ECONOMIC COMMISSION FOR EUROPE

BLUE CORRIDOR PROJECT

UNITED NATIONS

ECONOMIC COMMISSION FOR EUROPE

Working Party on Gas
Inland Transport Committee

BLUE CORRIDOR PROJECT

on the use of natural gas as a motor fuel in international freight and passenger traffic

Final Report of the Task Force

UNITED NATIONS

New York and Geneva
2003

NOTE

ENERGY/2003/8

Printed at United Nations, Geneva (Switzerland)

FOREWORD

The recent structural changes in east European countries and their transition to a market economy and the integration of some of these into the European Union have significantly increased the volume of motor vehicle traffic throughout the European continent. The volume of international freight and passenger traffic will continue to increase in line with the substantial growth and expansion of transnational corporations as well as the fitting-out of vehicle fleets with modern tractor-trailer units and coaches designed for international travel which offer enhanced carrying capacity and operational features.

The rapid increase in vehicle numbers has resulted in unacceptable levels of atmospheric pollution. In large cities, the transport share of air pollution represents up to 60-80% of all toxic atmospheric emissions, and with modern technologies it is quite difficult to achieve further substantial reductions in emissions from petrol and diesel engines. The substitution of alternative forms of fuel (especially gas) for petrol and diesel could play a significant role in cutting emissions.

From the social point of view the implementation of the Blue Corridor project could not only lead to enhanced development of infrastructure along the corridors, but could also expand the gas market, improve the health and living conditions of populations and create new jobs.

The proposed Blue Corridor Project has been conceived to meet the above challenges and the necessary preconditions for its implementation already exist. Many countries in the world have their own ambitious programmes for the development of transport powered by alternative fuels and especially by natural gas. The European Union has also put forward a proposal to promote the wide use of alternative fuels in motor transport by replacing petroleum fuel use in the transport sector by 20% alternative fuels by the year 2020.

This report is the result of collective work done by the Task Force, composed of experts from both the gas and transport sectors of UNECE member countries, as well as from a number of international and non-governmental organizations.

The ECE secretariat wishes to express its gratitude to all experts, companies and organizations who support the Blue Corridor project and have contributed to the preparation of this report.

Brigita Schmögnerová

Executive Secretary and
United Nations Under-Secretary General

Contents

LIST OF FIGURES

Executive Summary

The idea of the Blue Corridor Project was launched in the year 2000 by the non-governmental Vernadsky Ecological Foundation (Moscow). The objective of the project is to establish transport corridors for heavy duty transport vehicles using compressed natural gas (CNG) as fuel instead of diesel, both because of its economic and environmental advantages.

Natural gas has a number of important advantages over petroleum fuels. Natural gas is the cleanest burning alternative transportation fuel available today. It is safe, lighter than air and does not pool on the ground like liquid fuels. Natural gas is also economic, on average 40% cheaper than gasoline and it is more sustainable from the point of view of security of supply. Natural gas is a natural bridge to hydrogen transportation systems of the future.

The Blue Corridor Project is included in the programmes of work of the United Nations Economic Commission for Europe (UNECE) Working Party on Gas and Inland Transport Committee. These two intergovernmental bodies set up a Task Force in 2002 with experts from the gas and transport sectors to assess the technical and economic viability of the Project.

The Task Force held three working meetings: in June 2002 in Warsaw, at the invitation of the Clean Air Foundation and Energoproekt, in November 2002 in Hoofddorp, near Amsterdam at the invitation of the European Natural Gas Vehicle Association (ENGVA) and in March 2003 in Berlin, at the invitation of the European Business Congress (EBC). The Task Force consists of representatives from both Governments and private sector of the following UNECE member countries: Belarus, Bulgaria, Czech Republic, Finland, Germany, Hungary, Italy, Netherlands, Norway, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia, Turkey and the United Kingdom, as well as non-governmental organizations such as the Vernadsky Foundation, the International Road Transport Union, the European Natural Gas Vehicle Association, the Russian Natural Gas Vehicle Association (NGVRUS) and the Clean Air Foundation. Representatives of the secretariat of the United Nations Economic Commission for Europe served as coordinators of the Project.

The Task Force selected three pilot Blue Corridors: 1. Moscow – Minsk – Warsaw – Berlin (along the international road E 30); 2. Berlin – Czech Republic – Austria – Rome (along the international roads E 55 and E 45); 3. Helsinki – St. Petersburg – Moscow (along the international roads E 18 and E 105).

Feasibility studies were conducted for the three pilot corridors based on traffic volumes, savings in fuel costs, reductions in emissions and number of existing CNG fuelling stations. For example, on the Moscow – Berlin corridor, with projected daily traffic of 16,000 lorries in 2010, fuel savings would amount to more than 300 million Euros per year and harmful exhaust emissions would be reduced up to 60% (based on 100% conversion to CNG). For optimal fuelling potential, 25 new CNG stations would be required, at an average cost of 250,000 Euros each.

Aggregate data for the three pilot corridors based on a projection of 2500 vehicles for Helsinki – Moscow, 4000 vehicles for Moscow – Berlin, and 4000 vehicles for Berlin – Rome show fuel savings of the order of 37 million Euros per year and reductions in harmful exhaust emissions of 272,400 tonnes per year. The total implementation cost of the Blue Corridor Project is estimated at 63.4 million Euros for the conversion of the 10,500 vehicles and 15.9 million Euros for developing the necessary refuelling infrastructure.

Today there are about 2.2 million natural gas vehicles (NGVs) worldwide. In Europe, Italy with 400,000 vehicles and Russia with 36,000 have the largest fleets and in Germany the fleet is developing rapidly, with over 12,000 vehicles today. Since 1995, the number of NGVs in Europe has grown by more than 100,000 or 30% and the number of fuelling stations has doubled. There are currently over 12,000 natural gas fuelling stations in Europe. The EU has set a target of replacing petroleum fuel use in the transport sector by 20% alternative fuels by the year 2020 and will issue a Directive on the use of alternative fuels. This could mean 10% of the market for natural gas and the potential of 23 million NGVs by 2020.

Acknowledgements

The present paper is the result of the collective work of experts-members of the UNECE Task Force, set up in early 2002. The active and highly professional participation of members of the group enabled the completion of the work on the Final Report in a relatively short period of time.

Thanks go to the following experts for their contributions to the preparation of the present document: Mr. Vasili YELISEYENKAU (BELTRANSGAS, Belarus), Mr. Martin BOYADZHIEV (Overgas Inc., Bulgaria), Mr. Jaroslav TOMANEK (Ceska plynarenska unie, Czech Republic), Mr. Jan ZAKOVEC (Prazska plynarenska AS, Czech Repuplic), Mr. Martin KLOZ (Ministry of Environment, Czech Republic), Mr. Jouko ALALUUSUA (Ministry of Transport and Communications, Finland), Mr. Friedhelm WANNAGAT (Ruhrgas A.G., Germany), Mr. Bernd BARTUNEK (Westport Gmbh, Germany), Mr. Tamas KOROSI (Ministry of Economic Affairs, Hungary), Mr. Istvan GUBA (MOL, Hungary), Mr. Flavio MARIANI (ENI Spa, Italy), Mr. Roar STOKHOLM (Statoil, Norway), Mr. Andrzej HOSCILOWICZ (Polish Oil and Gas Company, Poland), Mr. Jerzy ROSZKOWSKI (Energoprojekt-Warszawa S.A., Poland), Mr. Mihael GORECHENKOV (Moldovagaz, Republic of Moldova), Mrs. Ligia MEDREA and Mrs. Gabriela ANGHELESCU (ANRGN, Romania), Mr. Radovan ILLITH (Slovak Gas Industry, Slovakia), Mr. Victor STATIVKO and Mr. Evgeny PRONIN (Gazprom, Russian NGV Association, Russian Federation), Mr. Sakir ARIKAN (BOTAS, Turkey), Mr. Bruce CHISHOLM (Sealweld International Co. Ltd., United Kingdom), Mr. Jeffrey SEISLER (ENGVA, the Netherlands), Ms. Ludmila van der MAREL (Clean Air Foundation, Poland), Mr. Soren RASMUSSEN (International Road Transport Union, Switzerland), Mr. Kirill STEPANOV (Vernadsky Foundation, Russian Federation), Mr. Andrey ANDREEVSKY (Vernadsky Foundation, Chairman of the Task Force, Russian Federation).

Special thanks should be addressed to the hosts of the three meetings held by the Task Force: Mr. Andrzej PATRYCY (Energoprojekt-Warszawa S.A., Poland), Ms. Ludmila van der MAREL (Clean Air Foundation, Poland), Mr. Jeffrey M. SEISLER (ENGVA), Ms. Nadejda DONIY (EBC, Berlin), Mr. Dmitry KUROCHKIN (EBC, Berlin).

The efficient and successful working of the Task Force was to a large extent due to the professional and competent management of work by members of the UNECE Secretariat, Mr. Alexandre CHACHINE (Working Party on Gas) and Mr. Christopher SMITH (Inland Transport Committee).

Because of space constraints, it has not been possible to include in the Final Report all the detailed national contributions from countries involved in the Blue Corridor Project. This information can, however, be obtained from the Vernadsky Foundation or the UNECE Secretariat.

1. BACKGROUND

The Blue Corridor Project was initiated by the Vernadsky Foundation (Russian Federation) in early 2000 with the main objective of establishing European transport infrastructure corridors for vehicles using natural gas as a fuel in the transboundary transport of goods and international passenger traffic. The project is based on the environmental and economic benefits of the use of gaseous fuels.

The recent structural changes in east European countries and their transition to a market economy and integration into the EU have significantly increased the volume of motor vehicle traffic throughout the European continent.

The volume of international freight and passenger traffic will increase annually in line with the substantial development of transnational corporations and the fitting-out of vehicle fleets with modern tractor-trailer units and coaches designed for international travel which offer enhanced carrying capacity and operational features.

However, the projected growth in international transport may be constrained by a shortage of liquid motor fuel. According to various forecasts on the development of the energy sector, natural gas is on course to become the world's number-one energy source in the twenty–first century. The environmental and economic advantages of gas in relation to other fuels augur well for its extensive use in various sectors of industry, agriculture, public utilities and transport. Road transport is a particularly promising area.

The rapid increase in the number of vehicles has resulted in unacceptable levels of atmospheric pollution. Exhaust gases from motor vehicles account for approximately 60-80% of all toxic atmospheric emissions in major cities. It is becoming increasingly difficult to achieve substantial reductions in petrol or diesel emissions. The substitution of alternative forms of fuel (especially gas) for petrol or diesel could play a significant role in cutting emissions.

The proposed Blue Corridor Project has been conceived to meet the above challenges and the necessary preconditions for its implementation already exist. Many countries in the world have their own ambitious programmes for the development of transport powered by alternative fuels and especially by natural gas: Argentina, Italy, Brazil, United States of America, Russian Federation, Sweden, China, Pakistan, Islamic Republic of Iran etc.

Experience in a number of countries demonstrates strikingly the desirability of establishing a Europe-wide international freight transport system using compressed and liquefied natural gas (CNG and LNG) in heavy–duty natural gas trucks and buses. Such a system could make a significant contribution to overcoming Europe's environmental problems in the foreseeable future.

