

Measure title: **Transition towards clean vehicle fleet in Krakow**

City: **Krakow**

Project: **CARAVEL**

*Measure
number:*

5.3

A Introduction

A1 Objectives

The measure objectives are:

- To research and test new solutions in the field of alternative fuels and innovative feed engine systems. Therein to gain and test a hybrid bus in order to collect exploitation data to be used for comparative study with other environment friendly vehicles.
- To withdraw by the end of the year 2007 old buses which are not constructed in accordance with environmental EURO norms.
- To test first 5 CNG buses operating on bus lines 192 and 492 which connect airport "Balice" to the city as well as on line 134 that leads to ZOO and is located in the area of clean high mobility corridor.
- To make comprehensive comparative analysis of different clean vehicle technologies, with respect to economic aspects of vehicle exploitation, for the purpose of future decision on big investment in environment-friendly bus feet of particular kind. The analysis will be based on research activities and results of exploitation tests of vehicles.
- To decrease a noise emitted by PT vehicles. Therein: to withdraw old type of buses, to give strong requirements to the potential bus providers, to try to develop new standard for tram tracks construction enabling the noise muffling and to muffle vibrations in trams' boogies.

A2 Description

A big problem in Krakow is motorisation that leads to air pollution. The better ecological solution is to reduce air pollution in big vehicles, like city buses, rather than in small cars. Engines using CNG as a fuel fulfil EURO IV and V standards. MPK has already had some experiences in using CNG buses. Actually, MPK buses are less than 10% of all running vehicles contributing to the air pollution in the city. In the area of MPK bus runs there are many cultural relics, which are saved by the national law.

The transition towards clean vehicles (those with much smaller impact on the environment in comparison to standard cars) is based on the MPK's policy of fleet gradual exchange focused on environmentally friendly vehicles. The policy assumes the withdrawal of the old generation buses (i.e. those equipped with engines constructed in the 60's) and their exchange into modern ones by the year 2008. In the meantime in order to limit the fumes emission the following activities have been carried out: *searching for special fuel components, installation of catalyzers, searching for and use of new low-sulphur fuels as well as special care for technical condition of engine feed systems*

The main goal of the transition is to directly and indirectly decrease the emission of: toxic components of exhaust fumes, CO₂ and noise. The policy includes: *limitation of individual transport and activities aimed to favor PT in order to decrease traffic in the city, exchange of old type of buses for those fulfilling Euro III and EURO IV requirements by the year 2008, decrease of noise emitted by buses and trams (in case of trams by developing new standard of tracks construction and muffling vibrations in boogies), purchase and assembly of further pieces of modern low-floor trams with innovative propulsion system that allows for energy*

saving, tests of 5 CNG buses, test of hybrid bus as well as further research on new solutions in the scope of EEV bus fleet.

B Measure implementation

B1 Innovative aspects

The innovative aspects of the measure are:

- **Use of new technology** – Within CRAVEL the public transport operator in Krakow (leading partner of the measure 5.3) will introduce and test CNG buses which will operate on regular bus lines. It is also planned to test a hybrid bus.
- **New conceptual approach** – MPK will elaborate a new transitions strategy plan for new clean vehicle fleet in Krakow. (WD5.3.1). The document will describe a process of old fleet exchange for new environment-friendly ecological vehicles.
- **New physical infrastructure solutions** – Bus fleet maintenance facilities will be adjusted to the requirements of CNG vehicles in order to ensure safety and security of the exploitation. A project of bus depot modernisation will include a place for CNG filling station.

B2 Situation before CIVITAS

In Krakow approximately 420 city buses are in daily operation. During a test phase from 1994 to 2000 MPK used 6 CNG buses and 1 LPG bus. The pilot had revealed that only an introduction of a high number of CNG buses is economically efficient, and thus Krakow was aiming for a large scale implementation in the future.

Between 02 and 06 of June 2005 MPK conducted the tests of CNG bus made by IRISBUS company (12 meters) which were carried on the regular line number 134 in the scope of operating, fuel consumption and performance parameters, functionality, possibility of refuelling; evaluating passengers' sensitivity - gaining their opinions and recognizing their feelings about testing bus.

