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ECONOMIC BENEFITS, SOCIAL ADVANTAGES, AND EMISSION REDUCTIONS: Bus fleet upgrade by Murmanskavtotrans



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New buses of Murmanskavtotrans

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Executive summary

Air pollution creates serious health, environmental and economic problems for urban, suburban, and rural inhabitants and also contributes to global climate change. Transportation powered by combustion engines is a major source of air pollution. Among the wide array of substances emitted into the atmosphere, black carbon (BC) is a major contributor to current warming, following carbon dioxide and methane. Diesel-powered vehicles are one of the largest sources of black carbon emissions. The main method of reducing BC emissions in this area is improving

the environmental characteristics of the transportation fleet. This brochure documents the benefits of a bus fleet upgrade in Murmansk, Russia.

Public Joint Stock Company (PJSC) Murmanskavtotrans, the largest transportation company in the Murmansk region, upgraded its bus fleet by replacing older buses with the new Euro V models. Replacing the Euro 0 buses with Euro V models allowed Murmanskavtotrans to reduce its black carbon emissions by 90%, or 1,050 kg per year and its NOx emissions by 24,500 kg per year.

The replacements improved the company's position in the passenger transportation market. The company also saved money through reduced diesel consumption and lower maintenance costs. The new buses are more comfortable for passengers, providing higher quality service. In addition to the economic benefits, upgrading the fleet substantially reduced harmful emissions, including black carbon, that lead to health and climate benefits for the surrounding community.

Introduction

Air pollution not only creates serious health, environmental and economic problems in urban, suburban, and rural areas, but it also causes global climate change. Diesel-powered combustion engines used in automobiles, buses, and other forms of transportation are major sources of air pollutants. One of the most important pollutants is black carbon (BC), produced by the incomplete combustion of fossil fuels, biofuels and biomass. Forest fires, agricultural burnings, gas flaring, and exhaust gases from diesel-fueled engines are among the largest global sources of BC emissions [1].

Black carbon is a component of fine particulate matter (PM_{2.5}). Due to their small size, PM_{2.5} particles can penetrate deep into the lungs. Exposure to PM_{2.5} particles, including black carbon, can harm the cardiovascular system and cause premature death. Black carbon is considered a major contributor to current global warming, following carbon dioxide and methane [2]. Black carbon has an additional warming effect in the Arctic when deposited onto ice and snow, which results in increased melting and thus increases absorption of solar energy in the region.

Road transportation is one of the largest sources of black carbon emissions. Diesel-powered buses with low environmental standards play a significant role. Russian bus fleets consist primarily of such buses. Black carbon emissions from these buses are 28 times higher than from modern buses [3]. Modernizing the bus fleet in Russia is slow, in part, because companies do not see the benefits.

The experience of Murmanskavtotrans in upgrading its bus fleet to Euro V buses clearly shows the advantages. The modernization improved the company's position on the market. At the same time, the company saved money on diesel fuel, significantly improved the working conditions of its staff, and improved the area's air quality. Finally, the new buses provide a higher quality service that has been noted by riders.

This booklet describes the experience of Murmanskavtotrans. The brochure was prepared by the Murmansk State Technical University, WWF Russia, and Battelle Memorial Institute (USA). This brochure is prepared for the Arctic Council with the aim to share best practices and experiences in reducing black carbon emissions from diesel sources in the Russian Arctic.

Black carbon: One of the most harmful components of exhaust emissions

In June 2012, the World Health Organization (WHO) reclassified diesel engine exhaust emissions as carcinogenic to humans. Black carbon is estimated to comprise the bulk of $PM_{2.5}$ emissions from diesel engines.

Research findings show that fine particles cause serious human health problems. Because they are so small ($PM_{2.5}$), black carbon and other fine particles can get into the lungs. Even the largest of the fine particles are approximately 30 times smaller than the diameter of an average human hair. The impacts of fine particles ($PM_{2.5}$), including black carbon, may result in premature deaths and risks to the cardiovascular system. People with pre-existing lung or heart disease, as well as elderly people and children, are particularly vulnerable to the impacts of $PM_{2.5}$. For example, exposure to $PM_{2.5}$ affects lung development in children and can worsen asthma. There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur.