The main features of the project may be summarised as follows:

- Economic benefits of gaseous motor fuel (reduced operating costs);
- Gradual reduction of environmental and noise pollution;
- Huge resource potential of natural gas;
- Sustained increase in the volume of transboundary vehicle traffic;
- Significant technical progress in the field of gaseous fuel and gas-cylinder equipment for motor vehicles;

- Expansion and improvement of the gas fuelling station network;
- The geopolitical dimension – integration, enhanced international humanitarian and commercial exchanges.

The project is designed to address issues connected with, inter alia, the plotting of routes across the continent of Europe, harmonisation and standardisation of technical and communication equipment, elaboration and coordination of laws and regulations and securing of gas supplies to areas along transport corridors. Participants in the project are:

- Governmental bodies (e.g. Ministries of Foreign Affairs, Transport, Energy, Resource Management and Environmental Protection, etc);
- Gas companies and gas sector enterprises;
- Transport companies;
- Vehicle and equipment manufacturers.

The project was presented at the annual sessions of the UNECE Committee on Sustainable Energy, Inland Transport Committee and Working Party on Gas. Following consideration at the fifty-sixth session of the United Nations Commission for Europe (UNECE) in May 2001 interest was expressed in the Blue Corridor Project **"as a way to promote environmentally friendly transport of goods in a major East-West pan-European corridor and because of its potential replication for other main arteries in Europe".** The Commission requested the Committee on Sustainable Energy (Working Party on Gas) and the Inland Transport Committee to consider the feasibility of the project and to report back to the Commission on the results.

In accordance with the decision of the Inland Transport Committee and the Working Party on Gas, a special Task Force representing experts from both gas and transport sectors was set up at the beginning of 2002 with a view to assessing the technical and economic viability of the Blue Corridor Project and modalities for its implementation.

The outcome of the meetings can be summarised as follows:

- officers of the TFBCP were elected;
- participants made presentations on the current state and future development of NGVs in their respective countries and expressed their views regarding the proposed project and made proposals concerning its evaluation;
- three pilot transport corridors were identified for the assessment of the project: Moscow – Minsk – Warsaw – Berlin (along the route E 30); Berlin – Rome (along the routes E 55 and E 45); and Moscow – St. Petersburg – Helsinki (along the routes E 105 and E 18), the latter with potential for the use of liquefied natural gas (LNG);
- eco-efficiency analyses on the selected pilot corridors were presented;
- proposals on building pan-European co-operation for the Project were made;
- the structure of the Final Report was adopted;
- general consensus on the importance and attractiveness of the Project was expressed;
- the decision to develop a website page for the Project was taken;
- the draft Final Report was discussed and adopted.

2. NGV DEVELOPMENT IN EUROPE AND WORLDWIDE

Today there are about 2.2 million natural gas vehicles (NGVs) in the world (almost 500,000 in Europe) and about 4,000 natural gas fuelling stations in the world (over 1200 in Europe). The world leaders in the field are Argentina, Italy, Brazil, Pakistan and the United States; in Europe Italy, Russian Federation, Ukraine, Germany and Belarus.

Table 1. NGV leaders

NGV leaders					
World			Europe		
Country	**Number of NGVs**	**Fuelling stations**	**Country**	**Number of NGVs**	**Fuelling stations**
Argentina	879587	1050	Italy	434000	405
Italy	434000	405	Russia	36000	218
Brazil	391468	516	Ukraine	35000	87
Pakistan	200000	200	Germany	12000	268
USA	111769	1250	Belarus	5500	24
India	100800	120	France	4550	105
Venezuela	44146	147	Sweden	1550	25
Egypt	42000	72	UK	835	37
China	36000	70	Netherlands	300	11
Ukraine	35000	87	Belgium	300	5
Russia	31000	215	Czech Rep.	300	9
Canada	20505	222	Switzerland	279	27

Source: Gas Vehicle Report, March 2003.

In Europe, since 1995, the number of NGVs has grown by more than 100,000 (30%) and the number of fuelling stations has doubled. In the European Union region the EU target to replace 10% of traditional fuels with methane by 2020 finds the industrial sector, various national and international associations all working towards the same goal. A similar situation prevails in many non-EU European countries. For the dynamics of NGV development see Annex 1.

Italy continues to top the statistics for the number of vehicles converted, the number of fuelling stations and the highest sales figures for new gas model vehicles. In Italy, diesel, whose low price and superior fuelling station infrastructure continues to draw consumers, is a threat to the sustained period of 10 years' growth in methane, but the current trend is about to change with the launching of new NGV models by several manufacturers.

Germany, also one of the main drivers of NGVs, is expected to have 300 fuelling stations (mainly dedicated to passenger and light duty vehicles) by the end of 2003 with 15 000 NGVs and there is an ambitious target to build up an infrastructure of 1000 fuelling stations by 2006. At the same time, Ruhrgas AG, in cooperation with leading car manufacturers, is engaged in developing a new steel type CNG storage tank for NGVs. This project is aimed at increasing the maximum range of existing NGVs by at least 30 per cent.

Both *Russia and Ukraine* have registered an increase in gas vehicle sales. In Russia, the Governmental Commission on gaseous motor fuel adopted in 2002 a Concept for the use of natural gas for transport. The Concept stipulates three stages. The first (2003 – 2005) envisages increasing the NGV fleet up to 65,000-70,000 vehicles and the construction of 10 -

12 new fuelling stations. The second stage (2006 - 2010) – 120,000-140,000 NGVs and 200-210 additional fuelling stations. The third stage (2011 – 2020) – increasing the NGV fleet up to 1 million vehicles. As of the 1 June 1 2003 there are 218 operational fuelling stations in Russia (with an aggregate capacity of 2 billion cubic meters per year), including 182 fuelling stations belonging to Gazprom.

In *France*, 1000 buses now run on natural gas, more than 1500 are on order and half of the country's cities of more than 200,000 inhabitants have fuelling stations. Some French automobile manufacturers now offer a range of buses and garbage trucks; the range of commercial vehicles available is also on the increase. This development will certainly continue, but the new challenge is to provide unrestricted use for drivers of private vehicles. A similar situation prevails in Spain, and also in Portugal.

Switzerland has just launched an ambitious pro-NGV publicity campaign aimed at lowering the price of its natural gas, the most expensive in Europe.

Turkey has a highly promising market for NGV development. The implementation of the new natural gas law should animate market activities including the CNG business. Currently, 132 buses and more than 250 taxis run on natural gas and many taxis have been converted to natural gas.

The *European Natural Gas Vehicle Association* (ENGVA), for its part, is carrying out continued efforts with the European Union to promote the "Target 2020 Working Group" and "NGV Pathways to 2020", which include promoting the use of NGVs in Europe's airports, an undertaking that involves the conversion of large fleets of all kinds of vehicles; building fuelling stations and devising the best publicity, as well as forging ahead with the Clean Cities plan to incorporate gas vehicles into municipal fleets, beginning with public authorities. These efforts include also the promotion of the Blue Corridor concept.

As mentioned above, in December 2001 the European Union put forward a proposal to promote the wide use of alternative fuels in motor transport by 2020: biofuels, hydrogen and natural gas. The share of biogas in the total balance of motor fuels should reach about 8 %, that of hydrogen – 5 % and that of natural gas - 10%.

If these proposals are translated into reality, by 2020 the European fleet of NGVs will amount to 23.5 million vehicles, with annual consumption of natural gas of almost 47 billion cubic meters.

The European NGV fleet will have the following make-up

Type of vehicle	**Number of units (thousand)**
Regional buses	69.9
City buses	22.8
Special trucks	149.79
Taxis	451.6
Vans	7600
Passenger cars	15200

Source: ENGVA.

In addition, the work on harmonising international regulations and standards with distributors, and car manufacturers continues to provide for the progressive development of the NGV infrastructure.

3. BENEFITS OF NGVS IN COMPARISON WITH VEHICLES USING TRADITIONAL FUELS

The use of natural gas as a vehicle fuel is beneficial for many reasons, which can be summarized in the basic advantages in the following fields:

- environment and health
- economics
- security of supply

3.1 Environment, health and global warming

Geopolitical changes in Europe over the last 10-12 years have caused freight and passenger traffic on the continent to increase at a rapid pace. According to analysis and forecasts of the UNECE Inland Transport Committee (TRANS/2002/7, 14 February 2002) "Road transport across Europe seemed to perform better than railways… In Europe as a whole, international transport of goods performed better than domestic transport, thus continuing a major trend observed in the UNECE region for decades… Further opening of CEE countries, resumption of economic growth in the EU and the Russian Federation could further contribute to a stronger demand for international transport in the next years".

This trend could result in an increased harmful effect on the environment. Not by accident the same document considers the improvement of the environmental performance of the transport sector as an important area of transport regulation.

Indeed, as estimates show, automobile transport accounts for up to 60-80% of overall pollution caused by human activities and in large cities its share in air pollution can be even higher.

The components of internal-combustion engine exhaust gases contribute to such negative phenomena as smog, acid rain and the greenhouse effect. The negative environmental impact of these phenomena is characterised by different geographic scopes: local – in the case of smog; regional (trans-border) – in the case of acid rain; global – in the case of the greenhouse effect.

Why natural gas is the solution

Premium Fuel. Natural gas vehicles are inherently cleaner burning than comparable gasoline and diesel vehicles. Diesel fuel is highly complex, and its exhaust contains over 40 compounds classified as known or possible carcinogens, mutanogens or endocrine disruptors. Natural gas engines produce little or none of these compounds.

Particulate Matter (PM) Emissions. Health officials have linked particulate matter emissions to a range of serious health problems, including increased hospital visits, respiratory disease, and decreased lung function. Diesel PM has been classified as a toxic air contaminant and as a probable carcinogen. Recent studies that measured in-use emissions indicate that natural gas vehicles produce nearly 90 percent less emissions of particulate matter than their gasoline and diesel counterparts.

Ozone. Ozone is caused by the photochemical reaction of nitrogen oxide and hydrocarbons. It causes harmful health effects ranging from eye irritation, sore throats and coughing, to lung damage, cancer, and premature death. Children tend to be more affected because their lungs and immune system are more susceptible to pollution and because they are exposed to higher levels of pollution when playing outdoors. Recent studies that looked at in-use emissions indicate that NGVs produce 40 percent less nitrogen oxide emissions.

Health problems are closely connected to economic ones. A recent three-country study conducted for the World Health Organization (WHO) estimated the health impact of air pollutants from traffic and their related costs (see tables below).

Table 2. Additional cases of disease or days off work due to air pollution

	Cases of disease or days off work attributable to total air pollution			Cases of disease or days off work attributable to road traffic		
	Austria	France	Switzerland	Austria	France	Switzerland
Long term mortality (adults > 30 years)	5,600	31,700	3,300	2,400	17,600	1,800
Respiratory hospital admissions (all ages)	3,400	13,800	1,300	1,500	7,700	700
Cardiovascular hospital admissions (all ages)	6,700	19,800	3,000	2,900	11,000	1,600
Chronic bronchitis incidence (adults > 25 years)	6,200	36,700	4,200	2,700	20,400	2,200
Bronchitis (children < 15 years)	47,700	450,000	45,400	20,600	250,000	24,100
Restricted activity days (adults > 20 years)	3,100,000	24,600,000	2,800,000	1,300,000	13,700,000	1,500,000
Asthma attacks (children < 15 years)	34,700	243,000	23,600	15,000	135,000	12,500
Days with asthma attacks (adults >15 years)	94,000	577,000	63,000	40,000	321,000	33,000
Population (millions)	8.06	58.26	7.08			

Source: "Health Costs due to Road Traffic–related Air Pollution", OMS/Swiss ETEC/Austrian MOE 1999, rounded figures.

