Measure title: 5.4 L Implementation and large-scale deployment of bio-diesel and CNG fleets in Ljubljana

City: **Ljubljana** *Project:* **MOBILIS** *Measure number:* **5.4L**

A Introduction

A1 Objectives

The primary objectives were:

- to introduce pure, i.e. 100 % biodiesel (B100), into PT fleet in Ljubljana;
- to improve quality of the existing production of biodiesel at Pinus;
- to establish cost-effective production of biodiesel at small farms in Slovenia.

A2 Description

There are three main components of this measure:

a) Large scale deployment of biodiesel in LPP buses (EURO 0) in Ljubljana. In the first step, testing of two buses has been performed starting in February 2006. Additional 18 buses were under testing since August 2006. It was envisaged that biodiesel will be deployed in 100 buses if results of 20 buses testing provides positive results. However, due to poor operational results and higher financial demands than initially expected the LPP decided not to use biodiesel in 100 existing (old) buses but rather to extend testing of 20 buses and to perform additional measurements of emissions of pollutants.

b) Improvement of the quality of biodiesel produced at Pinus. The target was to reduce content of water, free fatty acids and phosphorus in the raw material.

c) Production of biodiesel at small farms. It was about to demonstrate efficient production of oil rape in tonnes per hectare and year (t/ha*a) at testing polygons on two locations in Slovenia, and to develop equipment for efficient pressing of rape seeds (production of crude oil and cake per tonne of seed) by farmers (non-professionals in terms of machinery and engineering).

B Measure implementation

B1 Innovative aspects

Innovative aspects relate to component c) of the measure, i.e. production of biodiesel at small farms.

The innovative aspects are:

- New conceptual approach. It is about cost-effective production of crude oil usable for biodiesel production or direct application as a farm machinery fuel, and usage of cake after pressing the seed as fodder for cattle. Successful implementation of the approach, covering the whole chain from production to use, provides additional income to farmers. The model of such cost-effective production is given in Fig.1.

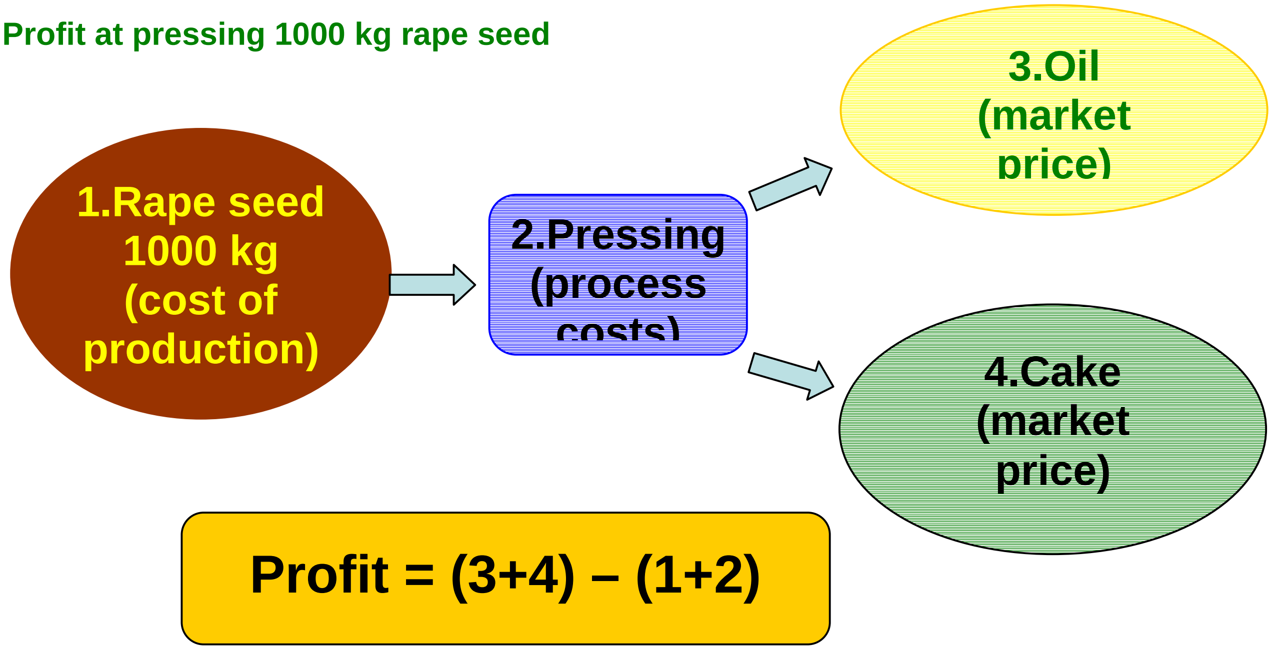

Figure 1: Schematic representation of the cost-effectiveness model

- Whole chain from production to use. It is important to stress that by implementing the approach the farmers recognise influential parameters and their specific contribution to the final success of self-producing of biodiesel and its economic, as well as environmental benefit.
- Targeting specific user groups. The measure contributes to higher independence and self-sustainability of farmers in terms of energy consumption, economy of farming, quality fodder self-production, maintaining productivity potential of soil, etc.
- Other – contribution to applicative research and development in the field of agriculture; improvement of self-esteem of the farmers; agriculture and environment.

Comment: If the scope of production of biodiesel at small farms significantly extends farmers' needs due to its positive cost-benefit balance, a surplus, which could (should) be offered at the open market could influence (i.e. lower) price of biodiesel. Such a potential, or rather a recognition, could mobilise users of biodiesel (e.g. the LPP PT fleet) to buy biodiesel at local farmers before price at open market drops, while the politicians could support general effort to grow a sustainable local supply. This reasoning could be seen as an additional innovative aspect which may be a subject of later, in-depth research.