The Global Burden of Disease 2010, a study accomplished under the aegis of the World Health Organization, showed that outdoor air pollution with $PM_{2.5}$ is much more hazardous to human health than previously believed: more than 3 million cases of premature death and more than 74 million years of healthy life lost are annually attributable to this risk factor [4]. Exposure to $PM_{2.5}$ is among the top ten leading risk factors for early death and is linked to 130,000-320,000 premature deaths in the U.S. in 2005 (5.4% of all deaths) [5]. According to a WHO study, exposure to $PM_{2.5}$ reduces the life expectancy of the population in Eastern Europe by about 8.6 months on average [6].

By darkening the surface of snow and ice and reducing its reflectivity (albedo), black carbon also facilitates the absorption of solar radiation, increases air temperatures, and accelerates snow and ice melting. These and other effects make the Arctic an exceptionally vulnerable region for black carbon emissions.

Passenger transportation above the Polar Circle: The case of Murmansk

Murmansk is the world’s largest city above the North Pole Circle, with the polar night lasting 40 days. Murmansk stretches for more than 20 kilometers along the eastern coast of the Kola Bay and is 50 kilometers from the open sea. It is located 1,967 kilometers to the north of Moscow and 1,448 kilometers to the north of Saint Petersburg. The population of Murmansk is about 300,000 people.

The city is located in a hilly region and has substantial altitude differences that determine the municipal transportation connections. The municipal vehicle fleet includes buses, trolleys, and fixed-route taxi vans. Buses play the key role in passenger transportation in Murmansk, and there is a large network of municipal and suburban routes (see Figure 1). In 2012, buses carried 57.8 million passengers, and passenger turnover was 627 million passenger-kilometers [7].

МАРШРУТЫ		ROUTES	
№ 1	Автопарк - ул. Лобова	№ 1	Avtopark - Lobova str.
№ 5	ул. Крупской - р-н "Встреч"	№ 5	Krupskoi str. - "Vstrech"
№ 10	ул. Героев Рыбачьего - з-д "Севморпуть"	№ 10	Geroev Rybachego str. - "Sewmorpyt"
№ 11	Нефтебаза - ул. Мира	№ 11	Neftebaza - Mira str.
№ 18	ул. Ковалёва - ул. Мира	№ 18	Kovaleva str. - Mira str.
№ 19	ул. Крупской - Морской вокзал	№ 19	Krupskoi str. - Morskoi vokzal
№ 25	Семеновское озеро - Молокозавод	№ 25	Semenovskoe ozero - Molokozavod
№ 27	ул. Крупской - Металлобаза	№ 27	Krupskoi str. - Metallobaza
№ 28	будни до 18.30, суббота до 18.00	№ 28	everyday till 18.30, saturday till 18.00
№ 29	будни с 18.30, суббота с 18.00, воскресенье пер. Якорный - ул. Мира	№ 29	everyday till 18.30, Saturday till 18.00, Sunday Frunze str. - Yakornyi str.

Figure 1. Bus routes in Murmansk.



Economic benefits, social advantages, and emission reductions:
Bus fleet upgrade by Murmanskavtotrans

Currently, there are 49 regular intercity bus routes in the Murmansk region. These routes are maintained by 24 carrier companies; the largest are Public Joint Stock Company Murmanskavtotrans and Open Joint Stock Company Electrotransport.

Transportation is the largest source of air pollution in the city

Like in many large cities, transportation is the largest source of air pollution in Murmansk. Since 2004, the vehicle fleet in Murmansk has grown by 26,000 cars and as of January 1, 2013 exceeded 100,000 vehicles [8]. However, the problem is not only an increased vehicle fleet, but also the age of the vehicles. More than 62% of trucks and 75% of buses have been in operation for more than 10 years. According to the Ministry of Natural Resources and Environment of Murmansk Region, the high number of air samples containing pollution above the maximum allowable concentrations in Murmansk is caused by the vehicle fleet [9].

Environmental standards for automobile transportation

Seeking to reduce harmful emissions from motor vehicles, most countries have adopted environmental standards that regulate the maximum allowable levels of harmful substances in exhaust emissions, including particulate matter and nitrogen oxides emissions from diesel engines.