B3 Actual implementation of the measure

The measure was implemented in the following stages:

- **Stage 1: Research on CNG technology and bus provider market (Mid 2005 – Beginning of 2006)** – In order to prepare the public procurement MPK made an analysis of available CNG solutions and providers of CNG vehicles. During the research consultations with other Polish PT operator were held for the purpose of gathering their opinion about exploited CNG vehicles. The results of market research and recognition were used for the preparation of bus specification required by regulations of public procurement.
- **Stage 2: Conducting a public procurement (first quarter of 2006 - third quarter of 2006)** – As the organization owned by the city of Krakow, MPK had to conduct a call for tender procedure in order to choose the best offer for the delivery of CNG buses. The contract for the delivery of 5 CNG buses was signed with the Polish company -Polskie

Autobusy Sp. z o.o. The offered type of bus was Jelcz 121 M CNG.

- **Stage 3: Official presentation of CNG bus in Krakow** took place on 23rd of November 2006. City officials participated in the event.
- **Stage 4: Delivery of 5 CNG buses** (December 2006 – January 2007) – first 5 CNG buses Jelcz 121 M CNG were delivered in December 2006 and beginning of January 2007.
- **Stage 5: Training session for drivers** (January – February 2007) Training for the first group of drivers in the scope of CNG buses operating was carried out in January 2007 and next in February 2007. Trainers paid particular attention on gas filling.
- **Stage 5: Exploitation tests of 5 CNG buses** (January 2007 – January 2008) – According to plans MPK has started the exploitation test of 5 CNG bus in January 2007, just after the delivery. During the test data regarding fuel consumption, noise emission etc. were gathered and compared to the results of conventional diesel vehicles.
- **Stage 6: Development of the transition strategy plan.** The working document WD 05.03.1 “Transition Strategy plan for clean public vehicles in Krakow” was finished in January 2006 and is based on MPK’s strategy for fleet exchange and renewal. The main goal of the strategy is to directly and indirectly decrease the emission of: toxic components of exhaust fumes, CO₂ and noise.
- **Stage 7: Withdrawal of old type bus Ikarus 280** (24th September 2007) – For last couple of years MPK has been gradually withdrawing old types of vehicles. In September 2007 the company officially withdrawn a last bus of type Ikarus 280 - the only one that did not fulfil EURO environmental norms.
- **Stage 8: Exploitation tests of hybrid and ethanol-propelled buses. The exhibition of ecological buses during the 100th Meeting of the European Union Committee held in Krakow on 3-5 July 2008.** In July 2008 MPK hosted a meeting of the EUC and in this occasion organised the exhibition of newest solutions of the ecological and modern PT vehicles. After the meeting two types of buses i.e. hybrid and ethanol-propelled were tested on PT lines in Krakow.

B4 Deviations from the original plan

The deviations from the original plan comprised:

- **Deviation 1: Abandoning the goal of purchasing 100 CNG buses** – The implementation and testing of 100 CNG buses will not take place within the duration of CARAVEL project. The introduction was conditioned by the purchase co-financed by a loan from the National Fund of Environmental Protection. Unfortunately all requests for financial support submitted to several organizations (therein to National Fund for Environmental Protection, Coherency Fund) met with point-blank refusal. Moreover, Russia–gas provider for Poland can stop gas delivery (as it happened in 2005). Consequently the introduction of 100 CNG buses which means the replacement of 25% of the whole bus fleet or any other significant amount of gas vehicles has no justification unless a new gas supplier enters the market. The national gas distribution system is based on a monopolized infrastructure, thus it is not possible to buy gas somewhere else.
- **Deviation 2: Delay in purchase of CNG buses** – Complicated and time-consuming procedure of public procurement was the main reason of the delay in purchasing 5 CNG buses previously planned by July 2006. The demonstration of clean CNG vehicles in Krakow started in December 2006 (month 23) instead of July 2006 (month 18), as it had been planned in the Inception Report. The delay of 5 months was caused by two main reasons: 1. necessity for including investment in CNG vehicles in MPK’s financial plan for the year following the start of Caravel project i.e. 2006 (and plans for next year are usually prepared in last quarter of the current

year), 2. Time needed to recognize CNG bus market as well as to prepare documents for public procurement and conduct a call for tender procedure.