B2 Situation before CIVITAS

Generally, there was poor awareness in Slovenia before 2005 about benefits of biodiesel (alternative fuels) in comparison to mineral diesel (D2). Comparative evaluations were closed in a academic/scientific area, popularisation of issues was poor even by NGOs. Use of public transportation was decreasing, same the quality of PT services. Efforts to improve the situation have been made mostly on political level (after joining the EU), while in day-by day life citizens were behaving without specific responsibility regarding energy use and transportation related environmental, health and other issues. Urban transport and health were not subjects of discussion neither in terms of modality share, nor as consideration of the quality of life. Farmers were left alone with their own potential for innovation and understanding of energy efficiency, fuel consumption and economy, while small (garage) producers of biodiesel were producing the fuel for themselves only and were not much concerned about its quality.

CIVITAS Mobilis brought considerable change in understanding of transportation issues. Alternative fuels usage is increasing (present level is around 5%), PT is more popular, cycling is in extension, farmers are encouraged to produce oil rape, crude oil and fodder.

B3 Actual implementation of the measure

The measure was implemented in the following stages:

- **Testing 2 buses by using pure biodiesel - B100** *(February 2006 – August 2006) – two buses running on B100 were compared with two buses running on D2. The following information was collected during the testing period for comparative purposes:*
  - *installation and maintenance of a new biodiesel fuelling station with a storage facility (investment, construction and operational costs)*
  - *initial servicing (bus preparation) for B100 usage (recording of dates, mileage, costs of servicing)*
  - *mileage of each bus; each bus has its specific code number*
  - *fuelling (dates, amounts, costs)*
  - *maintenance and servicing (dates, material used, spent working hours, material costs)*
  - *emission of soot (PM) while a bus was in a workshop*

  Based on data collected a comparison was made between a bus running on B100 and a bus running on D2 in terms of specific fuel consumption (per 100 km), energy efficiency, operational costs, costs for maintenance and servicing and soot emission. Amortization was not considered.
- **Testing 20 buses by using B100** *(August 2006 - ongoing) – Additional 18 buses are running on B100 except in winter time when temperature is below -7 °C (a problem of solids/crystallization of parafine in the fuel). The same measurement and data collection has been applied as for two buses stated above.*
- **Quality improvement of biodiesel at Pinus** instead of biodiesel production in Ljubljana *(February 2007 – ongoing)* **-** *The main achievements are: the separator start up was in April 2007, optimization of the glycerol and lecithin quality, optimisation of a two step de-gumming process in order to obtain oil with phosphorus content of 15 ppm, reduction of FFA (free fatty acids) content in oils, optimized parameters for washing of oil with glycerol, etc. Training on this subject was successfully accomplished.*

  In terms of dropping the idea of producing biodiesel in Ljubljana and related withdrawal of Teol and Sava from the project it is needed to say that the results of Strategic Environmental Assessment (SEA) were presented at a round table on the 18th April 2007. It focused on an overview of SWOT and feasibility analysis in relation to the planned production of biodiesel in TEOL. One of the key outcomes of the SEA was that production of biodiesel in TEOL is not appropriate due to land-use and the urban situation and development in the city. Accordingly, the measure 5.4L has been changed, i.e. Pinus joined the project instead of Teol and Sava with the proposal to improve its biodiesel production quality.
- **Oil rape production, seeds pressing, biodiesel production at small farms** *(February 2005 – ongoing) – the implementation was according to the plan (see components and indicators in Table 1 below)*

Table 1: Indicators describing biodiesel production at small farms – whole chain context

Key component	Indicators (expected values)
Yield of oil rape	The minimum expected yield is 3 t/ha*a. Eighteen sorts have been tested on two locations in Slovenia. Depending on climate and soil characteristics the best results in terms of yield and production costs are the basis for further assessment.
Pressing efficiency in terms of energy consumption	Recording of electric energy consumption for continuous pressing of seeds in small units is a basis for the evaluation of pressing efficiency. Comparative assessment with industrial oil extraction with solvents, as well as industrial mechanical pressing, is a basis for assessing efficiency.
Pressing efficiency in tonnes of crude oil produced per tonne of seed	The minimum expected efficiency is 0.3 t/t, the maximum expected efficiency is 0.4 t/t.
Amount of cake per tonne of seed	The expected amount is 0.6 t/t including up to 0.15 t of oil content. Higher oil content is not recommended for fodder due to oil instability reasons during storage. Digestion testing results in cattle is a basis for final assessment.
Additional key component: Esterification of crude oil – quality of biodiesel produced (esterification is a chemical reaction between an acid and an alcohol forming an ester; in the case of biodiesel it is a reaction between fatty acid in the rape seed oil and methanol)	Two sets of biodiesel quality tests are needed: one is regarding characteristics of biodiesel produced at farms in terms of regulation (EU standard), and second is its usefulness as a fuel for tractors/machinery. In terms of quality standardisation the energy content, density, viscosity and flammability are checked, while in terms of its utility the power of tractor engine and fuel consumption are checked.