Euro I, the first environmental standard, was adopted in the European Union as early as in 1992 and then expanded to many other countries around the globe. European environmental standards (“Euro” categories) regulate the amount of hydrocarbons, nitrogen oxides, carbon monoxide, and solid

Expert's opinion

The transition to Euro V environmental standard ensures a significant reduction in emissions, particularly in comparison with the so-called Euro 0. Emissions reductions are provided by two factors – the environmental performance of the engine and the use of exhaust after-treatment systems. The environmentally friendly engine reduces the emission of carbon dioxide, the main greenhouse gas, into the atmosphere. Exhaust after-treatment systems reduce products of incomplete fuel burning. The first “catalysts” reduced emissions of hydrocarbons fuels but the modern engines provide more complete post-combustion of residual fuel and reduce emissions of carbon monoxide (carbon monoxide), oxides of nitrogen and opacity index. Opacity, which is more typical for diesel vehicles, is caused by the presence of small particles of soot in the exhaust gases. This soot is known worldwide as “black carbon”.

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particles in vehicle exhaust emissions. There are standards for diesel and gasoline engines, as well as for light-duty vehicles, trucks, and buses. European emission standards are set for new cars sold in the member countries of the European Union.

Russia has adopted European emission standards, which are now applied to both domestically produced and imported cars. In Russia, vehicle exhaust emissions are re-

strained by Technical Regulation No. 609, “On the requirements of harmful emissions (pollutants) from motor vehicles released for free circulation on the territory of the Russian Federation” (Table 1) [10].

Delayed enforcement of the Euro V standard allowed many companies to put aside the renewal of their vehicle fleets. However, this is where the citizens of the Russian Federation may have a key role to play. For example, the Moscow Government adopted Decree No. 379-PP which prohibits trucks with engines that do not meet Euro III standards or better from entering the city’s center, within the Third Transportation Ring. From September 1, 2015, onwards, no vehicles below the Euro III emission category will be allowed into this area (Moscow Government Decree No. 90-PP dated March 4, 2014). According to Anton Kulbachevsky, Head of the Moscow Department for Natural Resources Management

Table 1. Particulate matter (PM) emission standards for buses, g/kWh

Standard	PM emissions, g/kWh	Enforcement date in the EU	Enforcement date in Russia
Euro I	0.36	July 1992	-
Euro II	0.15	October 1996	April 2006
Euro III	0.10	October 2000	January 2008
Euro IV	0.02	October 2005	January 2013
Euro V	0.02	October 2008	January 2016*
Euro VI	0.01	December 2013	-

* Initially, Euro V standard was to be enforced in Russia in 2014; however, on the recommendation of the Russian Federation Ministry of Industry and Trade, the Russian government delayed the enforcement of the new rules for Euro V certification of trucks and buses until the end of 2015. The delay is because not all of Russia’s regions can access the low sulfur fuel needed by the Euro V engines. (<http://www.rg.ru/2014/08/05/euro.html>)

and Environmental Protection, “Moscow’s vehicle fleet is the most prominent source of air pollutants” and “enforcement of Euro III for all vehicles within the Moscow Automobile Ring Road may result in up to 30-60% emission reduction.” [11].

Apart from that, the Moscow government has prohibited public procurement of vehicles with an emission category lower than Euro V, as reported by Moscow Mayor Sergey Sobyenin at the Fifth International Forum and Exhibition on Russian Transportation [12].

Other large Russian cities with unfavorable environmental situations may soon follow suit. Passenger and cargo transportation companies ought to be proactive and upgrade their vehicle fleets without waiting for bans or more stringent environmental standards. A good example of being proactive regarding bus fleet renewal is shown by Murmanskavtotrans. Purchasing Euro V buses, instead of Euro IV, which is typical in Russia, was a good strategic solution that allowed the company to lower fuel consumption, reduce maintenance costs, improve passenger service, and cut emissions.

General information about Murmanskavtotrans

Murmanskavtotrans is the largest passenger carrier in the Murmansk region. It maintains 75 bus routes with a total mileage of around 7,000 kilometers. Urban route No. 24 is the longest, covering 24.6 kilometers, while route No. 12 is the shortest, covering just 2.8 kilometers. Murmanskavtotrans buses carry more than 47,200 passengers daily. The bus fare is 22 rubles [13].