Air Toxic Emissions. Diesel engines are a major source of air toxic emissions, many of which have been classified as carcinogenic. Scientists and health officials are just beginning to understand the health dangers of air toxics. For instance, in California, health officials determined that 90 percent of the cancer risk from air toxics is from mobile sources and that diesel engines are responsible for 70 percent of mobile source air toxic emissions. A study estimates that natural gas vehicles produce between 70 - 85 percent fewer overall air toxic emissions than gasoline and diesel vehicles.

Table 3. Costs attributable to pollution

In millions of Euros	Austria		France		Switzerland	
	Costs attributable to total air pollution	Costs attributable to road traffic	Costs attributable to total air pollution	Costs attributable to road traffic	Costs attributable to total air pollution	Costs attributable to road traffic
Costs of mortality	5,000	2,200	28,500	15,900	3,000	1,600
Costs of morbidity	1,700	700	10,300	5,700	1,200	600
Total costs	6,700	2,900	38,800	21,600	4,200	2,200

Source: “Health Costs due to Road Traffic–related Air Pollution”, OMS/Swiss ETEC/Austrian MOE 1999, rounded figures.

Greenhouse Gases

Per unit of energy, natural gas contains less carbon than any other fossil fuel, and thus produces lower CO_2 emissions per vehicle mile travelled. While NGVs do emit methane, another principal greenhouse gas, any slight increase in methane emissions would be more than offset by a substantial reduction in CO_2 emissions compared to other fuels.

NGVs also emit very low levels of carbon monoxide (approximately 70 percent lower than a comparable gasoline vehicle) and volatile organic compounds. Although these two pollutants are not themselves greenhouse gases, they play an important role in helping to break down methane and some other greenhouse gases in the atmosphere, and thus increase the global rate of methane decomposition. This more rapid breakdown could more than offset the small increase in direct methane emissions from NGVs.

According to the analysis of Global Warming Impact (GWI), published by ENGVA (editor P. Verstegen), "The contribution made by road traffic to increasing emissions of greenhouse gases is expected to grow in the coming decades... For a complete picture the full fuel cycle from "well to wheel" has to be considered. In that case the so-called 'indirect emissions' from well exploration, transport, refining, storage and distribution have to be included. Literature on full fuel cycle emissions tends to be conflicting. Still, a majority conclude that, from a global warming point of view, natural gas is preferable to diesel and liquefied petroleum gas (LPG)".

In conformity with methods existing in several countries and especially in the Russian Federation, an assessment of exhaust emissions by motor vehicles, economic damage caused by atmospheric air pollution and ecological cleanness of motor vehicles is made on the basis of the so-called "reduced pollutant emission index".

When calculating this index, exhaust emissions are "reduced" (or recalculated) to the harmful impact of carbon monoxide equivalent (CO) with the help of appropriate coefficients.

Table 4. CO reduction coefficients

Polluting substance	CO	CH	NO_X	C
Reduction coefficients	1.0	2.0	70.0	60.0

Source: "Decree of the Council of Ministers of the Russian Federation", No. 13 of 9 January 1991.

Magnitudes of emissions were calculated for different long-distance heavy-duty vehicles (HDV) with a load-carrying capacity from 12 to 20 tonnes and for international buses driven by diesel and natural gas engines. The model used in this study is based on Euro-II recalculated for the European Transient Cycle (ETC).

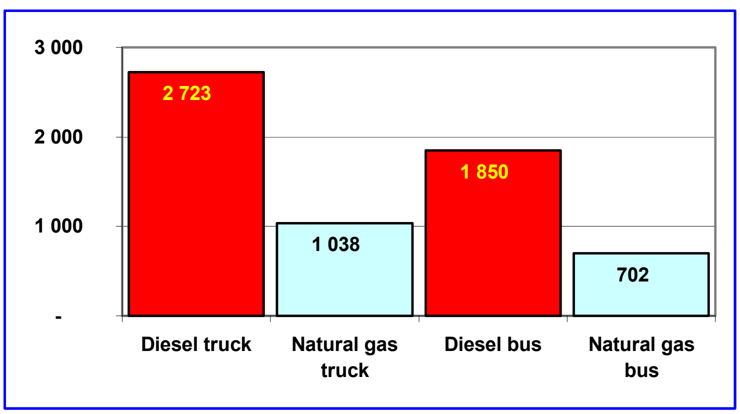
Table 5. Specific and reduced to CO exhaust emissions (Mred), kg per tonne of fuel used

Type of fuel	Polluting substance				
	CO	CH	NO_X	C	M_{red}
Heavy-duty vehicles					
Diesel	54.64	6.84	36.84	1.26	2723.1
Natural Gas	24.15	11.34	14.25	0.07	1038.2
Long-distance buses					
Diesel	54.64	5.26	24.56	1.1	1850.4
Natural Gas	24.15	9.59	9.5	0.06	702.3

Source: NGVRUS.

The figure below compares the environmental impact of diesel and natural gas long-distance HDVs and international buses.

Figure 1. Comparative figures of exhaust emissions, kg per tonne of fuel used



Source: NGVRUS.

The conversion of each cross-border motor vehicle to natural gas would allow an almost two-fold reduction of exhaust emissions, "reduced" to CO. Thus, the use of natural gas by long-distance HDVs and international buses would have a positive impact upon the environmental situation in Europe.

3.2 Economics, marketing and new technologies

The last decades have shown that, in order to secure a promising market introduction, alternative fuel technology not only has to offer significant environmental benefits, but also needs to compete with conventional technologies, such as gasoline and diesel engines, on the basis of investment and operating costs. Tax incentives or other promotional efforts may be appropriate to support the initial introduction, but only competitive operating costs will persuade customers to adopt new technologies.

The market for future commercial vehicles, such as heavy-duty trucks and city buses, is driven by three key aspects: compliance with future emissions standards, high power for driveability and fuel economy for cost reasons.

As a result, the cost of each transportation technology (diesel or alternative fuels) for complying with market requirements will become a strong argument. The vehicle procurement cost and operating expenses, such as fuelling and maintenance, are the key factors for assessment of market potential.

Under these circumstances, engine systems which offer cost advantages with low overall exhaust emissions at diesel-like power and fuel economy will have an excellent chance to obtain a share of the commercial vehicle market.

For compliance with future emissions standards in Europe, such as Euro IV/V and EEV (Environmentally Enhanced Vehicles), diesel engine technologies will become more costly because of the necessary consideration of exhaust gas after-treatment systems. Since low-sulphur diesel fuel, additives for SCR (Selective Catalytic Reactor) catalyst systems and particulate trap maintenance will have to be introduced into the existing diesel vehicle fleet structure, vehicle fuelling as well as maintenance costs will increase considerably.

However, today's lean-burn natural gas engines, which are based on a homogeneous charge, otto cycle combustion system approach, do not result in an overall fuel economy comparable to their diesel counterpart. State-of-the-art lean-burn CNG engines show a deterioration in energy consumption of 20 to 35%, depending on the duty cycle of the vehicle.

To overcome this disadvantage, natural gas engine concepts relying on the direct induction of natural gas (DING), feature the benefit of achieving diesel-like fuel consumption at torque characteristics equivalent to diesel. Especially under transient operating conditions, such as in the operation, for example, of city buses and garbage collection trucks, the utilisation of DING engines offer the full advantage of natural gas as a clean and low cost fuel, while maintaining the advantages of the diesel powertrain regarding power density and overall engine efficiency.

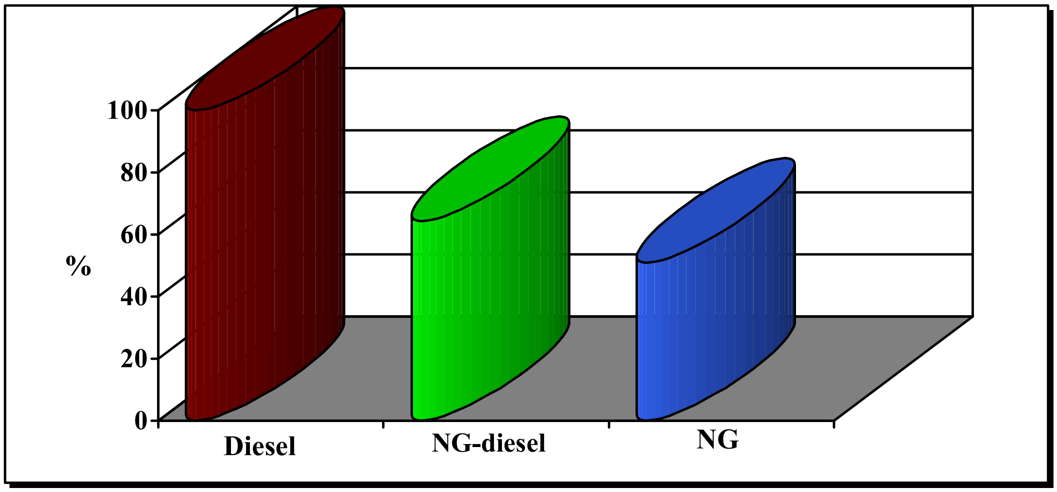
As a result, natural gas based commercial vehicle powertrain systems will become more attractive, since natural gas is less expensive than diesel fuel in most regions of the world.

Fuel cost constitutes one of the most significant items of constant expenditure for international road transport. Nowadays, the fuel factor in transport costs may amount to 48%. In its turn, the share of haulage in product/service costs at the final seller's place (retail) accounts for 28% to 38%. Fuel costs may amount to 20% of the cost of any product or service.

In this context, the fuel cost in itself is an important factor when calculating the economics of road transport.

The data on real hauls of Russian transportation carriers to European countries made it possible to work out a design model for the fixed charges and their relation to the type/cost of fuel. This estimate takes into account: 1. volumes of fuel filled en route in different countries, 2. difference in the cost of diesel fuel and natural gas in Russia, Belarus, Poland and Germany.

Figure 2. Fuel cost



Source: NGVRUS.

By using natural gas as motor fuel, international transport companies will enhance their competitiveness either through reduced tariffs for their services or cost savings.

In practically all potential Blue Corridor countries the relation between the cost of diesel fuel and natural gas is favourable for the conversion of long-distance vehicles to gas fuel. For instance, the cost of one cubic metre of natural gas in Norway is 27% of the cost of one litre of diesel fuel, 41% in Poland, 46% in Russia, 49% in Belarus, 50% in Italy, 63% in Austria, and 65% in Germany.

Table 6. Motor-fuel prices in different European countries (as of the end of 2002)

	Petrol, Euro/l	Diesel, Euro/l	CNG, Euro/m^3	Blue Corridor
Russia	0.36	0.24	0.11	Moscow – Minsk – Warsaw - Berlin
Belarus	0.54	0.37	0.18	
Poland	0.81	0.64	0.26	
Germany	0.91	0.84	0.55	
Austria	0.93	0.78	0.49	Berlin - Rome
Italy	1.07	0.88	0.44	
Norway	1.22	1.11	0.30	

Source: Data provided by TFBCP members.

3.3 LNG – liquefied natural gas fuel

Liquefied natural gas as a vehicle fuel is technically very interesting and, at the same time, very challenging from a market development standpoint. The technical problems are fairly well resolved. For the industry, an implementation period is now emerging.