B4 Deviations from the original plan

The deviations from the original plan comprised:

- **No biodiesel production in Teol Ljubljana** – Teol and Sava withdrawed from the Mobilis project in 2007 (no biodiesel production in Ljubljana is to be established). Pinus joined the project instead of Teol and Sava. Production of biodiesel is already available at this company (its location is approx. 100 km NE from Ljubljana); the primary objective of its participation is to ensure adequate quality of the product. In line, in terms of evaluation the first results of the Strategic Environmental Assessment (SEA) were presented at a round table on the 18th April 2007. It contained an overview of goals and SWOT analysis in relation to the implementing of the CIVITAS MOBILIS measures in Ljubljana. Special attention was given to the production of biodiesel in TEOL. Coherently with the results of SEA, the measure was changed significantly. One of the outcomes of the SEA is that production of biodiesel in TEOL is not appropriate due to land-use and the urban situation and development in the city.

- **Biodiesel will not be deployed on 100 LPP buses** – Higher costs than expected for buses preparation and maintenance during operation (doubled frequency of servising is needed), fuel costs (10 % fuel consumption increase in comparison to situation before; price of B100 and D2 are almost identical), as well as buses inoperability in winter conditions at temperatures below -7 °C are the reasons that LPP can not afford deployment of B100 on 100 buses.

B5 Inter-relationships with other measures

The measure is related to other measures as follows:

- **11.8.L** Set-up of information points and campaign on clean vehicles and alternative fuels in Ljubljana. The measure builds on the fact that campaigning is a strong tool when one wants to have impact on behavioural change. The measure is promoting alternative fuels and sustainable mobility by training personnel in the city administration and by developing info-points for general public and tourists.

  During the implementation of 11.8 it has been recognised that using existing touristic info-points also for informing the public about clean vehicles and alternative fuels was not a good idea. Detailed explanation is in the result sheet for 11.8L.

C Evaluation – methodology and results

C1 Measurement methodology

C1.1 Impacts and Indicators

Table 2: A list of evaluation indicators.

No.	Impact	Indicator (units)	Frequency/period of measurement or data collection
1	**Environment - emissions**	**CO (ppm)**	**Measurements in the FME laboratory in the period 2005-2006**
		NOx (ppm)	
		PM (ppm)/soot (Bosch)	
		HC (ppm)	
		Soot (Bosch) from buses at LPP workshop (mg/m^3)	**Measurements at the events of bus servicing (at each 20.000 km); in 2006 and 2007 two buses, since 2007 twenty buses**
2	**Energy – fuel consumption**	**Bus fuel efficiency (L/100 km)**	**Calculations in 2006, 2007, 2008**
3	**Society - awareness**	**Awareness level**	**Twice during the project; questionnaires were aimed at bus drivers and bus (PT) users**
4	**Economy - operating costs**	**Operating costs of buses running on B100 (€/10000 km)**	**Calculations in 2006, 2007, 2008**
5	**Economy - operating costs**	**Cost-effectiveness of biodiesel production at small farms (€/tonne)**	**Calculations in 2006 and 2008**

Detailed description of the indicator methodologies:

- **Indicator 1** (*Emissions of CO, NOx, PM, HC*) – Emissions of pollutants were measured in a laboratory; a bus engine was on the brake during measurements – see Figure 2.

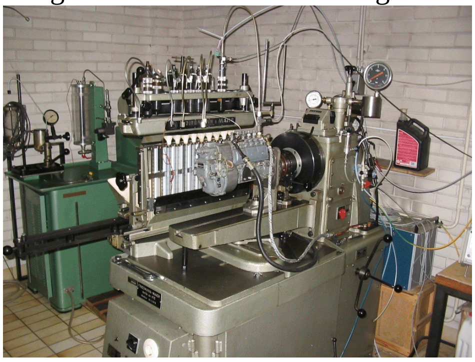

Figure 2: Testing and emission measurement facility at the Faculty of Mechanical Engineering in Maribor

The concept of measurements was collection and examination of exhaust gases at different engine power (n [rpm]) and fuel mix (B0 – B100 mixed with D2). The indicator enables assessments in terms of environmental benefits of using B100 in comparison to D2. Expected benefits are lower emissions and consequently improved air quality in the city.

- **Indicator 2** (*Bus fuel efficiency*) – Recording of the fuel consumption and mileage of each tested PT bus is a basis for comparative assessment between B100 and D2. Recording was conducted by the LPP.
- **Indicator 3** (*Awareness level*) – Questionnaires/interviews were planned to be applied three times during the project. The foci of the surveys are elements which describe understanding and attitudes (perceptions) of the bus drivers and PT users regarding urban transportation issues and alternative fuels. Differences in answers during time were expected to be a basis for evaluating trends in the awareness level. By mid 2008 two surveys have been performed. Next is planned for the end of 2008/beginning of 2009.
- **Indicator 4** (*Operating costs of buses running on B100*) – Operating costs include: investment and maintenance of the new biodiesel fuel station at the LPP, preparation of each bus (this is the first service just before operation/testing starts), regular servicing and maintenance costs during operation (work + material), fuel costs. Recording of costs was conducted by the LPP.
- **Indicator 5** (*Cost-effectiveness of biodiesel production at small farms*) – the approach is presented in Figure 1. Data on particular cost item were collected by the Agricultural Institute of Slovenia (AIS).