Bus fleet upgrade program of Murmanskavtotrans

In 2013, the company faced a number of negative trends, including reduced ridership, reduced technical readiness of the bus fleet, increased maintenance costs, and safety concerns. The managers decided to upgrade the bus fleet. In January 2013, they participated in a seminar organized by the Murmansk State Technical University and the Battelle Memorial Institute. The seminar was held in the framework of the international project “Reducing black carbon emissions in the Russian Arctic” sponsored by the U.S. EPA. During the seminar, the participants discussed the benefits of Euro V vehicles, including increased fuel efficiency and the reduction of black carbon emissions [14].

PJSC Murmanskavtotrans was the first company in the region to acquire buses that met the highest environmental requirements. In 2013, it leased 29 buses produced by Minsk bus plant (MAZ). All of the buses belong to the Euro V emission category.

The new, bright yellow buses have a number of strengths. The buses were tailor-made and supplied in the Arctic version to account for the region's climate (Figure 2). Special considerations include double glazing and additional space heating systems. All of the buses came with efficient Mercedes-Benz diesel engines, which use innovative selective catalyst reduction (SCR) technology for emission reductions. They are equipped with automatic transmission, kneeling systems, and automatic fire suppression. Purchasing the new buses allowed Murmanskavtotrans to retire 20 obsolete Euro 0 buses in 2013 and another 8 in 2014.



*Figure 2. Euro V buses used in Murmansk region.
Photo by D. Ryabov.*

Why is it beneficial to adopt the practices of Murmanskavtotrans?

Purchasing Euro V buses provides the following advantages to the company:

Improved position in the passenger transportation market.

Purchase of the Euro V buses allowed the company to substantially improve its position in the passenger transportation market. When bidding for new bus routes, transportation enterprises can now obtain additional points for certain competitive advantages, including having Euro IV and Euro V buses.

Significant improvement of the bus fleet by Murmanskavtotrans forced other companies to update their fleet. For example, the municipal company Electrotransport also purchased new buses. In August 2014, Electrotransport received 37 Euro IV buses [15]. The Murmanskavtotrans example created a snowball effect, and other regional carriers are considering fleet upgrade programs.

Improved fuel efficiency.

Engines in higher emission categories are more efficient in terms of fuel use and therefore more cost effective. The average fuel consumption by Euro 0 buses (already retired from the Murmanskavtotrans fleet) was about 40 liters per 100 kilometers. Fuel consumption by Euro V buses is 33 liters per 100 kilometers or less. According to the State Statistical Committee, the price of diesel increased from 12,000 rubles per metric ton in 2005 to 16,340 rubles per metric ton in 2010 and to 23,512 rubles per metric ton in 2012, with the

average retail price in 2012 being 34,075 rubles per metric ton. Because the fuel prices keep rising, improved fuel efficiency helps further reduce costs.

Euro V engines require high-quality fuel with a low sulfur content. Murmanskavtotrans purchases Euro V diesel (with a sulfur content of 10 ppm) to guarantee milder wear and extend the service life of the engines. The company started buying Euro V diesel a while ago and there was no need to modify the fuel supply chain. It also buys diesel exhaust fluid AdBlue for SCR. The price for AdBlue (20.5 rubles per liter) is lower than the price of diesel and average consumption of AdBlue is generally 5% of diesel use.

Reduced maintenance costs.

Renewing the vehicle fleet always brings maintenance costs down. Buses with engines in the lowest emission category have the severest wear by all indicators. Euro 0 and other outdated buses continuously require service at the maintenance shop. After the new buses were purchased, there is no more need for repair, and Murmanskavtotrans reduced its maintenance shop capacity. New buses are inspected every 5,000 kilometers while old buses were checked every 3,000 kilometers. The oil in new buses has to be changed every 30,000 kilometers instead of 10,000 kilometers in old buses. Their improvements helped the company reduce its overall costs.

Improved passenger satisfaction.