In small fuel tank sizes, which are suitable for small vehicles, CNG is generally more appropriate because space and weight are not critical criteria and the cost per vehicle system is less. For large vehicles, particularly fleet vehicles, LNG becomes attractive because of reduced on-board weight and space requirements. In addition, the large vehicle system costs are less for LNG.

<u>Transport.</u> LNG can be transported by ship, barge, rail or by highway trailer. For vehicle applications, the most common transportation method is the highway trailer. These trailers carry approximately 45,000 litres of LNG depending on the weight limitations for the area. The transportation cost is not a significant deterrent with more widely distributed LNG sources but if the LNG source is remote, transportation is an additional cost and can be a competitive disadvantage.

<u>Fuelling Facility.</u> The fuelling facility cost is higher than conventional fuels in terms of equipment as the LNG must be stored, handled and dispensed at cryogenic temperatures. The components for the LNG facility include the LNG storage tank, LNG pump and fuel dispenser. For the LCNG facility, the system includes the storage tank, pump and dispenser but also includes the vaporiser and CNG storage. The economic key to the fuelling facility cost is to achieve high throughput volumes soh that the unit cost - price per litre - is attractive.

<u>Safety.</u> Historically, LNG has received more scrutiny from a safety and regulatory standpoint than other fuels. This has led to a higher level of safety analysis and risk management. The record shows that the LNG industry has a superior safety record.

3.4 Sustainable Energy

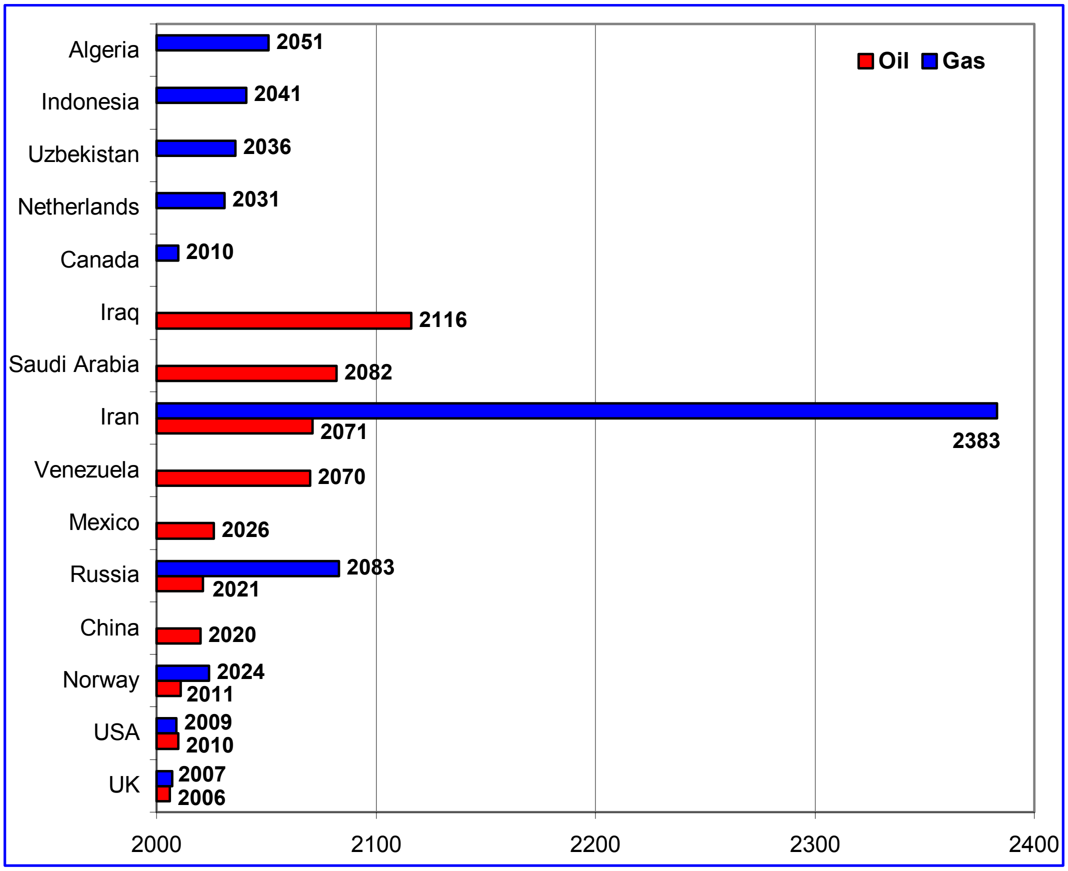
Humanity consumes a lot of energy to satisfy its needs. Energy consumption over the twentieth century increased more than 15-fold. Nowadays, hydrocarbon fossil fuels, first of all oil, natural gas and coal, are the primary source of power supply for the world economy. These fuels account for about 85% of total primary energy. Estimates forecast that the share of oil in the world’s energy balance will remain at 40% in the following 30 years. The share of natural gas may grow from 23% up to 27%.

The capacity of non-traditional sources is still insignificant and they are far from large-scale commercial use. Scientists predict that the zenith of alternative power generation may be attained not earlier than the middle of the 21st century. By 2020, the share of primary energy generated from renewable sources will account for only 6 %.

According to *Oil & Gas* magazine, world explored reserves of oil are evaluated at about 140 billion tonnes and those of natural gas at 150 trillion cubic meters. Meanwhile, 67% of explored oil reserves (93 billion tonnes) and 35% (52.5 trillion cubic meters) of gas are located in the Middle East countries. The share of east European countries including the States of the former USSR accounts for approximately 6% of explored oil reserves (8 billion tonnes) and 38% (56.6 trillion cubic meters) of natural gas. As for western Europe, the situation is as follows: 1.7% (2.3 billion tonnes) of oil and 3.1% (4.5 trillion cubic meters) of gas.

The *Commersant – Dengi* magazine (Russian Federation) in a reference to the Organization of Petroleum Exporting Countries (OPEC) cites data concerning the possible physical depletion of oil and gas explored reserves in main producing countries if the current level of recovery and consumption remains unchanged. According to the magazine's sources, oil and gas reserves in some countries will have been depleted already in the near future.

Figure 3. Forecast of oil and gas explored reserves depletion in major producing countries



Source: Commersant – Dengi magazine with reference to OPEC.

It is possible that this scenario is too pessimistic, but geographic inequality of oil and gas production and the use as well as the depletion of presently producing fields provide grounds for serious concern.

The International Energy Agency estimates that transport as the most rapidly developing sector of the world's economy consumes approximately 26% of primary energy sources. Meanwhile, oil products still account for 99% of transport's energy requirements. The share of transport in energy consumption will increase by 2% – 2.5% per annum and may amount to 29 % by 2030.

Today the world car fleet amounts to some 800 million vehicles. The average increase is estimated at 2 – 3% a year. With an annual increase of 2, 2.5 and 3%, the world car fleet may surmount the one billion barrier in 2013, 2015 and 2019, respectively. Satisfying the energy demands of the world's car fleet using only petroleum derivatives is deemed to be unfeasible in the next 20 years.

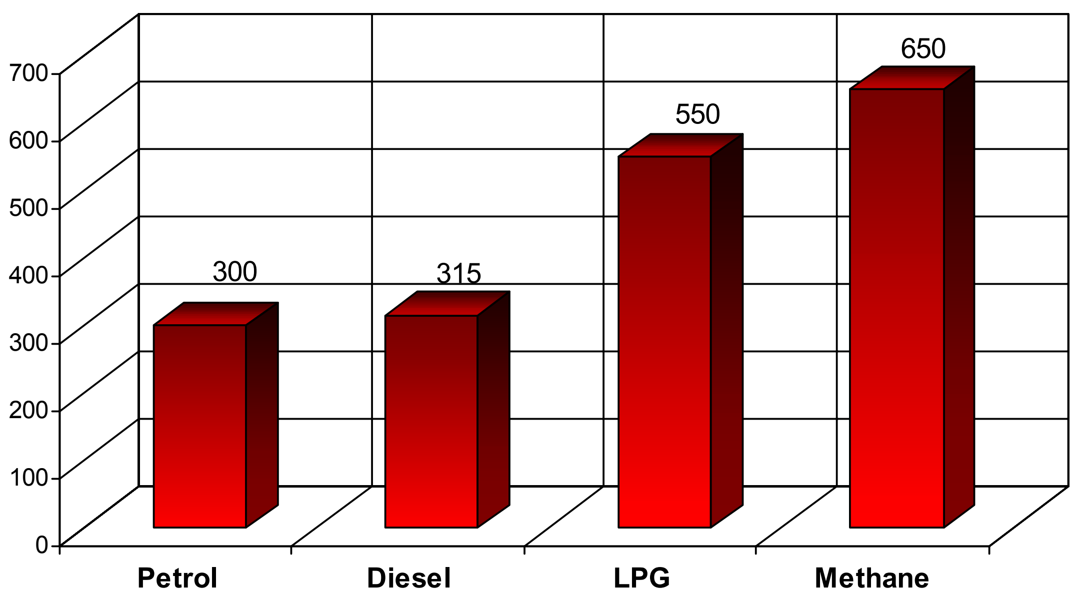
Hence, the wider use of non-oil fuels (first of all, natural gas) is one of the key imperatives for the human race.

The President of the Washington DC-based Natural Gas Vehicle Coalition, Mr. Richard Kolodziej, stated: "For the United States, the energy security arguments in favour of natural gas vehicles have never been greater" (*NGV Worldwide*, November 2002). The same arguments are fully valid for Europe.

<u>Safety</u>
Natural gas is the most non-hazardous motor fuel in terms of risk of fire and explosion. Gasoline pools on the ground create a fire hazard. Natural gas is almost two times lighter than air and, unlike gasoline, dissipates into the atmosphere in the event of an accident. That is why many countries allow the construction of automotive gas-filling compressor stations in close proximity to residential and office buildings in cities. Moreover, some countries have allowed filling for NGVs in underground garages.

Natural gas has a high ignition temperature, about 650 degrees Celsius, compared with about 300 degrees Celsius for gasoline. It also has a narrow range of flammability. In concentrations in air below about 5 percent and above about 15 percent, it will not burn. The high ignition temperature and limited flammability range make accidental ignition or combustion of natural gas unlikely.

Figure 4. Ignition temperature of various kinds of fuel (^{o}C)

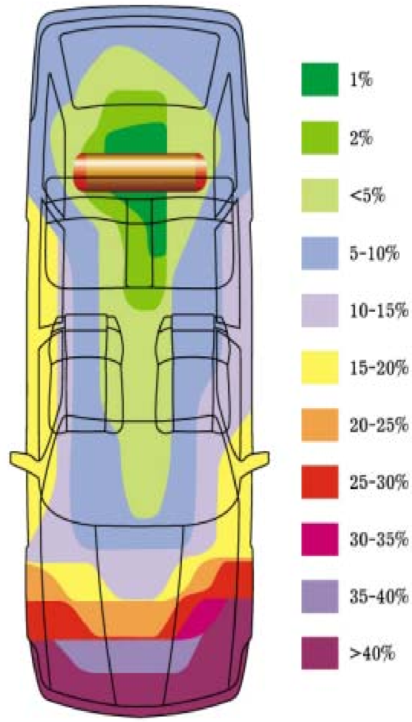


Source: ENGVA.

The fuel storage cylinders used in NGVs are much stronger than gasoline fuel tanks. The design of NGV cylinders are subjected to a number of "severe abuse" tests, such as heat and pressure extremes, gunfire, collisions and fires.