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C1.2 Establishing a baseline

Participation of Ljubljana (Slovenia) in the CIVITAS Mobilis project, and particularly design and implementation of the measure 5.4.L, was the first response to European and national policy of large introducing alternative fuels (biodiesel) in the country. The idea was to run 100 PT buses in Ljubljana (Euro 0) on biodiesel. Before starting such a large-scale deployment of biodiesel the testing of 20 buses in two stages was envisaged. The baseline situation was as follows:

- no biodiesel use in PT fleet in Ljubljana
- no industry level of the biodiesel production in the country was available
- farmers were not motivated to produce oil rape simultaneously applying crop rotation

The situation could be briefly described by means of the indicators as shown in Table 3:

Table 3: Indicator based description of the baseline situation

No.	Impact	Indicator	Comments
1	**Environment - emissions**	**CO, NOx, PM, HC**	**There was general awareness of the impact of transport on the environmental/air quality, however, benefits of substituting D2 by biodiesel and its contribution specifically to the improvement of the situation in Ljubljana were not clear. The problem of modality split (low usage of PT in the city, low level of cycling), issues with congestions in the city centre, lack of parking places and air pollution have been recognised.**
2	**Energy – fuel consumption**	**Bus fuel efficiency**	**Since there was no operational alternative for D2 in PT buses the problem was not recognised in a clear way.**
3	**Society - awareness**	**Awareness level**	**Only members of the NGOs and cyclists were calling for additional awareness**
4	**Economy - operating costs**	**Operating costs of buses running on B100**	**Comparative assessment with D2 is the basis for decision-making related to the large scale deployment of biodiesel in PT fleet.**
5	**Economy - operating costs**	**Cost-effectiveness of biodiesel production at small farms**	**Presently, farmers are not producers of crude oil or biodiesel from oil rape, however, additional income (or savings) in this context are appreciated.**

C1.3 Building the business-as-usual scenario

In terms of the three components of the measure the business-as-usual (BAU) scenario could be described as follows – see Table 4.

Table 4: Description of the BAU scenario

Component	Assumptions	BAU scenario
Large scale deployment of biodiesel in LPP buses (EURO 0) in Ljubljana	Assumptions and expectations behind testing 20 buses and deployment of biodiesel in 100 buses were that this will clarify how PT fleet will be renovated and which new vehicles will be purchased in the future. It was a question of purchasing 100 new buses (in two or three steps), at least EURO III. In the 90-ies there was a test performed in Ljubljana of using CNG as a bus fuel. ***If measure 5.4.L was not implemented the assumption is that new PT fleet will run on D2. Traffic increase in 4 years is up to 10%, same applies to emissions from buses using D2 as fuel.***	BAU scenario means that new PT fleet will use mineral diesel as a fuel. Introduction of alternative fuels will probably reach the level of 5% which is an ordinary mix throughout the country provided by national fuel suppliers. No environmental benefits in terms of air quality improvement are expected in the city, but rather further environmental degradation. Also, in terms of modal split no improvements are expected.
Improvement of the quality of biodiesel produced at Pinus	Pinus is relatively small producer of biodiesel (around 8.000 tonnes per year). The managers try to achieve high quality of the product however both process parameters and analytical control (presently used analytical methods and laboratory capabilities) need improvements. ***If measure 5.4.L was not implemented the assumption is that Pinus is not capable (can not afford) investments in technology innovations and own laboratory capabilities.***	Biodiesel produced at Pinus will not meet all quality standards defined by European regulation (EN 14214)
Production of biodiesel at small farms	***If measure 5.4.L was not implemented the assumption is that farmers will remain economically non-motivated to start producing oil rape for crude oil or biodiesel production as a fuel and cake as fodder.***	The problem of inefficient agricultural production in Slovenia remains, with poor crop rotation, increase of fodder import, etc.

C2 Measure results

C2.1 Economy and quality of products

Testing of buses

In terms of economy testing of buses showed higher costs than initially expected. The cost categories comprise of the following:

- Investment into the biodiesel storage facility and fuelling station at the LPP
- Regular price of biodiesel; for certain period of time the price was higher than for D2. Now, the price of biodiesel is bit lower than of D2, but not significantly. Therefore, LPP was applying biodiesel for testing purposes only and was not motivated to purchase more expensive fuel for regular operation.
- Change of fuel filters. This change is significantly more frequent if using B100.
- Servicing. When using B100 service intervals are shorter (frequency is increased by a factor of 2 – every 20 000 km).
- Preparation of engines before testing the buses. This is additional service operation.

Average servicing costs for a bus running on B100 during testing period was around 3900 Euro, while for a reference bus (using D2) was around 3400 Euro, taking into account operating hours and actual mileage of the buses. Note that the frequency of servicing buses using B100 was higher by a factor of 2 (shaded boxes in Table 5). A summary in Table 5 shows costs for running the 20 B100 buses and the 2 D2 buses.

Table 5: Costs for running buses on B100 and D2 - summary

Category	Operational costs			Servicing costs		
	Fuel consumption (L)	Operating hours (h)	Mileage (km)	# of working hours	Cost of work (€)	Material (€)
twenty B100 buses	603571	87397	1269411	5742	129417	78255
average B100 bus	30179	4370	63471	287*2	6471*2	3913*2
two D2 buses	77063	12707	177972	849	22114	6878
average D2 bus	38532	6354	88986	425	11057	3439

Production of oil rape

Average figures of cost-effective production of oil rape and crude oil with cake after pressing rape seeds are given in Figure 3.