- **Deviation 3: Use of external gas filling station** - During the phase of testing 5 new CNG buses an external gas filling station will be rented and used. The planning and research related to building own CNG filling station will continue to be ready once the decision towards greater number of CNG buses is made.
- **Deviation 4 : Change of operating line for CNG buses** – Due to the location of the chosen external gas filling station the first 5 CNG buses will operate on lines number 192, 492 (which lead to the airport) and line 134 (to ZOO) instead of lines 115 and 125 - linking the new demand responsive public transport service with city centre.
- **Deviation 5 : Abandoning the goal of Clean Electricity Pact** - Since July 2007 new legal regulations that separate energy production from energy distribution became binding. Despite the fact that theoretically this legal act allows new energy producers to enter the market, a real practical change require some time. At the time being all entities distributing energy are obliged by Polish law to ensure a certain share of green energy from renewable sources in total volume of sold power. According to the official statement sent to MPK by its current energy provider, an increase of the mentioned share of green power in total energy bought by MPK will cause the energy unit price to rise. Therefore, after making an analysis of possible energy cost increase MPK has decided to postpone the establishment of the pact for the future when the real market liberalisation effects will be noticeable. Nevertheless the changes in the electric power market will be investigated as well as the policy of purchasing ecological and energy saving vehicles will be continued. Also special training for ecological bus driving will be carried out.

B5 Inter-relationships with other measures

The measure is related to other measures as follows:

- **Clean high mobility corridor in Krakow no. 8.3** – Clean CNG vehicles will operate on lines going through the corridor area.
 - **Mobility Forum in Krakow no. 11.7** – Progress of adopting CNG buses in MPK will be discussed within the Forum
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C Evaluation – methodology and results

C1 Measurement methodology

C1.1 Impacts and Indicators

Table of Indicators

Evaluation Category	N°	Indicator	Units	Source of data	Methodology for indicator construction (survey, modelling, etc)	Baseline date
CI2		Reduction in CO2	%,g/vkm	PK	Modelling	12.2007
CI3		Operating Costs	€/pkm,€/vkm	MPK	Measurement	From 12.2005 to 6.2007
CI4		Vehicle fuel efficiency	MJ/vkm	MPK	Measurement	From 12.2005 to 6.2007
CI5		Fuel Mix	%	PK	Modelling	12.2007
CI6		CO levels	g/m3	PK	Modelling	12.2007
CI7		NOx levels	g/m3	PK	Modelling	12.2007
CI8		Particulate levels	g/m3	PK	Modelling	12.2007
CI9		CO2 emissions	g/vkm	PK	Modelling	12.2007
CI10		CO emissions	g/vkm	PK	Modelling	12.2007
CI11		NOx emissions	g/vkm	PK	Modelling	07.2007
CI 14		Small particulate emissions	g/vkm	PK	Modelling	07.2007
Own		Acceptance level	%	MPK	Survey	07.2007
Own (66)		Effective bus exploitation	km/month per vehicle	MPK	Measurement	
Own (33)		Noise level		MPK	Measurement	

Detailed description of the indicator methodologies:

- **Indicator *Operating costs*** – it refers to costs incurred for the exploitation of CNG buses and their comparison to conventional diesel buses exploited in the same conditions. The source of data is costs registration system for each CNG vehicle as well as exploitation results record system. In order to compare results for both types of buses (CNG and diesel) incurred costs will be referred to vkm made by CNG buses.
- **Indicator “*Vehicle fuel efficiency*”** – The information comes from measurement in CIVITAS area using clean vehicles. CNG consumption in buses will be

provided by accounting work system for every bus individually and for groups of the same type of buses for oil (operating on the same or comparable PT line. Consumption indicator CNG/ON is serving through buses producing as parameter which distinguish their buses from others producers. The value indicator: m3/100km i l/100 km. (This is the value for buses with diesel oil propulsion. The indicator will be the baseline for future comparison to CNG buses fuel efficiency.)