As a rule, gas cylinders are mounted in the least vulnerable and statistically least damageable parts of the motor vehicle. The BMW Company has calculated the destruction probability of the car body. The analysis displayed in the illustration below suggests that the destruction probability of the car body in the cylinders area is as low as 1-5%.

Figure 5. Destruction probability of the car body



Source: BMW Co.

Statistics gathered by the American Gas Association are instructive. 2400 motor vehicles running on gas fuel during 10 years of operation had an aggregate distance run of 280 million kilometres. They had 1360 road traffic accidents over that period. In 180 cases the impact was on the area of the gas cylinders but none of the cylinders was damaged. Gasoline inflammation was registered in five cases.

Pathway to a Hydrogen Future

Natural gas is likely to be a primary source of hydrogen for fuel cell vehicles of the future. Reforming hydrogen at local stations from natural gas and storing hydrogen on-board vehicles is the most energy, environmental and cost effective option. In addition, because of the many synergies between NGVs and hydrogen fuel cell vehicles, a growing NGV market today will facilitate the growth of the hydrogen vehicle industry of tomorrow.

Also there is the question of public acceptability. Before hydrogen vehicles are generally accepted, there needs to be a major behavioural shift in our society. The public is very familiar and comfortable with liquid transportation fuels, but generally unfamiliar with gaseous transportation fuels. As NGV use continues to grow, the public is becoming more familiar with and accepting of gaseous-fuelled vehicles. The NGV industry is setting the stage for the more rapid acceptance of hydrogen.

For these reasons, many industry sources believe that NGVs will be an important pathway to a hydrogen transportation future.

4. ANALYSIS OF TRANSPORT CORRIDORS

The Task Force has accomplished a study on the expected effects of the implementation of the Blue Corridor Project. Three pilot corridors were selected for analysis:

- Moscow – Minsk – Warsaw – Berlin (along the route E 30, Pan-European corridor No. 2);
- Berlin – Rome (along the routes E 55 and E 45);
- Helsinki – St. Petersburg – Moscow (along the routes E 105 and E 18, pan-European corridor No. 9) considered with potential for the use of LNG.

The following basic criteria were developed and used for the selection of the pilot corridors (with an important contribution by Task Force member Mr. Sakir Arikan, BOTAS, Turkey):

a) Legislative framework: legislation, existing incentives, readiness of participating countries and Governments to support the Project;

b) Environmental and technical parameters:

- traffic intensity and corresponding load on the environment;
- NGV infrastructure development along the roads in the respective countries;

c) Commercial parameters: volume and potential for transboundary trade, capabilities of fleet companies etc.

d) Geopolitical importance of the roads, i.e. connection between northern and southern seas, between western and eastern Europe with the prospect of reaching Asia and Siberia (connection with the Trans-Siberian railway).

The present analysis is the result of independent economic and environmental estimations by Task Force members. Some differences in methodologies used in the analysis of the different corridors may be explained in part by the availability or unavailability of official basic data. However, the independent character of the estimations makes the conclusions more impartial and reliable.

The selection of the three pilot corridors does not mean that the practical implementation of the project will concern only and exclusively the above corridors. In particular, the Task Force expressed the opinion that another pilot corridor could be Paris-Zurich-Vienna-Budapest-Bucharest-Haskovo-Istanbul-Ankara given the potential for transboundary trade along this mid-West-East route in Europe. The goal of this analysis is to present an estimation of the potential economic and environmental effects of implementation of the project along some pilot corridors. At a further stage the conclusions of the Task Force may serve as a basis for setting up a network of international NGV transport links in Europe.

4.1 Transport corridor Moscow – Minsk – Warsaw – Berlin (along the route E 30, pan-European corridor No. 2, 1855 km)

According to the data presented by the UNECE Inland Transport Committee (TRANS/WP.5/2002/4), every day 24,000 motor vehicles travel along international transport corridor No. 2, one third of them (8,000) being diesel trucks. According to forecasts, by 2010 these figures may double and reach 48,000 and 16,000 respectively.

The Vernadsky Foundation conducted an environmental and economic analysis of the corridor. The emissions analysis is based on the data contained in Figure No. 1 on specific exhaust emissions and harmful emissions reduced to CO using special coefficients (see Figure No.1).

Also the calculations were made using the following basic data:

	Diesel	**Natural Gas**
Use of fuel (l, m^3/100 km)	33	37.8
Fuel price (€/l, m^3)*	0.85	0.49

Source: NGVRUS.

* Average prices in Europe as of the end of 2002, according to data presented by Task Force members.

Table 7. Specific and "reduced" to CO harmful exhaust emissions (M_{red}) for heavy-duty vehicles (12 – 20 tonnes) g/km

	CO	**CH**	**NOx**	**C**	**$M_{(red)}$**
Reduction coefficient	**1**	**2**	**70**	**60**	
Diesel	18.0	2.2	12.1	0.4	893.4
CNG	9.1	4.3	5.4	0.03	397.5

Source: Vernadsky Foundation.

The above-mentioned 16,000 heavy-duty vehicles will make on average 9 million vehicle kilometres a day. The analysis showed the following results concerning exhaust emissions on the corridor.

Table 8. Harmful exhaust emissions by heavy-duty diesel and CNG vehicles (tonnes per day)

	CO	**CH**	**NOx**	**C**
Diesel	162	19.8	108.9	3.6
CNG	81.9	38.7	48.6	0.3

Source: Vernadsky Foundation.

Using the reduction coefficient it was calculated that by 2010 the total amount of exhaust gases reduced to CO emissions produced by HDVs on this corridor will account for 8040.6 tonnes a day or up to 2,934,819 tonnes per annum for vehicles using traditional diesel fuel.

At the same time in the hypothesis of total conversion of the above fleet of HDVs to CNG fuel, emissions would amount to 3579.3 tonnes a day, or 1,306,444 tonnes a year. Thus, harmful emissions could be reduced by 1,628,375 tonnes or by 55 % annually.

Regarding the economic aspects, the picture is as follows. In 2010, HDVs travelling along the Berlin-Moscow corridor would consume every day 2970 tonnes of diesel fuel or (in the case of conversion to CNG) 3402 thousand cubic meters of CNG. Annual fuel consumption would amount to 1,084,050 thousand litres and 1,241,730 thousand cubic meters, respectively. Even based on the current cost of fossil fuel (although according to forecasts oil prices will tend to increase at a more rapid rate than gas) the economy on fuel would make up more than 300 million Euros a year.

The table below sums up the estimated overall emissions, fuel expenses and oil savings in relation to freight transport along the corridor Moscow – Berlin in 2010.

Table 9. Aggregate data. Forecasts for 2010 based on a daily run of 16,000 trailers from Moscow – Berlin

Type of fuel	Reduced emissions (tonnes day/year)	Abatement of reduced emissions (tonnes day/year)	Cost of fuel (Million Euros day/year)	Savings on fuel (Million Euros day/year)	Savings of petrol fuel (tonnes day/year)
Diesel	8040.6/ 2934819		2.5/921.4		
CNG	3579.3/ 1306444	4461.3/ 1628375	1.6/608.4	0.9/313	2970/ 1084050

Source: Vernadsky Foundation.

As to the number of natural gas fuelling stations, the situation is as follows. Currently there are 10 fuelling stations along the road. While the German and Belarus parts of the corridor are practically ready to ensure the pilot functioning of the corridor, the Russian part and especially the Polish part would require the construction of a minimum of 4 stations in total. The number of existing and new stations required is shown in the table below.

Table 10. CNG fuelling stations along the corridor Moscow – Berlin

Country	Operational stations	Minimum new stations required	Optimal number of new stations required
Russia	3	1	3
Belarus	10	0	2
Poland	0	3	5
Germany	2*	0	0
Subtotal	**15**	**4**	**10**
Total	15	19	25

Source: Vernadsky Foundation.
* For the time being dedicated to passenger cars.

It is important to bear in mind that the "optimal" figures show only the number required for the implementation of the pilot project. To become fully operational and attractive for carriers a road needs to have a more saturated network of fuelling stations.

4.2 Transport corridor Berlin – Rome (along international roads E 55 and E 45)

The length of the corridor is 1695 km. An important part of the corridor (678 km) is on the territory of Italy. A detailed analysis of the Italian segment of the corridor was carried out by the representative of ENI in the Task Force, Mr. Flavio Mariani. He presented analysis for two main routes, reaching Rome from the north of the country: Brennero - Rome and Tarvisio - Rome. The analysis of the route Tarvisio – Rome following the routes E55 and E45 appears below in line with the definition of the Task Force.

Figure 6. Italian motorway system

Source: ENI.

<u>Traffic analysis</u>

Route Tarvisio, Taranto (Pescara) to Rome. Based on the data on vehicles kilometers travelled by HD vehicles in the year 2001, the calculation was made of:

- diesel oil consumption;
- equivalent CNG consumption, in the theoretical case of 100% substitution of HD diesel vehicles with HD CNG vehicles;
- global emissions of pollutants in both cases;

These calculations were made using coefficients developed by the Vernadsky Foundation.

From the data published by the Italian Association of Motorway Concessionaires (AISCAT), the total number of vehicle kilometres run by the HD vehicles along this route was 3.363 million in the year 2001.

The calculation resulted in a total consumption by diesel HD vehicles of about 1,109,658,000 litres/year, equivalent to a consumption of CNG of about 1,271,063,000 m^3/year, in the theoretical hypothesis of 100% conversion of these vehicles; (10%, ten times less, would be a more likely target, in line with that of the EU).

The global aggregate harmful effect of polluting emissions has been evaluated to be about 3,026,340 tonnes/year of CO equivalent in the case of HD diesel vehicles. These would decrease down to about 1,345,040 tonnes/year, in the case of CNG.

NG fuelling stations

The Italian NGV market today ranks second in the world. The total number of CNG refuelling stations in Italy is 413 (April 2003), which puts it in first place in Europe. The refuelling station structure is at present more developed in the northern and central part of Italy, but it has also been spreading in other regions over the last decade. It is made up of both dedicated and multifuel refuelling stations. Some of them (27) are supplied by cylinder truck as they are not connected to the pipeline structure. Some of them (13) are private and serve only HD (buses, garbage trucks) and commercial vehicle fleets.

It is worth noting that most of the fuelling stations in Italy are located at some distance from highways. That is why the option of using external fuelling stations should be considered. These stations, even if not exactly on the motorway, are very close to it, so that a diversion, out and back to the motorway, is not going to take too long. A number of them are well within a distance of 8 ÷ 0.4 km from a motorway entrance. In this way, the refuelling options are increased as the refuelling stations are more evenly scattered along the route.

For instance, at present there is only one refuelling station along the A 23 motorway from Tarvisio to Palmanova. There are 4 refuelling stations along the A 4 motorway from Palmanova to Padova; there are 6 on the A 13 from Padova to Bologna; 22 on the A 14 from Bologna to Pescara; and finally, there are 3 on the A 25 from Pescara to Roma.

The average distance between the refuelling stations on the A 13 between Padova and Bologna is 20 km. The average distance on the A 14 between Bologna and Pescara is 17 km. The total number is thus 36 refuelling stations.

Some additional comments are required on the main reasons why many of the CNG refuelling stations are very close to the motorways, but not on them. Most of them are quite old and they were built in a period when, for economic reasons, being as close as possible to the existing natural gas pipeline had a greater importance than being on the main road. Today, being close to a pipeline is still critical, but main roads and motorways have grown in importance, and the pipeline network itself has grown wider, approaching main roads more often.