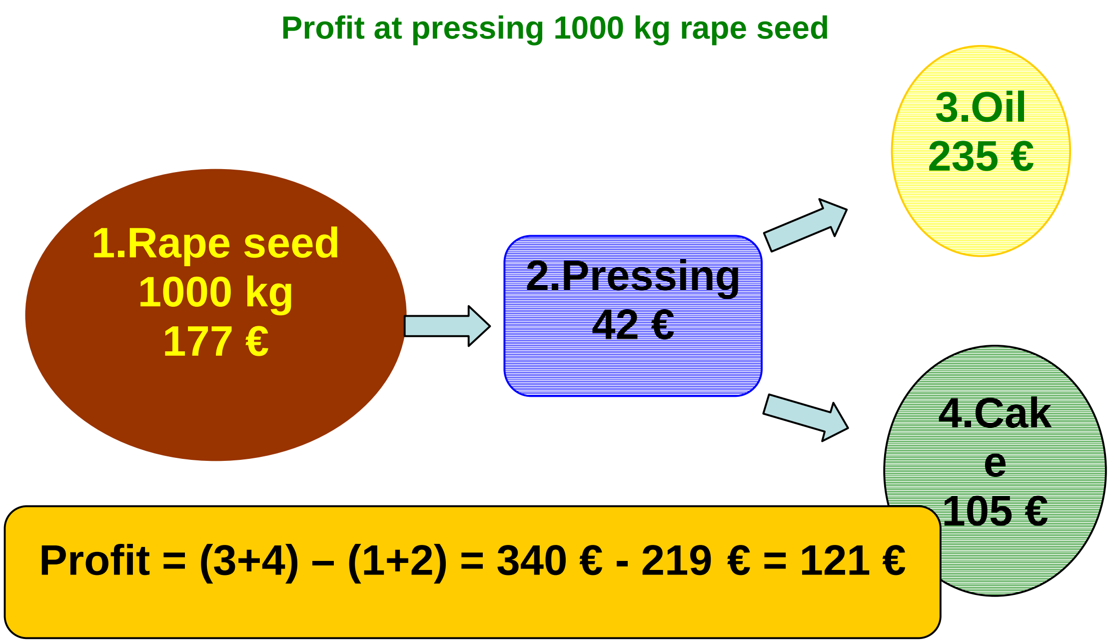

Figure 3: Average figures of cost-effective production and processing of 1 tonne of rape seeds (based on prices in the period 2005-2007 in Slovenia). Rape seed production costs on tested locations can vary up to 30%, cost of seed pressing is relatively stable (variations up to 5 %), while market prices for oil is stable, also the price of cake. Consequently, the output variability (uncertainty) is up to 20%, and similarly the expected profit in the testing conditions.

The quality of biodiesel produced at small farm is given in Tables 6, 7 and 8.

Table 6: Quality of biodiesel produced at small farms

Parameter	Unit	Analytical method	Standard EN 14214	B100
Density at 15°C	kg/m^3	SIST EN ISO 12185	860 – 900	890,9
Kinematic viscosity at 40 °C	mm^2/s	SIST EN ISO 3104	3,5 – 5,0	10,12
Flamability	°C	SIST EN 2719	above 101	154
Impurities	mg/kg	SIST EN 12662	max. 24	28
Water content	mg/kg	SIST EN ISO 12937	max. 500	> 1000
Combustion energy (heat)	J/g	mod. DIN 51900		40172
Phosphorus content	mg/kg	PML 07.30		< 5

Comment to Table 6: The main disadvantage of biodiesel produced at small farms is its higher viscosity and water content compared to standard

Table 7: Comparative assessment of fuels in tractor testing (biodiesel produced at small farms)

Fuel	D2	B100	B50	B20
Density [kg/m^3] (SIST EN ISO 12185)	850,0	890,9	870,5	858,2
Combustion energy [MJ/kg] (mod. DIN 51900)	45,8	40,2	42,9	44,6
Relative difference in combustion energy relative to D2 [%]		-12,3	-6,3	-2,6

Comment to Table 7: Lower combustion energy for about 12 % compared to mineral diesel is close to expected 10% reduction.

Table 8: The improved quality of biodiesel produced at Pinus

Indicator	Unit	Standard		Results	
		min.	max.	Crude oil	Processed oil
FAME	% m/m	96,5	-	96,9	97,4
C18:3	% m/m	-	12,0	7,4	7,5
Density (20^{o}C)	g/ml	0,8600	0,9000	0,8850	0,8848
Water content	mg/kg	-	500	320	142
Impurities	mg/kg	-	24	27	12
Oxisdation stability (110^{o}C)	h	6,0	-	5,7	6,1
Acidity	mg KOH/g	-	0,50	0,39	0,26
Iodine number	g J_2/100 g	-	120	129	128
Methanol	% m/m	-	0,20	0,08	0,05
Monoglycerids	% m/m	-	0,80	0,77	0,74
Diglycerids	% m/m	-	0,20	0,18	0,17
Triglycerids	% m/m	-	0,20	0,04	0,03
Free glycerol	% m/m	-	0,02	0,01	0,01
Total glycerol	% m/m	-	0,25	0,24	0,23
Na + K	mg/kg	-	5,0	6,2	6,4
Ca + Mg	mg/kg	-	5,0	3,0	3,0
Phosphorus	mg/kg	-	10,0	12,3	2,1
CFPP	^{o}C	-	-	- 6	-6
Poly triglycerids	% m/m	-	-	0,05	0,04

Comment to Table 7: Pinus obviously succeeded in lowering water content and phosphorus in raw material by improving the process. This has been achieved after intensive testing of change of a number of process parameters. The testing lasted for about two years; performed adaptations of the process parameters did not require increase in maintenance costs since the changes were relatively quick (a couple of weeks or a month each).

In comparative terms biodiesel produced at small farms is of lower quality than biodiesel produced at Pinus. This is understandable due to lack of experience and lower technology level at the experimental farm (e.g. esterification process with improvised mixing, separation of water and biodiesel by means of gravity only, etc.) in comparison to technology level and staff competence at Pinus. However, since biodiesel produced at the farm does not meet a water content standard, the viscosity standard and general impurity standard – all three are not difficult to meet - there is a reasonable probability that these standards will be met if adequate equipment is applied (e.g. process vessels with mixing) together with previous focused training of the farmers.