Upgrading the bus fleet implies to more environmentally friendly engines also provides benefits to the city's residents. New buses are more comfortable for passengers (Figure 3). Passengers may now count on more reliable service; there is no more risk of a bus breaking down on the road;

Expert's opinion

Are Euro V buses more environmentally friendly?

Yes, by far. People in Murmansk remember how dirty the old Ikarus buses were. Those who lived close to the bus stops “Ledovoe” and “Morskaya” should remember the smog every morning. I remember, too, when the engines started in the maintenance facility, it was impossible to stay in – your eyes were full of tears. We could not breathe and had to open the door (in the winter!) to get fresh air. Now, we have a completely different situation. One can stand close to the bus and not smell the exhaust.

What advantages do the new buses bring to the city?

First of all, comfort for the passengers. Second, emissions are close to zero. Third, aesthetics; it is always pleasant to have clean roads, beautiful lawns, and nice vehicles. Fourth, the new vehicles are much more reliable, so one can get to his destination without additional stress.

Vladimir Klimov

*Director of the Maintenance Service of the Depot No.3
OJSC Electrotransport*

and the probability of a car accident caused by dated vehicle malfunction goes down. Additional weatherization provides comfort even during the Arctic winter. The kneeling buses provide easier access and are more convenient for passengers with limited mobility.



*Figure 3. Passenger compartment inside a new bus.
Photo by D. Ryabov.*

Reduction of air pollutants, including black carbon.

A substantial reduction of air pollutants, including black carbon, is one of the most important environmental benefits of the bus fleet renewal (Figure 4). A Euro 0 bus emits 1.14 g of particulate matter per kilometer travelled. The emission factor of a Euro V bus is 0.04 g/km [16]. Therefore, replacing just one Euro 0 bus with a Euro V bus helps cut emissions 28-fold! Replacing the Euro 0 buses with Euro V

models allowed Murmanskavtotrans to cut its black carbon emissions by 90%.

Bus fleet upgrade by Murmanskavtotrans reduced black carbon emissions by more than 1,050 kg per year. In addition to BC emission reductions, the fleet upgrade helped reduce NO_x emissions by about 24,500 kg per year. CO₂ emissions were also reduced. The total BC emissions



*Figure 4. Exhaust emissions from an old bus.
Photo by D. Ryabov*

from diesel transport were 12 metric tons in Murmansk City and 49 metric tons in the Murmansk Region. Thus the fleet upgrade by Murmanskavtotrans helped significantly reduce emissions.

Expert's opinion

On the transition of Murmanskavtotrans to the operation of Euro V vehicles

According to Murmansk Department for Hydrometeorology and Environmental Monitoring and based on the results of monitoring accomplished by OJSC “NII Atmosphere,” exceedance of a one-time maximum permissible concentrations of nitrogen dioxide is reported in Murmansk. Automobile transportation emissions are the major contributor to the elevated concentrations. Comprehensive transition to the modern standards for allowable emissions from automobile transportation (Euro V), such as that accomplished by Murmanskavtotrans, will allow the area to substantially cut emissions of nitrogen dioxide and other pollutants from car exhaust and improve the air quality in Murmansk and Murmansk region.

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Conclusion:

Example for other cities

The Murmansk experience should be replicated in other cities in Russia. Replacing Euro 0 and Euro I with Euro IV or V vehicles brings many advantages for human health, the environment and for the economy. Two important conclusions can be drawn from Murmanskavtotrans' bus fleet upgrade:

For transportation companies. Replacing outdated buses with new models brings economic benefits to the company, comfort and reliability to passengers, and helps reduce negative impacts on the environment and climate. Bus fleet upgrades are cost-effective for passenger transportation companies.

For other Russian cities. Building on the positive experience of Murmanskavtotrans, other cities may inspire transportation companies to speed up their vehicle fleet renewals by integrating environmental requirements into their passenger service tender documentation. Because environmental standards only regulate emissions by new vehicles and have no impact on emissions by older vehicles, this measure will promote renewal of the vehicle fleet. In turn, updating the fleet will lead to reduced emissions, improved passenger service quality, and a better quality of life for residents.

The Murmanskavtotrans case clearly shows that a bus fleet upgrade brings economic benefits to the company, improves quality of transport service and significantly reduces emissions into the atmosphere. Thus, the company, population and environment are the winners.

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