implementation)
- Measurability (difficulty of measuring and verification of the achieved emissions reductions)
- Co-benefits (health benefits, diversification of income, new jobs, life quality)

The participants were asked to mark the criterion with 1 if they think that the criterion is of low importance, with 2 of medium importance and with 3 if they find the respective criterion of high importance. The results of this weighting exercise are presented in Table 7.

Table 7.Weighting: Results

	Criterion	Weight
C1	Economic effectiveness	0.21
C2	Environmental effectiveness	0.20
C3	Feasibility	0.22
C4	Measurability	0.19
C5	Co-benefits	0.18
	Σ	1

Although with relatively close weights (meaning that in view of the workshop participants, all the criteria are almost equally important) the participants gave the leading role to the "feasibility" as the strongest determinant of the "quality" of the mitigation strategy, followed by economic and environmental effectiveness. Although with slightly lower weights, the measurability of the achieved GHG emissions reduction and associated co-benefits remain almost equally important determinants of the mitigation strategy quality.

F.2. EVALUATION OF THE MITIGATION STRATEGIES

Once the criteria and their weights were set, in the next step the participants were asked to evaluate each of the five mitigation strategies with marks 1(lowest) to 5(highest) against each criterion. The analytical phase of this assignment provided quantified values for the first two criteria (environmental effectiveness and economic effectiveness), so the evaluation according to these two criteria was straightforward. With regards to the remaining three criteria the participants performed the evaluation on the basis of their personal understanding and knowledge. The evaluation results are presented in Table 8.

Table 8.Evaluation: Results

Mitigation strategy/Rank	Score	Rank
Improvement of vehicle fleet	7.72	4
Introduction of low carbon fuels	8.57	1
Improvement of travel behavior	7.78	3
Advancement of vehicle equipment	7.10	5
Campaigns for awareness rising	8.03	2

Owing to its highest environmental effectiveness, considerable health and socio-economic co-benefits and relatively good measurability and feasibility, the introduction of low carbon fuels is the wining mitigation strategy in transport sector. This is also in line with the EU target for the share of biofuels in total energy consumption of the transport sector which should be also implemented in the country as EU candidate country.

Definitely, the lowest specific cost (or highest economic effectiveness) accompanied with easiness of implementation was the decisive factor for the second score of the awareness rising campaigns. However, the achieved emission reduction is difficult, if not impossible, to measure.

For the same reasons plus the associated health co-benefits, the improvement of travel behavior took the third place in the ranking list. Quantification and measurement is a burning problem of this mitigation strategy also.

Although with relatively high environmental effectiveness and specific costs similar to the ones of the introduction of low carbon fuels, the improvement of vehicle fleet took the lower part of the ranking list. The possible reasons should be looked at the decision-making at car-owner level, so harmonized action is difficult to implement, as well as at the fact that the investment comes from the families' budget, which directly affects the decision about purchasing a new vehicle. The measurability of the achieved emissions reductions could be an issue since detailed and disaggregated data are needed about the vehicles, fuel consumption, and kilometers passed.

Finally, the last on the ranking list is the mitigation strategy related to advancement of vehicle equipment. This can be explained with the moderate or low scores of this strategy against the all criteria. Here again the measurability of the achieved reductions is a burning problem, since it is difficult to record the individual actions along this mitigation strategy.

G. CONCLUSIONS

G.1. SUMMARY OF THE MAIN FINDINGS

- The total achievable reduction in transport sector (if all considered mitigation strategies are implemented with the assumed breakthrough rate) in 2020 is estimated to be 0.45 Mt CO_2, or 22% of the baseline emissions (2 Mt CO_2)

- Three of the five mitigation strategies are of negative costs (win-win type) although with relatively low environmental effectiveness: 4% of the achievable reduction can be realized at negative costs. These strategies include Campaigns for awareness rising, Improvement of travel behavior and Advanced vehicle equipment.

- The bulk of the achievable emission reduction can be realized at relatively high specific costs (around 90 US$/t CO_2).

- The highest environmental effectiveness is associated with the introduction of low carbon fuels (0.25 Mt CO_2), which is more than half of the total achievable emission reduction.

- The highest economic effectiveness is associated with the rising awareness campaigns aimed at improvement of driver behavior (-625 US$/t CO_2).