C2.2 Energy

Bus fuel efficiency

Summary of data collected during testing of buses is in Table 9. Table 10 provides additional information for testing periods specifically.

Table 9: Summary on bus fuel efficiency

Category	Average specific fuel consumption (L/100 km)	Average power (KW)	Difference (%)
B100 bus	47.33	136	Fuel consumption increase: 7,5 %
D2 bus	44.04	150	Engine power decrease: 6%

Table 10: Specific information on testing periods, number of kilometres, fuel consumption, additional costs for B100

Testing period	Fuel consumption increase (%)	Total km B100	Total km D2	Total fuel B100 (L)	Total fuel D2 (L)	Additional fuel cost for B100
21.2. - 21.7.2006	107,04	50.407	1.490.173	24.338	672.194	5.584
22.7. - 1.12.2006	108,26	404.972	851.054	175.461	340.605	39.614
2.12.06 - 31.1.2007	116,50	20.486	560.631	7.083	166.387	1.786
Year 1:	106,99	475.865	2.901.858	206.882	1.179.186	46.984
1.2. - 28.2.2007	103,85	7.720	261.255	3.745	122.047	714
1.3. - 30.11.2007	105,23	814.433	1.552.856	389.582	705.855	85.648
1.12.07 - 31.1.2008	104,04	17.589	557.421	9.167	279.209	1.479
Year 2:	102,67	839.742	2.371.532	402.493	1.107.110	87.842
1.2. - 28.2.2008	102,39	7.954	253.944	3.933	122.638	846
1.3. - 30.11.2008	106,36	777.812	1.251.980	381.205	576.878	97.389
Year 3:	105,52	785.766	1.505.924	385.138	699.516	98.235
Total in three years	**107,46**	**2.101.373**	**6.779.314**	**994.512**	**2.985.813**	**233.060**

Tractor/farm machinery efficiency

Results of testing biodiesel produced at small farm on tractor Agromehanika AGT are given in Figure 4.

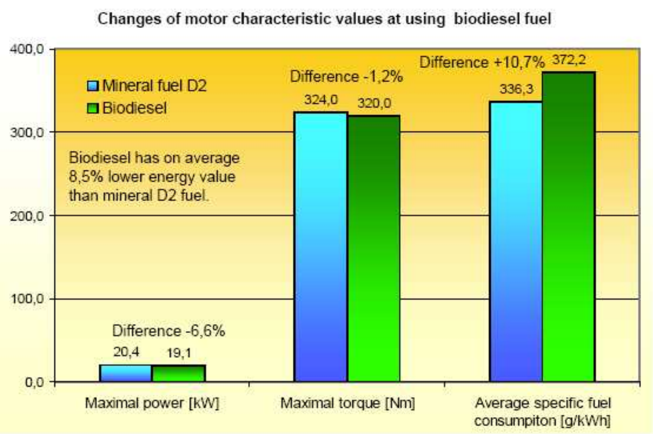

Figure 4: Tractor engine performance using D2 or B100

C2.3 Environment

Emissions of CO, NOx, PM/soot, HC

Summary of measurement results performed at the FME laboratory are presented in Figures 5, 6 and 7.

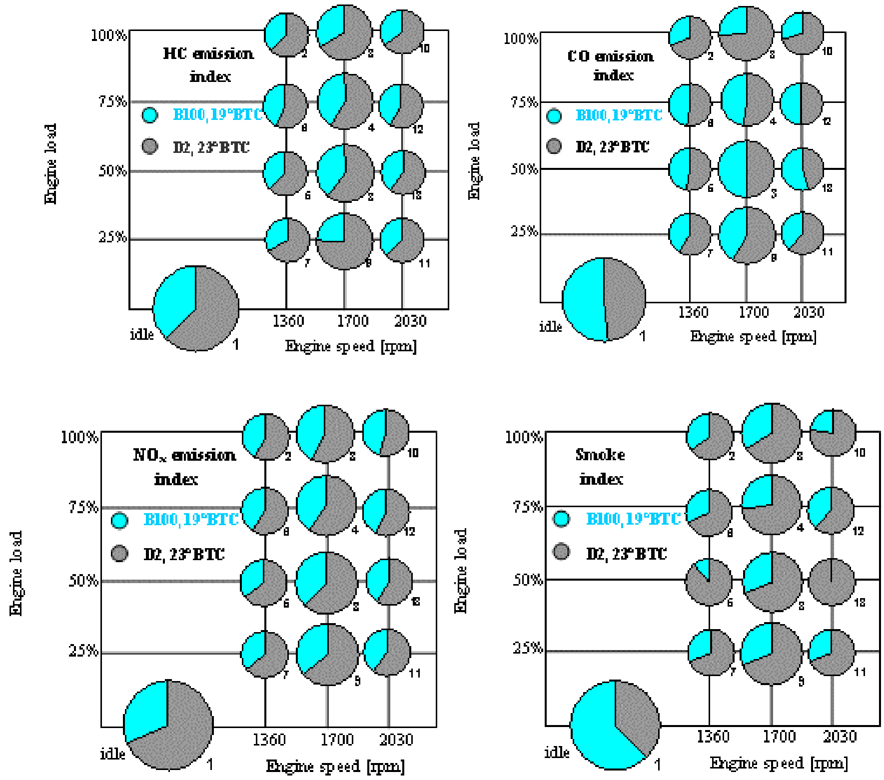

Figure 5: Emission indices for different engine loads and engine speeds on brake (rpm) measured and calculated according to the European ESC test (blue area in the circles shows B100 emissions indices, grey area shows D2 emission indices). The results show that indices of HC and NOx, are consistently higher for D2 than B100 at all engine speeds and loads in all 13 points of the test; higher CO indices for B100 have been recognised in three points of the test; smoke indices for B100 are higher only in one point, i.e. when the engine is under no load (idle).