- **Indicator “Effective bus exploitation”** – The information comes from measurement in area using clean vehicles. Measurement concerns t ridership within analyze period (e.g. month) with CNG buses and comparable diesel buses. Value indicator will be percentage difference of CNG and diesel buses. (Km/month per vehicle).
- **Indicator Acceptance level** – it is a percentage of surveyed respondents (heads of Krakow households) who expressed their acceptance for CNG buses in Krakow PT fleet. The indicator will be measured before and after the implementation of the service. The acceptance level will be assessed during the survey that will be performed in 2006 and 2007 (perception by the citizens).
- **Indicator Noise level** – is defined as a change of noise level for both types of buses i.e. CNG and diesel. The noise level will be measured in dB (A) inside vehicle in certain measurement points, according to the norm PN-90/S-04052. External noise level will be also measured with accordance to adequate regulations binding in Poland.

C1.2 Establishing a baseline

Base line data for indicator **Acceptance level** were collected during survey conducted in *time period*: 21st of July – 11th of August 2006.

Sample size: 1210 households in Krakow (Interviewer interviewed only persons who use to make most important decisions in a particular household)

Sampling method: random stratified selection spanning 18 districts of Krakow

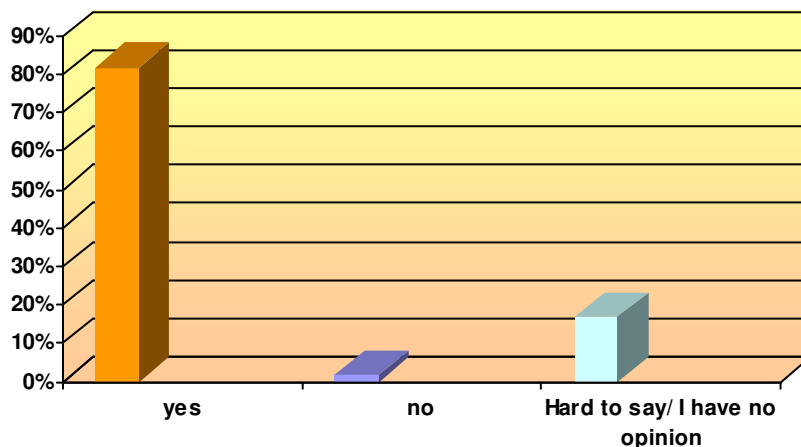
Research method: personal interviews based on questionnaire (paper & pencil method)

Level of acceptance for CNG buses implementation

At the end of 2006 CNG-propelled buses will start to operate on PT lines. Do you think it is a good idea? Possible answers: Yes, it is.; No, it is not. (Please say why)

		2006	
		amount	%
	Yes	988	81,7%
	no	20	1,7%
	Hard to say/ I have no opinion	202	16,7%
	Total	1210	100%

Level of acceptance for CNG buses implementation



C1.3 Building the business-as-usual scenario

Activities related to CNG solution realized in the CIVITAS/CARAVEL project had a character of the research programme with the aim to check a feasibility of introducing the technology on a bigger scale in Krakow. Without the experience gained in CIVITAS MPK's knowledge about CNG vehicles and their exploitation would be based only on information given by the CNG users and research on gas propulsion conducted by MPK in 90ies. Simply saying, we would lack a practice with contemporary CNG vehicles as well as we would not make precious contacts with bus producers and public transport actors who already implemented the technology. It is very probable that financial resources incurred for 5 CNG vehicles would be spent for 6 diesel buses. We would examine and tests other ecological solutions like hybrid cars or those propelled by alternative fuels e.g. ethanol.

C2 Measure results

The results are presented under sub headings corresponding to the areas used for indicators – economy, energy, environment, society and transport.

C2.1 Economy

Based on the survey in 2007 nearly 63% (see table C2.5-2) of respondents admitted they would like to have ecological PT buses in Krakow. But the tendency to pay more instead of having Public transportation with ecological fuel was much lower - 45 % (C2.1-2).