G.2. POLICY RECOMMENDATIONS

- The national transport mitigation strategies prioritized by transport sector stakeholders taking into account their economic effectiveness, environmental effectiveness, feasibility, measurability and co-benefits include:

  - ❖ Priority 1:Introduction of low carbon fuels
  - ❖ Priority 2: Awareness rising campaigns
  - ❖ Priority3: Improvement of travel behavior
  - ❖ Priority 4: Improvement of vehicle fleet
  - ❖ Priority 5: Advancement of vehicle equipment

- ***Introduction of low carbon fuels:*** According to the national RES strategy [43] it is necessary the Government to adopt a Rulebook on the manner of securing relevant share of biofuels in the total energy consumption in transport. It is recommended this to be achieved by putting the blends into market circulation under a clearly defined dynamics aimed to increase share of biofuels, initially with diesel fuels, and later with petrol fuels as well. For that purpose, measures are needed by which the State will promote the use of blends with biofuels without significant increase of fuel prices (by reducing the excise on biofuels and by introducing increased excise for oil derivatives not used in transport). Also, as part of the program on agricultural development, it is necessary to stimulate the production of domestic raw materials for biofuels by supporting producers of biofuels to invest in agricultural production of raw materials, guaranteed purchase, favorable crediting lines, etc.

The CNG has a considerable potential for reduction of GHG emissions at low (even negative) costs. However, the higher utilization is conditioned by gasification of the country. Some examples of CNG support include: Italy – grants of up to €2 000 to purchase new CNG vehicle and grants of up to €650 for converting a vehicle (until 2009)[33]; Spain –grants of up to €2 000 for a new buses or refuse trucks, lower tax on natural gas as vehicle fuel (approx. 6.5 times lower than diesel), and grants of up to €60000 for filling stations.

- ***Awareness rising campaigns:*** This strategy is aimed at improving the driver behavior which considerably affects fuel economy. Minimizing unnecessary braking (for instance, by not tailgating), observing the speed limit, anticipating the actions of other drivers, and avoiding excessively rapid acceleration can increase kilometers per liter by a few percent over normal driving behavior. Studies of programs to promote these behaviors, however, have found that it is difficult to sustain the gains without regular awareness rising campaigns and driver training.
- ***Improvement of travel behavior:*** This strategy includes more actions aimed at promotion of more sustainable modes of transport and travel behavior. The implementation of some of these measures requires big investments and must be part of greater national projects. In this study we considered using public transport instead of own car and biking and walking instead of driving. This will be facilitated by:
  - ❖ Renewal of public transport bus fleet in order to increase the use of public transport.
  - ❖ Promotion of greater use of bicycle. This measure includes investments in the bicycle network infrastructure, as well as a public campaign for greater use of bicycle.

Furthermore, this mitigation strategy should also include the following measures, which are considered in the [44] as well:

- ❖ Introduction of tramway in Skopje. The benefits of new public transport fleet for the city of Skopje and its citizens are numerous and valuable. The greater energy efficiency and the lower pollution of the environment are just a small part of the total benefits, the detailed analysis of which is out of scope of this report.

- Introduction of integrated traffic management system, in particular within the centre city of Skopje (the small and the big ring)

- Parking policy. The aim of this measure is to discourage the use of automobiles in the cities. Therefore, the implementation of this measure (paid parking) should result in positive financial effects for both: the cities (increased local budget) and for the government (reduced fuel consumption). The city of Skopje has already introduced the concept of zonal parking in the centre city. It is implemented by the local public company for parking.

- Car-free days. The implementation of this measure includes the public campaign through media (TV, radio, posters, etc.)

- Promotion of greater use of railway for intercity travel. The improvement of national railway infrastructure is a capital undertaking that include huge investments. However, within this measure, it is expected to increase the railway intercity passenger ridership by improvement of rail timetables – better service suited to the passenger needs, and by public campaign.

\- ***Improvement of vehicle fleet:*** As recommended in the National Energy Efficiency Strategy [44], the promotion and support of this measure should be achieved through regulatory and fiscal measures implemented by the government. The possible policy measures can be aimed at achieving incentives for purchasing and using of clean and energy efficient cars. Hence, the first group of policy measures may include various schemes, such as:

- Reduction of taxes for purchase of new clean and energy efficient car and keeping the same existing costs for the other cars

- Reduction of taxes for purchase of new clean and energy efficient vehicle and increasing the taxes for other cars

- Provision of bank credits with lower interest rates, if a new clean and energy efficient car is purchased. The difference from commercial rates can be covered by the government, but also other financial arrangements can be made between the government and the commercial banks.

The second group of policy measures includes schemes such as:

- Lower costs for vehicle registration for clean and energy efficient cars

- Lower costs for parking in the center of the city for the clean and energy efficient cars

- Lower ecological tax and tax on property (if there is any) for clean and energy efficient cars

- ***Advancement of vehicle equipment***: This strategy is aimed at promoting the utilization of advanced equipment (i.e. low resistance tires and low viscosity lubricant) which can considerably contribute to fuel economy improvement. Furthermore, it is possible to reduce the fuel consumption by another few percent via optimal vehicle maintenance. Here again, regular awareness rising campaigns and driver training are crucial factors of success.

G.3. FOLLOW-UP

- Including the necessary analytical work and participatory prioritization of the mitigation actions, this study is a first step in developing national NAMAs in transport sector. The next phase should include developing MRV mechanisms for the identified mitigation actions.

- Replication of this pilot study in support of NAMAs development for other sectors.

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