The existing liquid fuel refuelling stations on the motorways always belong to the big oil companies, which in the past considered CNG as an unimportant option for them, or even as a competitor. Consequently, they were not interested in including CNG dispensers in their refuelling stations.

Small private companies soon realised how profitable building CNG refuelling stations as close as possible to the motorways could be, when the developing pipeline network allowed this. CNG customers driving along the motorways could thus refuel without having to get too far from them.

Today many big oil companies have realised that CNG is not a competitor. They now often see it as just another fuel, and even a more profitable one; so they seem to be more willing to install CNG dispensers in their refuelling stations that are on the motorways and highways. This new promising move, which has already started in some cases, will take a few years.

The German part of the corridor (about 180 km) with two existing and eight projected fuelling stations is practically ready for NGV passenger car traffic and could be extended to serve also HDVs.

In the Czech Republic (288 km), according to information provided by Task Force members Messrs. J. Zakovec and J. Tomanek, there are three CNG fuelling stations located practically on the highway E55 and one 15 kilometres away. The environmental impact of transport in the Czech Republic, located at the crossroads of trans-European motorways, is dramatic (see table 11 below), and the shift of international transit transport to natural gas could substantially alleviate the situation.

Table 11. Czech Republic – Emissions from transport in 2000 (thousands of tonnes)

	Total emissions	**Emissions caused by heavy-duty vehicles**
CO_2	11 181.0	4 816
CO	243.1	84.0
Nox	180.6	99.9
C_xH_x	70.8	22.5
SO_2	4.2	2.9
Particulate matter	3.1	2.4

Source: Ministry of Transportation of the Czech Republic.

Moreover, there is an important economic factor: CNG in the Czech Republic is 57.7% cheaper than diesel fuel (as of December 2002).

In Austria (250 km) there are two CNG fuelling stations along the motorway E 55 (in Villach and Linz) with a distance between them of about 170 km.

The following general conclusions can be made about the entire corridor Berlin – Rome:

- Consumption of diesel fuel – 2823 thousand tonnes per year.
- Consumption of CNG – 3238 million cubic meters per year.
- Emissions in diesel mode (Mred) – 7627 thousand tonnes per year.
- Emissions in CNG mode (Mred) – 3362 thousand tonnes per year.
- Decrease in emissions with use of CNG – 4265 thousand tonnes per year.
- Economy on fuel – 812.9 million Euros.

In principle, the corridor Berlin – Rome is ready for NGV traffic. At the same time, further investigations should be made to check that all the fuelling stations are suitable to service HDVs in an acceptable time. There are more than good chances of them having big enough compressors, but some doubts might be justified on the refuelling stations being wide enough for the biggest lorries to easily make manoeuvres in and out.

4.3 Transport corridor Helsinki – Moscow and aggregate data for the on three pilot corridors

Roughly similar aggregate data on the two above pilot corridors and on the corridor Helsinki – St. Petersburg – Moscow were acquired in the independent preliminary economic and environmental assessment of the Blue Corridor Project completed by the joint team of Gazprom, the Russian National Gas Vehicle Association (NGVRUS) and Avtogaz, headed by Task Force member, Mr. Eugene Pronin.

Three types of gas management systems were evaluated: dual fuel (CNG + diesel), dedicated CNG and dedicated LNG. There is large-scale production of LNG in the St. Petersburg area. However, there are currently no natural gas trucks or buses in Finland or commercial CNG fuelling stations.

The model fleet accounts for a total of 10,500 NGVs, including:

- 1,600 dual fuel vehicles,
- 6,400 dedicated CNG vehicles and
- 2,500 dedicated LNG vehicles.

The following classes of vehicles were selected for the model:

- Helsinki – St. Petersburg – Moscow: 500 LNG buses + 2,000 LNG trucks;
- Moscow – Minsk – Warsaw – Berlin: 1,000 buses + 3,000 trucks;
- Berlin – Rome: 1,000 buses + 3,000 trucks.

The following distribution of the fleet among the corridors was accepted:

- Helsinki – St. Petersburg – Moscow: 2,500 LNGVs;
- Moscow – Minsk – Warsaw – Berlin: 4,000 vehicles (800 dual fuel + 3,200 dedicated CNG vehicles);
- Berlin – Rome: 4,000 vehicles (800 dual fuel + 3,200 dedicated CNG vehicles).

The annual distance travelled by the vehicles was calculated according to the following assumption: each vehicle makes 24 round trips along the Helsinki – St. Petersburg – Moscow corridor and 16 round trips along the two remaining corridors.

The following are some of the results of the study.

Table 12. Expected fuel cost savings*

Blue Corridor	Euros per 1 round trip of a vehicle	Million Euros per model fleet/year
Helsinki – St. Petersburg – Moscow (LNGVs)	82.7	4.96
Moscow – Minsk – Warsaw – Berlin		
dual fuel vehicles	231.2	2.96
dedicated CNG vehicles	273.2	13.99
Berlin – Rome		
dual fuel vehicles	194.5	2.49
dedicated CNG vehicles	248.1	12.70
TOTAL		37.10

* The estimation is made on the basis of current prices in the corresponding countries.

Source: NGVRUS.

Accordingly, when compared to diesel, the gas-diesel fuel cost makes up:

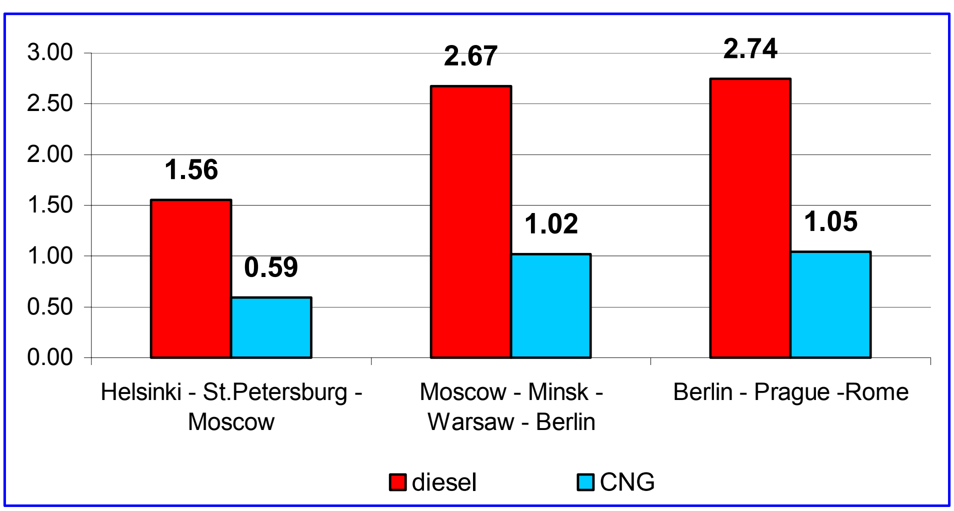
- 43 % along the corridor Moscow – Minsk – Warsaw – Berlin;
- 27 % along the corridor Berlin – Rome;

When compared to diesel, gas alone costs make up:

- 64 % along the corridor Helsinki– St. Petersburg – Moscow;
- 52 % along the corridor Moscow – Minsk – Warsaw – Berlin;
- 35 % along the corridor Berlin – Rome.

The environmental effect is estimated as follows.

Figure 7. Exhaust emissions reduction, tonnes of CO equivalent per 1 round trip of 1 truck, heavy duty dedicated CNG/LNG engines compared to EURO-2 diesel engines



Source: NGVRUS.

For the model fleet the following amounts of harmful emissions (CO equivalent) are expected to be reduced:

Table 13. Aggregate reduction of harmful emissions (CO equivalent), heavy duty dedicated CNG/LNG engines compared to EURO-2 diesel engines

Blue Corridor	Thousand tonnes per model fleet/year
Helsinki – St. Petersburg – Moscow (LNGVs)	57.8
Moscow – Minsk – Warsaw – Berlin	105.9
Berlin – Rome	108.7
TOTAL	272.4

Source: NGVRUS.

In dedicated (CNG/ LNG) natural gas mode, compared to the original Euro-2 diesel engine, CO equivalent emissions will be reduced by 61%.

Table 14. Diesel fuel to be replaced by natural gas

Blue Corridor	Thousand tonnes per model fleet/year
Helsinki – St. Petersburg – Moscow (LNGVs)	34.3
Moscow – Minsk – Warsaw – Berlin	
dual fuel vehicles	10.7
dedicated CNG vehicles	50.3
Berlin – Rome	
dual fuel vehicles	10.9
dedicated CNG vehicles	51.6
TOTAL	157.8

Source: NGVRUS.

However, the location of natural gas filling stations does not necessarily follow the highways used by international trucks and buses. Some of the stations along the model corridors are 3 to 10 km off the highway. That is why additional (new) fuelling units/stations (mother or daughter; fixed or mobile) will be required. These will include:

- Helsinki – St. Petersburg – Moscow: 4 LNG production and 16 LNG/LCNG fuelling units;
- Moscow – Minsk – Warsaw – Berlin: 20 CNG fuelling units;
- Berlin – Rome: 16 CNG fuelling units.

A new station may have 2 – 4 fuelling units with a capacity of 2.0 – 2.2 million cubic meters of NG per year each.

5. PROJECT ECONOMICS - INVESTMENTS AND RETURNS

Implementation of the BCP will require additional funds for the R&D of high performance NG buses and trucks as well as the development of the fuelling infrastructure. These additional costs were calculated for the model fleet on each corridor. The "on-board equipment" column includes R&D costs. No R&D is required for the fuelling infrastructure.

Table 15. Required investments

Blue Corridor	On-board gas equipment, million Euros	Fuelling infrastructure, million Euros	Total funds required, million Euros
Helsinki – St. Petersburg – Moscow	13.0	6.6	19.6
Moscow – Minsk – Warsaw – Berlin	25.2	5.2	30.4
Berlin – Rome	25.2	4.1	29.3
TOTAL	63.4	15.9	79.3

Source: NGVRUS.

The estimated payback period both for the model fleet (10,500 vehicles) and for the fuelling station network is 2.2 years. See Annexes 2 and 3.

6. CONCLUSIONS

6.1 Benefits and existing prerequisites

The benefits and advantages of natural gas as a vehicle fuel can be summarised as follows:

- Natural gas is the cleanest burning alternative transportation fuel available today. NGVs have surpassed all other competitors in delivering superior emissions performance. Moreover, NGVs have been certified to the most demanding environmental emission standards.
- Natural gas is safe. It is lighter than air and it does not pool on the ground like gasoline. The fuel storage cylinders are stronger than gasoline tanks. Natural gas is not toxic or corrosive, and will not contaminate ground water.
- Natural gas is economic. On average, natural gas is 40% cheaper than gasoline. In many cases maintenance costs are lower, too.
- The use of natural gas is more sustainable from the point of view of security of supply.
- Natural gas is perfectly poised as the bridge to a hydrogen fuel cell transport system. Natural gas will move the industry into the future.

There are favourable conditions for the implementation of the Project:

- Significance of road transport, including international passenger and freight transportation, continues to grow. Today the world's car fleet amounts to some 800 million vehicles. Its average increase is estimated at a rate of 2 – 3 % per annum.