C2.1-2 Would you be willing to pay higher price for a public transport in return for introducing ecological fuel vehicles into the PT fleet?		2007	
		Amount	%
Absolutely, yes	125	10,8%	
Yes, but it depends how much more I should pay	405	35%	
No	626	54,2%	
Total	1156	100%	

	Unit costs [zł/km] in 2007 (according to IFS system)		
	Jelcz M121M/4CNG	Jelcz M121MB - diesel	Cost factor
Total workshop costs	2,2709	2,3507	0,96
Diesel		1,0129	
CNG	0,8898		
Technological liquids: engine oils, radiator liquids, lubricators	0,0304	0,0128	
Remuneration (drivers, mechanics etc.)	1,2316	0,9000	

The obtained results state the effect of real bus exploitation (powered both CNG and diesel). During first year, CNG buses were adapted to MPK standards, while diesel buses were operating. In the first phase of exploitation, there are necessity of incurring additional costs connected with technical service and engine oil change. Higher unit costs of drivers salaries is the result of lower mileage of CNG buses in comparison of traditional ones (moreover, CNG bus drivers receive additional 8% of their salaries due to bus type). Unit cost is also affected with necessity of visiting CNG refilling station, which is placed far away form normal operating line (bus driver gets his salaries, in spite the bus is not operating). Calculation shows, that unit cost difference do not exceed 14% (0,1231 zł/km) and is placed significantly below operator expectations and do not guarantee investment efficiency.

C2.2 Energy

The "Fuel consumption" of Jelcz M121M/4CNG (powered by gas) in comparison with Jelcz M121MB/V (diesel bus powered by oil)

C 2.2-1 FUEL CONSUMPTION FOR CNG AND DIESEL BUSES			
Month	Unit CNG fuel consumption Bus type: Jelcz M121M/4CNG [m3/100 km]	Unit diesel fuel consumption Bus type: Jelcz M121MB/V [l/100 km]	Indicator [m3/l]
Year 2007			
January	59,82	34,74	1,72
February	59,31	34,86	1,70
March	60,96	35,11	1,74
April	60,57	34,81	1,74
May	61,06	35,21	1,73
June	62,07	35,23	1,76
July	60,13	34,77	1,73
August	58,93	35,36	1,67
September	62,12	36,40	1,71
October	64,43	37,45	1,72

November	64,98	37,20	1,74
December	63,15	38,75	1,63
Year 2008			
January	62,24	38,07	1,64
February	61,116	37,77	1,62
March	60,42	37,93	1,59
April	60,56	37,61	1,61
May			

A level of fuel consumption (CNG or oil) is a reflection of the bus construction and exploitation conditions. The unit fuel consumption indicator [m^3/l] is a crucial one when comparing exploitation effectiveness. The value of the indicator for buses operating in Krakow is from 1,6 to 1,7. It is comparable to the figures reached by vehicles from other cities and very similar to indicators given by a bus producer. However the indicator is higher than figures showed by the protagonists of the CNG technology (1,4).

C 2.2-2			
ENERGY CONSUMPTION FOR CNG AND DIESEL BUSES			
Month	Unit energy consumption Bus type: Jelcz M121M/4CNG	Unit energy consumption Bus type: Jelcz M121MB/V	Energy consumption indicator
	[MJ/ km]	[MJ/ km]	[2/3]
1	2	3	4
Year 2007			
January	20,60	12,40	1,66
February	20,42	12,45	1,64
March	20,99	12,53	1,67
April	20,85	12,43	1,68
May	21,02	12,57	1,67
June	21,37	12,58	1,70
July	20,70	12,41	1,67
August	20,29	12,62	1,61
September	21,39	12,39	1,73
October	22,18	13,37	1,66
November	22,36	13,28	1,68
December	21,74	13,83	1,57
Year 2008			
January	21,43	13,59	1,58
February	21,06	13,48	1,56
March	20,80	13,54	1,54
April	20,85	13,43	1,55
May	20,14	13,32	1,51

The energy consumption per unit of performed transportation services reached by CNG buses was 60% higher than that measured for diesel vehicles. The discrepancy is far from the operator’s expectations and no theoretical justification was found. A potential reason of such high energy consumption by CNG car could be an error made when evaluating the amount of the gas fueled –up or hesitation of CNG energetic value. This problem will be a subject of further investigation and analysis.