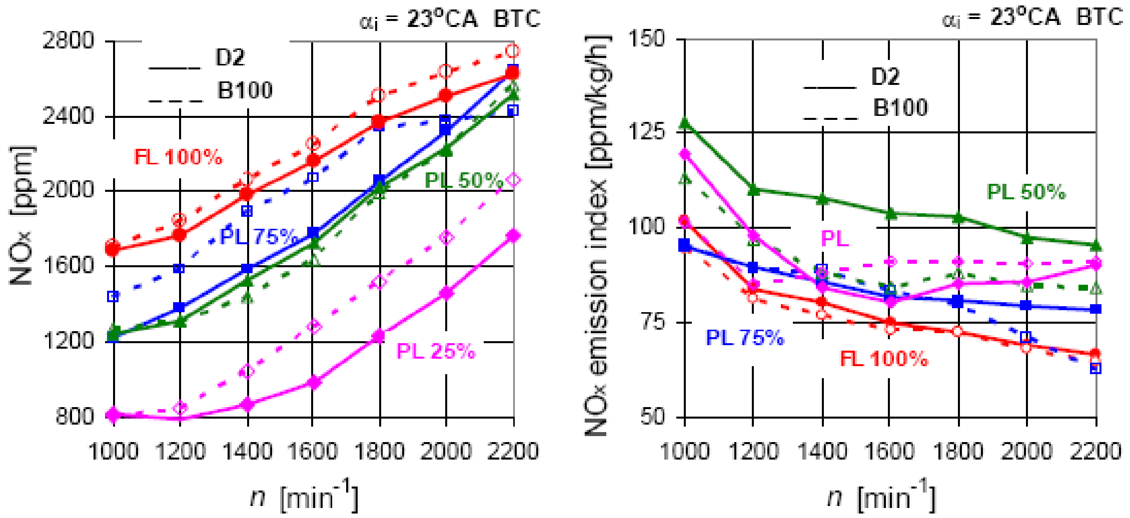

Figure 6: Emission concentrations and emission indices for NOx at different engine speeds on brake (rpm) and different loads (PL) using D2 or B100. Compared to other pollutants emission of NOx is the only higher for B100 than D2 – see also Figure 7 below.

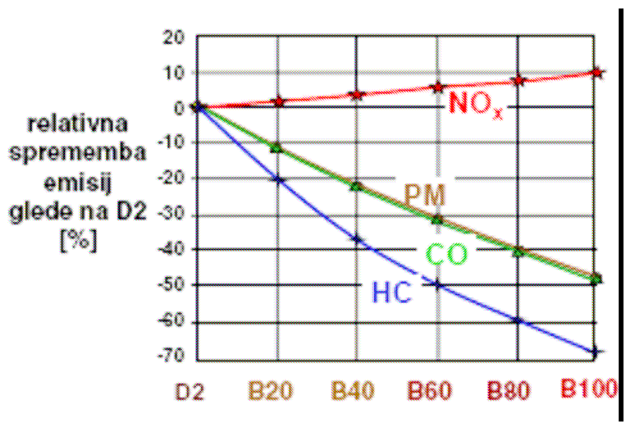

Figure 7: Relative change in emissions of HC, CO, NOx, and PM according to different B concentrations (B0=D2, B20, B40, B60, B80, B100=pure biodiesel). A reference is D2.

Relative change summary based on laboratory results for Euro 0 bus engine (also extraction from Figures 5, 6, and 7):

PM	-46 %
HC	-68 %
CO	-49 %
NOx	+13%
Smoke	-45 %

Evaluation

Baseline data: PT network in Ljubljana involves 204 buses (104 buses are old, Euro 0; others are new, partly Euro 3 and partly Euro 4), there are 21 bus lines; total mileage of the bus-lines 233 km. Annual mileage: 11.5 million km. Average bus engine power 162 kW, average engine load 30%, average travel speed 10 km/h.

Assumption for comparative assessment if applying biodiesel instead of D2: Euro 3 emission factors (adopted as average for the existing PT fleet), BAU – 10% increase of emissions from transport in 4 years, Mobilis scenario: emissions change according to laboratory measurements and bus testing

CO: 2.1 g/kWh x 48kW = 100.8 g/h x1.15 mio h = 115.9 t (-49% B100) – 56.8t
NOx: 5.0 g/kWh x 48kW = 240.0 g/h x 1.15 mio h = 176 t (+13% B100) + 35.8t
HC: 0.7 g/kWh x 48kW = 31.6 g/h x1.15 mio h = 36.3 t (-68% B100) – 24.7t
PM: 0,10 g/kWh x 48kW = 4.8 g/h x1.15 mio h = 5.5 t (-46% B100) – 2.5t

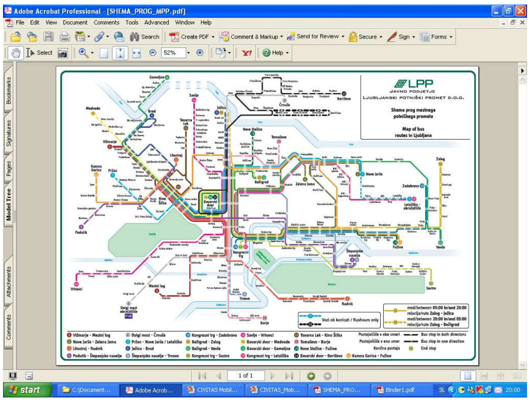

Figure 8: PT network in Ljubljana

<u>Average annual change in NOx and PM emissions at the city level (comparative assessment BAU: Mobilis scenario):</u>

The change is presented in Figures 9 and 10.