- The total NGV fleet in Europe numbers almost 500 thousand units and the total number of fuelling stations exceeds 1100 units.
- The use of natural gas as a motor fuel in international freight and passenger transport under the Blue Corridor Project fully conforms to the policy of the European Union, that is aimed at the diversification of the fuel market. By 2020, the European NGV fleet may amount to some 23.5 million units and the annual consumption of natural gas may make up almost 47 billion cubic meters.
- Storing natural gas onboard the vehicle in its liquefied condition creates the possibility of doubling the distance run by a vehicle per one filling.
- International freight haulage is a profitable business.

The Blue Corridor Project is applicable for all European countries in terms of its economic and environmental benefits. Results of the study show that implementation of the pilot project could result in substantial cost savings, abatement of harmful emissions and replacement of traditional oil fuel.

6.2 Potential stakeholders of the project

The potential stakeholders of the project could be :

- appropriate governmental bodies.
- international transport companies.
- gas companies and enterprises.
- Designers and and manufacturers of vehicles and gas fuelling equipment.
- local administrations and local communities.
- International intergovernmental and non-governmental organizations etc.

6.3 Replicability

The project is fully replicable on the European continent beyond the pilot corridors with the possibility of establishing a network of "Blue Corridors". It could include such countries as France, Portugal, Netherlands, Ukraine, Bulgaria, Slovakia, Sweden and others. Moreover, there is the potential for connecting the European "Blue Corridors" with those in Asia for instance through Turkey, where new NGV programmes are being developed. Equally the project could be replicated in North and Latin America, where NGVs are developing rapidly.

The "potential of replicability for other main arteries in Europe" is outlined in the UNECE 2001 Annual Report (E/2001/37, para. 32).

6.4 Challenges

Despite the increasing number of companies becoming involved in NGV commercialization, the industry suffers from a classic ‘chicken and egg’ problem: NGV customers are often reluctant to purchase vehicles until the fuel is widely available, and fuel retailers are reluctant to install natural gas pumps until more customers are driving NGVs. To break this vicious circle government policy and action are needed. The task is education of policymakers, lawmakers and regulators regarding the benefits of NGVs, development-targeted legislative initiatives that create market-drivers and build demand for NGVs.

In the area of legislation, the goal is to stimulate NGV market development by the adoption of legislation that rewards NGVs for the environmental, energy security and other benefits they provide. Legislative targets include tax incentives, appropriations/grants, other incentives, increased governmental and intergovernmental support for R&D and the removal of regulatory barriers.

Although the existing European network of natural gas stations is practically capable of fuelling international trucks and buses with natural gas under the Blue Corridor Project, some parts will require a more developed network, because the location of natural gas fuelling stations does not necessarily follow the highways used by international trucks and buses.

To pass on to the practical phase of putting into effect the Blue Corridor Project, member countries should come to agreement on a number of issues related to fuelling international transport by natural gas. These are the following:

1. Standardization of CNG/LNG fuelling equipment, connectors.
2. Standardization of requirements for cylinders, their certification in project member-countries.
3. Adjustment of ways and techniques to determine:
   - 3.1. measurement of the amount of CNG/LNG filled in cylinders/cryogenic tanks (volumetric or mass method);
   - 3.2. residual quantity of CNG/LNG at customs inspection posts when crossing state borders.
4. Harmonization of requirements concerning the composition and characteristics of CNG/LNG - humidity, impurity content, odorant content, etc.

It is noteworthy that it was very difficult to get accurate baseline data. For this very reason some of the conclusions and findings may lack precision. More comprehensive international efforts are needed in order to develop a sound business plan at a further stage.

6.5 Future steps

Future steps towards practical implementation of the pilot stage of the project include:

- Establishing an International Consortium incorporating interested governmental bodies, companies, international and national organizations – 2004;
- Approaching international financial institutions e.g. European Bank for Reconstruction and Development (EBRD), World Bank, European Commission – 2003 – 2005;

- Feasibility study and business plan on the project carried out by the International Consortium – 2004 – 2005;
- Implementation of the pilot project – 2006 – 2010.

Final conclusion: the work carried out by the Task Force allows the conclusion that the Blue Corridor Project is an environmentally and financially viable project for the European continent.

Moreover, its implementation will help to create new jobs, encourage R&D, promote further co-operation and integration in Europe and stimulate social and economic development of adjacent areas.

Interested Governments, companies, international and national organizations are encouraged to join the International Consortium for the implementation phase of the Blue Corridor Project.

Annex 1. Dynamics of NGV development in Europe

	NGVs					
Country	**1995**	**1996**	**1997**	**1998**	**1999**	**Present**
Austria	13		17	37	83	150
Belgium	116	217	220	243	300	300
Czech Republic	30	30	30	30*	300	400
Denmark	9	5	4	4*	1	1
Finland	3	22	22	22*	33	35
France	603	1220	1250	1250*	3309	4550
Germany	1100	2415	3600	3600*	6000	25000
Great Britain	370		400		835	835
Hungary						
Ireland	34		65	65*		81
Italy	280000		300000	300000	320000	400000
Luxembourg		18	20	25		25
Netherlands	450		574	574*		574
Norway	5		14	18	88	88
Poland	20		20	20*	37	345
Portugal				1	13	192
Russia	26000		27000	28000	29000	31000
Slovakia						70
Spain	11		48	48*	120	317
Sweden	108		510	1137	1550	2000
Switzerland	20	20	60	60*	200	520
Totals	**306892**		**333854**	**335533**	**361869**	**466483**

	Fuelling Stations 1997			Fuelling Stations 1998			Fuelling Stations 1999			Fuelling Stations Present		
Country	**Fast**	**Slow**	**VRA**	**Fast**	**Slow**	**VRA**	**Fast**	**Slow**	**VRA**	**Fast**	**Slow**	**VRA**
Austria	2		15	3		15	5		18	11		23
Belgium	2	2	57	2	1	60	3	2	60	3	2	60
Czech Republic			1	11			7			13		
Denmark	1	3		1		3			1			1
Finland				2		3	2		2	2		2
France			110				105		100	105		100
Germany	55		450	55		450	122			227		
Great Britain	17		65	18		46	37		60	37		60
Hungary			11			3						
Ireland	2		6	1						2		
Italy	280			280		108	355			395		
Luxembourg	2	2		2	3							
Netherlands	14			27								
Norway	2			1			3			4		
Poland				4		13						
Portugal							4			4		
Russia	187			187		2	207			215		
Slovakia										2		
Spain	6			6			12			17		
Sweden	8	4	8	16		29	25			29		
Switzerland	7		40	3			13			26		
Totals	**398**	**11**	**763**	**432**	**4**	**730**	**693**			**887**		

*1998 Latest figures not available. Indicates previous year number

Source: ENGVA.

Annex 2. Pilot Blue Corridors. Estimated Investment and Returns

Blue Corridor	NGV Fleets		Aggregate Additional Cost of Gas Equipment and CNG Cylinders/LNG Tanks for NGVs, millions of Euros **a)**	NG Sales per year		Additional Fuelling Units Required (new construction)		
	NG Trucks	Buses		Mcm **b)**	Cost, Mln Euros	Capacity, Mcm **b)**	Units **d)**	Cost, Mln Euros
Helsinki – Moscow (LNG)	2000	500	13.0	47.2 **c)**	5.27	45.0 **c)**	16	6.60
Moscow – Berlin (CNG)	3000	1000	25.2	84.6	16.46	42.3	20	5.20
Berlin – Rome (CNG)	3000	1000	25.2	86.8	40.48	34.7	16	4.16
TOTAL **e)**	8000	2500	63.4	218.6	62.21	122	52	15.96

	Aggregate value	Specific value per vehicle
NGV fleet for the BCP, thousand vehicles	10.5	
Investment required (on-board equipment + infrastructure), thousands of Euros	80,000.0	7.6
Emissions reduction (CO_2 equivalent), tonnes per year	395,152.3	37.6
Fuel cost savings, thousands of Euros per year	37,101.0	3.5
Macroeconomic specific payback period, years	2.2	2.2

Source: NGVRUS.

a) – *Cost of onboard equipment includes the cost of R&D.*

b) - *Mcm – Million cubic meters.*

c) - *The volume of LNG consumed is translated into standard cubic meters.*

d) - *The number of fuelling stations (sites) could be less than in the table: Each station (site) may have 2 - 4 units capable of 2.0 – 2.2 Mcm of NG per year each.*

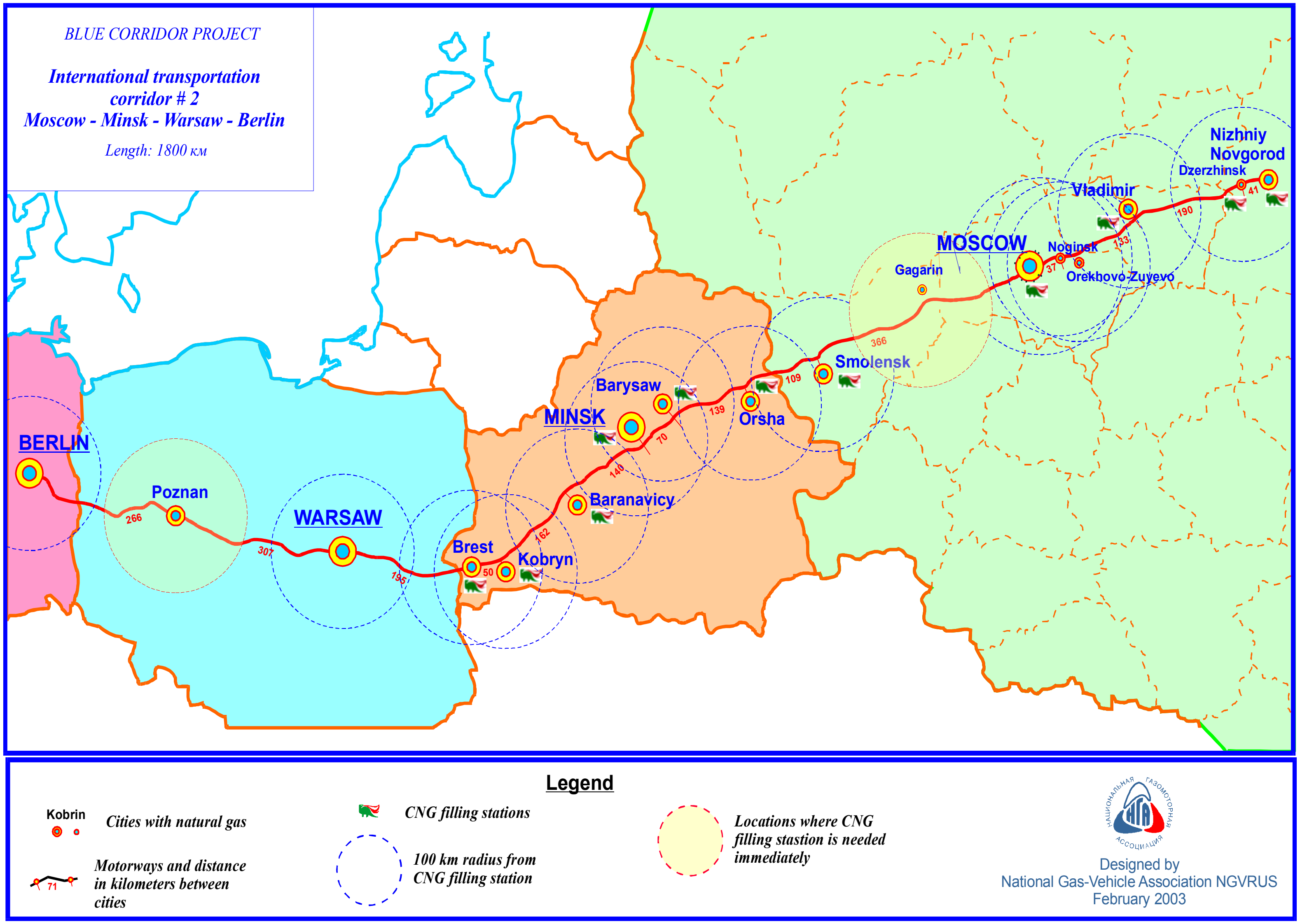
e) – *Total required investment includes additional cost of on-board equipment (including related R&D) + cost of construction of new CNG/LNG fuelling units.*