C2.3 Environment

Average difference of noise level (measurement in dB) in CNG and Diesel buses

DJ685 and DJ686 - powered by diesel

DJ204 and DJ203 - powered by Gas (C2.3-1&2)

C2.3-1	Average difference of noise level (measurement in dB)			
Number of bus	RPM	Driver cabine	Second door	Over engine
DJ686 OIL DJ204 CNG	Inside the bus			
	500	-0,7	+1,7	-1
	2000	+4	-2,7	+0,7
	2500	+2	+0,7	+0,7
DJ686 OIL DJ204 CNG	Out of bus			
	500	-8	-7	-6
	2000	-16	-16	-16
	2500	-10	-8	-9

C2.3-2	Average difference of noise level (measurement in dB)			
Number of bus	RPM	Driver cabine	Second door	Over engine
DJ685 OIL DJ203 CNG	Inside the bus			
	500	-2,7	0	-0,7
	2000	+3,3	+3	+0,7
	2500	+2,7	-0,7	+1
DJ685 OIL DJ203 CNG	Out of bus			
	500	-7	-6	-5
	2000	-14	-14	-16
	2500	-11	-11	-11

Main conclusions regarding noise measurement:

- Generally, higher noise intensity inside the bus was observed for CNG vehicles. However, when engine was running with a speed of low RPM there were more silently inside the CNG bus.
- CNG bus meets requirements of permissive noise level inside the vehicle.
- The acoustic isolations that separate engine side from passenger's space have an influence on the noise permeation but were not compared due to technical difficulties.

C2.4 Transport

The comparison of average monthly mileage of two same model buses (Jelcz M121m/4CNG) which powered by Gas and Diesel can be seen in following table. (C2.4-1)

C2.4-1 AVERAGE MONTHLY BUS MILEAGE FOR CNG AND DIESEL VEHICLES			
Month	Average monthly bus run Bus type: Jelcz M121M/4CNG [km/vehicle/month]	Average monthly bus run Bus type: Jelcz M121MB/V [km/vehicle/month]	Indicator [%]
Year 2007			
January	4118	8545,5	48,2
February	6527,2	7678	85,0
March	6630,8	8392,6	79,0
April	6826	8382,5	81,1
May	7056,4	8485	83,2

June	7290,2	8226,3	88,6
July	6806,0	8178,7	83,2
August	7759,8	8062,1	96,2
September	6594,2	8036,8	82,1
October	4934,0	8464,8	58,3
November	3390,0	8598,3	39,4
December	6943,8	8899,5	78,0
Year 2008			
January	7013,8	9107,6	77,0
February	7369,0	8089,7	91,1
March	8401,8	8524,3	98,6
April	8463,6	8107,1	104,4
May	7013,8	9107,6	77,0

The “Effective bus exploitation” indicator describes the operational effectiveness of the CNG and Diesel buses exploited in similar technical and operational conditions. The measurement is made by a registration of transportation services effectively performed by CNG buses and similar diesel vehicles, in the time unit (month). CNG buses like other types of vehicles owned by MPK perform transportation tasks which are planned according to the public service contract, where payment is based on the vehicle/km unit.

Compared to CNG buses, the effective exploitation (represented by %) of Diesel vehicles was better at the beginning of research period and during the time when the gas filling station was out of order (i.e. October 2007 – November 2007). The satisfactory level of effective bus exploitation for both types was reached after one year and is much higher than the average mileage for the whole fleet in Krakow.

C2.5 Society

Survey aimed to measure the public awareness of first CNG buses operating on PT lines and citizens’ opinion about ecological bus fleet.

Sample size: 1320 households in Krakow (Interviewers interviewed only persons who use to make most important decisions in a particular household)

Sampling method: random stratified selection spanning 18 districts of Krakow (*random walking method*)

Research method: personal interviews based on questionnaire

The survey was conducted during: **09.06-.5.07.2007**.