Annex 3. The Blue Corridor – Economic and Environmental Model

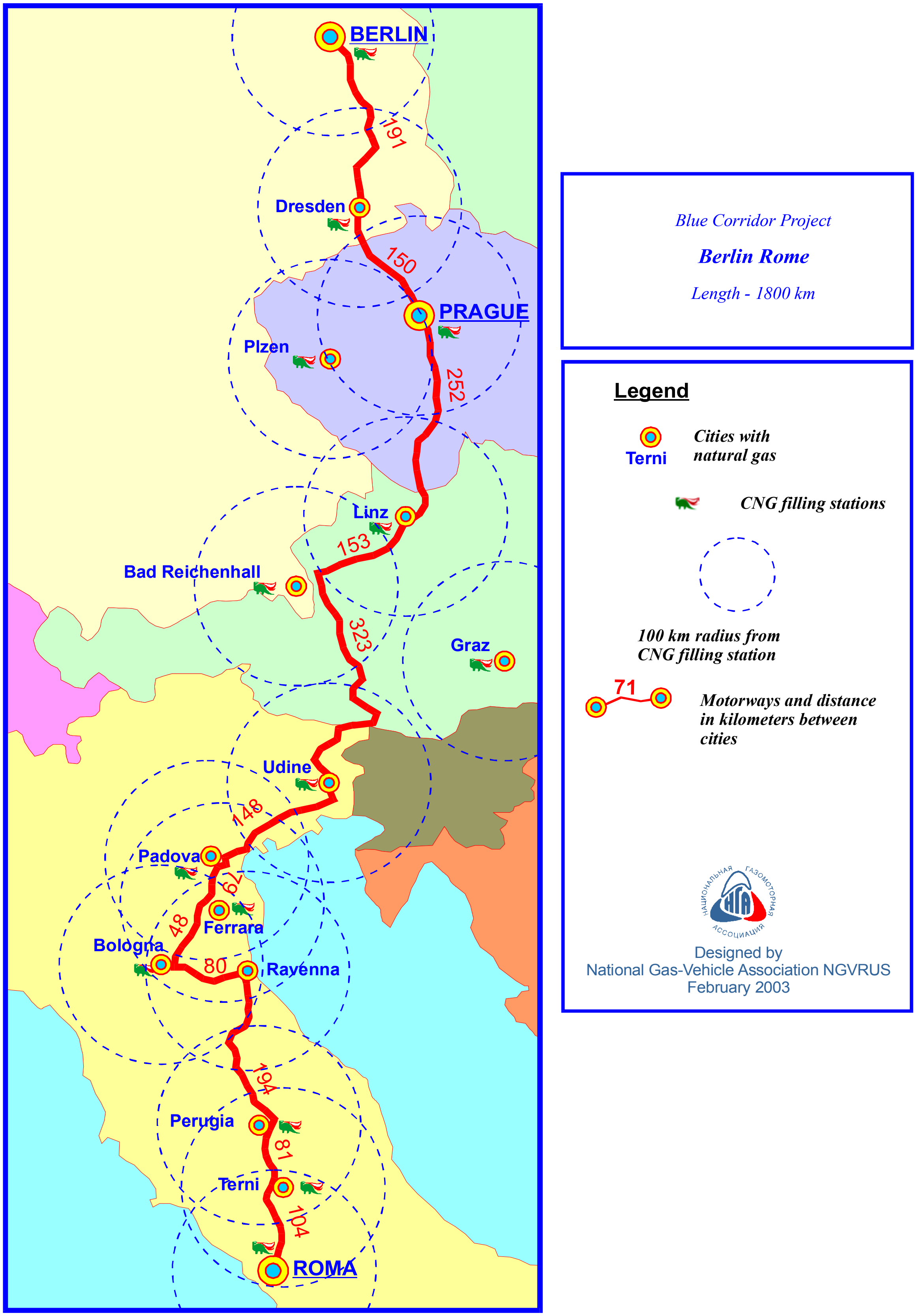
Blue Corridor	General Data				Fuel cost savings		Diesel fuel replacement, Tt/modelfleet/year	Emissions (CO equivalent) reduction, Tt/model fleet/year	Number of new filling units required	Investment required, Mln Euro		
	Length, km	Trucks	Buses	Number of round trips per year	Euros per 1 round trip of a vehicle	Mln Euro per model fleet/year				Refueling infrastructure	On-board gas equipment	Total funds required
Helsinki – St. Petersburg – Moscow (LNGVs)	**1,050**	**2,000**	**500**	**24**	**82.7**	**4.96**	**34.3**	**57.8**	**16**	**6.6**	**13.0**	**19.6**
Moscow – Minsk – Warsaw – Berlin	**1,800**	**3,000**	**1,000**	**16**		**16.9**	**60.9**	**105.9**	**20**	**5.2**	**25.2**	**30.4**
Berlin – Rome	**1,800**	**3,000**	**1,000**	**16**		**15.2**	**62.5**	**108.7**	**16**	**4.1**	**25.2**	**29.3**
TOTAL		**8,000**	**2,500**			**37.10**	**157.8**	**272.4**	**52**	**15.9**	**63.4**	**79.3**

Source: NGVRUS.

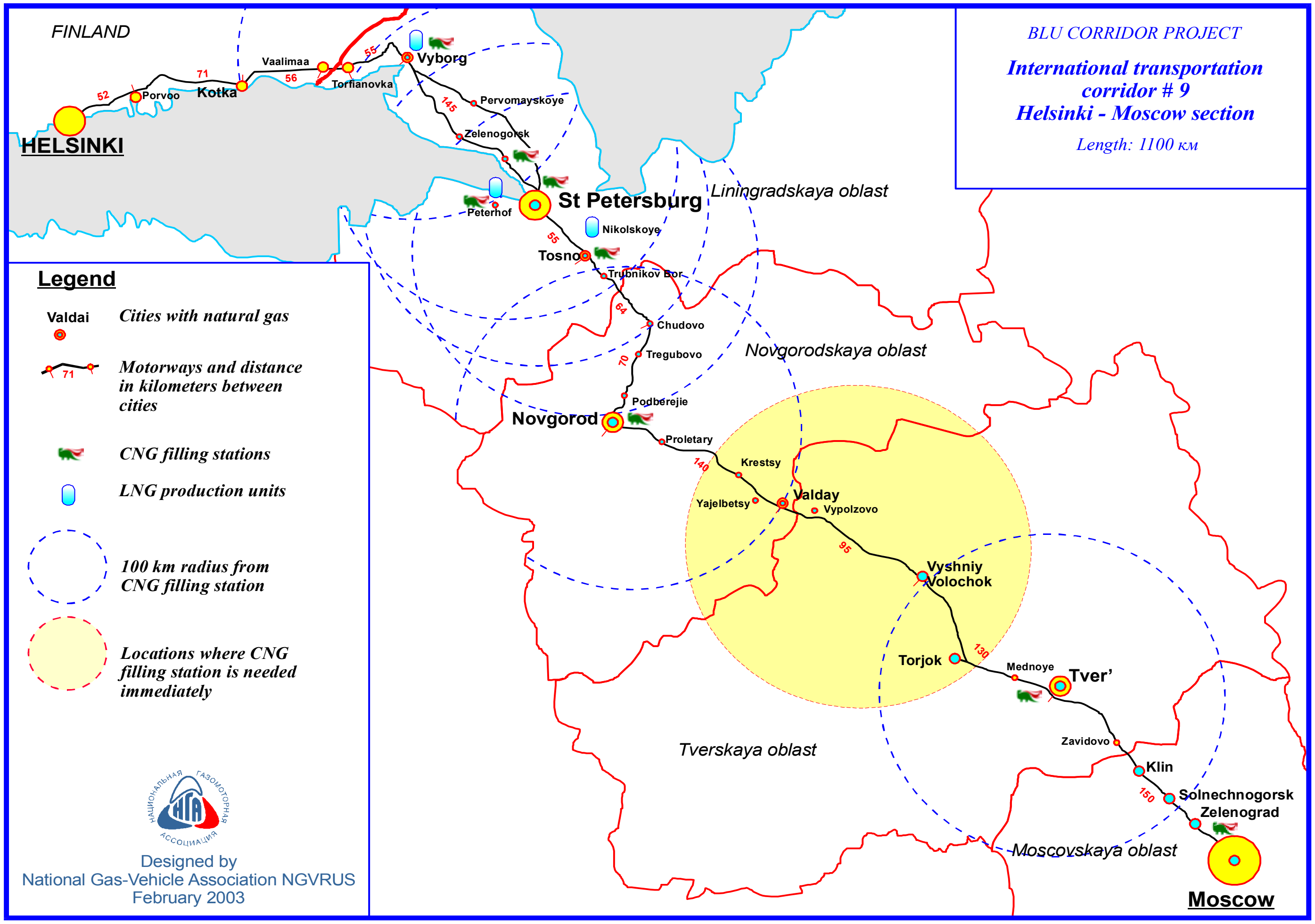
Annex 4. Route of the corridor Moscow – Minsk – Warsaw - Berlin



Annex 5. Route of the corridor Berlin – Rome



Annex 6. Route of the corridor Helsinki – St. Petersburg - Moscow



List of Abbreviations

AISCAT	*Associazione Italiana delle Societa Concessionarie Autostrade e Trafori* – Italian Association of Motorway Concessionaires
BCP	Blue Corridor Project
CEE	Central and Eastern Europe
CIS	Commonwealth of Independent States
CNG	Compressed Natural Gas
DING	Direct Induction Natural Gas engine
EBC	European Business Congress
EBRD	European Bank for Reconstruction and Development
EEV	Environmentally Enhanced Vehicle
ENGVA	European Natural Gas Vehicle Association
ENI	National Hydrocarbon Corporation (Italy)
GVR	Gas Vehicle Report (magazine)
GWI	Global Warming Impact
HDV	Heavy-Duty Vehicle
HGV	Heavy Goods Vehicle
LCNG	Liquefied-to-Compressed Natural Gas
LDV	Light-Duty Vehicle
LNG	Liquefied Natural Gas
LNGV	Liquefied Natural Gas Vehicle
LPG	Liquefied Petroleum Gas
NG	Natural Gas
NGV	Natural Gas Vehicle
NGVRUS	Russian National Gas Vehicle Association
OEM	Original Equipment Manufacturer
PM	Particulate Matter
SCR	Selective Catalytic Reactor
TFBCP	UNECE Task Force on the Blue Corridor Project
UNECE	United Nations Economic Commission for Europe
VRA	Vehicle Refuelling Appliance
WHO	World Health Organization