According to survey results 54% of respondent haven’t heard about CNG buses in PT fleet. But nearly 63% (table C2.5-2) of respondents admitted they would like to have ecological PT buses in Krakow. 26% of interviewees do not care about ecological vehicles.

C2.5-1 Have you heard about first CNG buses in PT fleet in Krakow?		2007	
		Amount	%
Yes	594	45,6%	
No	709	54,4%	

Total	1303	100%
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C2.5-2 <i>Would you like buses powered by ecological fuel (CNG, ethanol, etc) and with lower emission of polluting substances to operate on PT lines in Krakow?</i>	2007	
	Amount	%
Yes	818	62,6%
No matter	345	26,4%
No	143	10,9%
Total	1306	100%

C3 Achievement of quantifiable targets

No.	Target	Rating
1	Decreasing of operating costs	*
2	Improvement of the overall image of the PT services;	**
3	Increase of PT passenger-km in CIVITAS area using clean vehicles	**
4		
NA = Not Assessed * = Not achieved ** = Achieved in full *** = Exceeded		

C4 Up-scaling of results

On one hand up-scaling of the measure could base on complete fleet exchange or at least in one depot, which for example operate the Krakow Inner City, to decrease the air pollution. Filling station for the depot should be constructed, to minimize nuisance with this issue. Also the image of the company as a "clean" operator would rise, as major part of city visitors spent time in the City Centre.

But on the other hand the exploitation of a significant amount of CNG buses now, in existing technical and organisational conditions, is risky. Any problems with external gas filling station (as they appeared in autumn 2007) would cause huge difficulties in realisation of planned PT tasks which consequently would result in execution of contractual forfeits stipulated in the public service contract between MPK and Municipality

C5 Appraisal of evaluation approach

Indicators chosen to evaluate the measure were selected in appropriate way and exactly fit the needs.

C6 Summary of evaluation results

- Basing on the desk research and exploitation tests: one-year test on 5 CNG buses, short test on hybrid and ethanol-driven vehicles one can say that nowadays there are different ways and solutions that enable to get low emission levels. A satisfactory environmental results can be reached by implementation of high quality traditional fuels, bio-flues and their mixture or advanced construction of engines and propulsion systems.
- The use of gas fuel in spark-ignition engines results in increase of energy consumption per mileage unit. The decision to conduct exploitation tests on 5 CNG

buses required significant investment whereas the real fuel cost savings were much lower than expected. The CNG-driven bus is 20-25% more expensive than similar diesel vehicle. And even lower CNG fuel price cannot compensate high purchase and transition costs and make the investment cost-effective.

- The decision on introduction of CNG technology always depends on local conditions and factors. Basing on the Krakow experience one can recommend the CNG buses only if:
 - an operator has own gas filling station of good capacity,
 - maintenance facilities are proper to serve CNG vehicles with respect to all safety and security rules,
 - terms of contract with CNG provider ensure seamless fuel delivery at good price.Otherwise external financial and political (governmental) support is strongly required.
- Taking into account results of one-year tests of CNG-driven buses, outcomes of comparative analysis of both vehicle types - CNG and diesel - and their prices MPK's specialists came to the conclusion that optimal solution when speaking about the transition towards clean fleet would be substitution of old generation vehicles for new diesel ones constructed in accordance with the EURO V standard.
- The exploitation test on a SOLARIS hybrid bus conducted in July 2008 proved a fuel consumption decrease by 15 % in comparison to similar vehicle with traditional propulsion system. Furthermore, the percentage of fuel savings depends on a bus route, number of stops and driver's skills. A proportional decrease in pollutants emission was also observed. noise level was much lower than that emitted by a conventional diesel bus, and could have been observed even without making any measurement. And finally, a start of the hybrid bus exploitation did not required any additional investment in a workshop infrastructure (as it was necessary in case of CNG vehicles).
- The results of research on ethanol-driven bus were satisfactory. However the implementation of this technology requires some adjustments of the fueling-up equipment as well as a guarantee of the fuel delivery. Moreover, taking into account ethanol-fuel price and tax level it is supposed that the exploitation costs will not be lower than those of diesel vehicles.

D Lessons learned

D1 Barriers and drivers please complete

D1.1 Barriers

- **Financial:** The project of introducing 100 CNG buses within 5 years are very ambitious and costs more than 30 million Euro. MPK Public Transport Company is not able to finance via its own budget. It is necessary to apply for other sources of financing: Cohesion Fund of EU, National Fund of Environmental Protection, and Ecological Fund. MPK can spend 3 million Euro a year in order to finance the investment. A lack or delay of external financial support will postpone or suspend the project realisation.
- **Legal:** The state owned earth gas supplying company PGNiG (natural monopoly) started a restructuring process (separation between production and distribution activities). The new law regulation on earth gas sector binding since 2005 and was supposed to adjust Polish sector regulation to the EU standards (regulations). But noticeable practical changes require more time.

- **Organizational:** For the positive cost calculation of the project and ability to provide reliable CNG buses services it is necessary to (sign) have long-term contract with the CNG supplier. Until the end of the restructuring process of state owned PGNiG company there is not enough competitors which would enter the supply tender.
- **Technical:** The high capacity CNG filling installation (infrastructure) should be built before the new buses are delivered. This in turn, requires strong coordination (competence and responsibilities allocation) among the infrastructure owner, constructing company and CNG supplier. The whole process can take more than 2 years.

D1.2 Drivers

- Good cooperation between MPK and the provider of CNG vehicles before delivery and during whole testing period.
- Exchange of experiences with PT operators from other Polish cities, where buses of this type have been exploited for several years.
- Involvement of MPK's staff in project realization and willingness to test new technical solutions.

D2 Participation of stakeholders

- **Miejskie Przedsiębiorstwo Kumunikacyjne SA (MPK, public transport operator)** — purchased and tested 5 CNG buses
- **Gazownia Krakowska (PGNiG - CNG fuel provider)** – signed the contract with MPK for delivery of the gas fuel
- **Polskie Autobusy Sp. z o.o. (CNG bus provider)** – the company awarded in result of the public procurement
- **Local politicians** – involved in the official presentation of the bus JelczM121CNG in November 2006
- **Inhabitants of Krakow** – users of the CNG buses, also interviewed about their opinions of the CNG vehicles during the research conducted on the sample of households in 2006 and 2007.
- **Local media** - involved in the information campaign concerning CNG buses and activities aimed at transition towards clean fleet
- **Producers of clean ecological buses (Solaris, Scania, Ecobus – Mercedes)** – delivered their clean buses for the exhibition of modern and ecological vehicles organized by MPK (at MPK's facilities) in July 2008.

D3 Recommendations

Exploitation of CNG buses in Krakow lasts second year. CNG system was installed in JELCZ M121 equipped with engine MAN E 2866 DUH03. MPK has already similar buses equipped with diesel engine (Mercedes). Jelcz is well known construction among PT operators in Poland, with proven technical solutions which guarantee carefree exploitation for 12 years. CNG system is also well designed and verified by many operators in Poland. As a CNG powered engine users, we can recommend this system for implementation in city buses.

Moreover, we can positively assess automatic transmission VOITH D854.3E, as a equipment proven within implemented measure.

Our recommendation for CNG system is determined by possibility of easy access to refilling station and technical base for this type of engines. It is also important to have the contract for CNG supply, which ensure cost effectiveness of investment.

We do not recommend CNG for PT companies operating on open market (as a financial independent companies), without external funds.

D4 Future activities relating to the measure

MPK in Krakow has 496 buses and only 9% of them do not fulfill Euro standards. They will be withdrawn till the end 2008 or at the beginning of 2009. In rolling stock: 7% of buses fulfill Euro-I, 50% fulfill Euro II, 33% fulfill Euro III and 1% fulfill Euro IV standards. In 2008 there will be introduced 55 new buses with Euro V engines (it is standard comparable with CNG buses). Taking into consideration difference in prices of diesel and CNG buses, the optimal solution is to withdraw buses which do not fulfill lower Euro norms, and exchange them into modern buses, equipped with Euro V engines using diesel fuel. Implementation of CNG engines should depend on external, additional funds, based on national regulations, and which do not affect PT companies budgets.