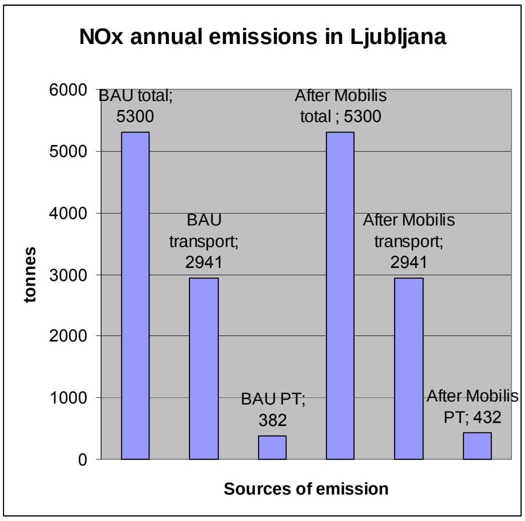

Figure 9: Expected (modelled) change in NOx emissions at the city level. Comparison of BAU and Mobilis scenario: "total" comprises all sources of emission (industry, transport, heating, etc.), "transport" comprises emissions from all transportation activities in the city, "PT" comprises emissions from public transportation

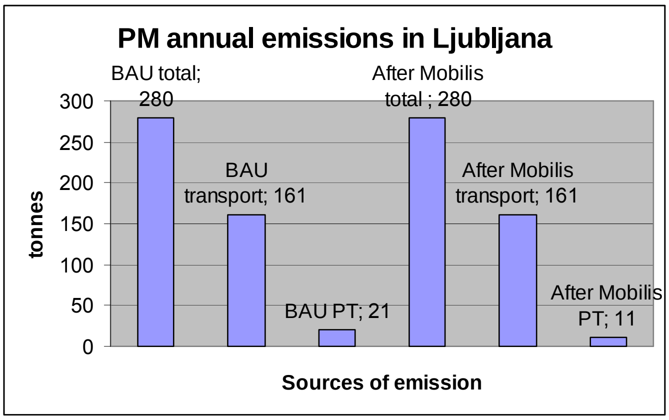

Figure 10: Expected (modelled) change in PM emissions at the city level. Comparison of BAU and Mobilis scenario: "total" comprises all sources of emission (industry, transport, heating, etc.), "transport" comprises emission from all transportation activities in the city, "PT" comprises emissions from public transportation

Comments to the evaluation

Total costs of testing 20 buses exceed 200.000 € (see Table 10 for details), excluding the work of the LPP personnel involved in other activities of the measure 5.4L. A difference in costs between a bus running on B100 and a bus running on D2 is around 500 € (running on B100 is more expensive); after normalisation for mileage and fuel consumption this figure rises to around 650 €.

Modelling results of pollutants emission change do not take into account actual conditions of the buses' operation, e.g. weather conditions, peak hours, real engine load, engine speed, bus occupation, daily and seasonal variations, traffic conditions throughout the city – local specificities, etc. Therefore, they are uncertain in demonstrating actual situation and potential changes in terms of air quality improvement generally and at specific locations in the city, e.g. city centre, as well as change/improvements of health status of the citizens of Ljubljana. As a consequence, a team which has been working on the evaluation of the introduction of B100 into PT buses in Ljubljana concludes and proposes the following, which has been accepted by the measure leader (LPP) and will be carried out by the end of the project:

- Further testing of 20 (or even more) Euro 0 buses in the same way as in 2007 will bring non-justifiable additional costs without added value in terms of contributing to the conclusion about specific environmental and health improvements in the city of Ljubljana
- It is clear that substitution of D2 with B100 generally means lower pollution, i.e. lower emission of pollutants (except NOx). However, if one wants to identify more accurately what are the emissions in real life, i.e. during real operation of the buses, he/she must collect data on a concrete vehicle speed, its acceleration/braking, rpm of the engine, bus/engine load etc. associated with the geographical position of a bus. These data, together with the available results of laboratory measurements would enable accurate calculation of the emissions at specific location of the bus, i.e. throughout the whole bus route. Summing this information for all buses and routes in the city will bring clear picture about possible improvement of air quality in the city of Ljubljana after substituting D2 with B100.
- Real data on bus performance during its operation and consequent modelling results of air quality improvement will also serve as a basis for selecting and purchasing new buses in Ljubljana.

Additionally, SEA proved as a very useful evaluation approach at city (cluster of measures) level. It enables better insight into overall direction and effects of the measures and is mutually supportive with the process evaluation.

C2.4 Society

Awareness is generally increasing. Specific survey results are in Slovene only. Biofuels are generally acceptable by bus drivers and PT users.

In addition, based on regular surveying done by Ljubljana Public Holding and Ljubljana Public Transport, we can observe that majority of respondents share an opinion that public transport contributes to lower environmental pollution. In the graph below – Figure 11 specific figures are available (excerpted from the surveys made in 2005 in 2007, dealing with public transport issues). Average value (on 1-5 scale) is also high, 3,89 in 2005 and 3,6 in 2007. Such an opinion share women, elderly, more educated, higher income respondents and respondents from the City centre.

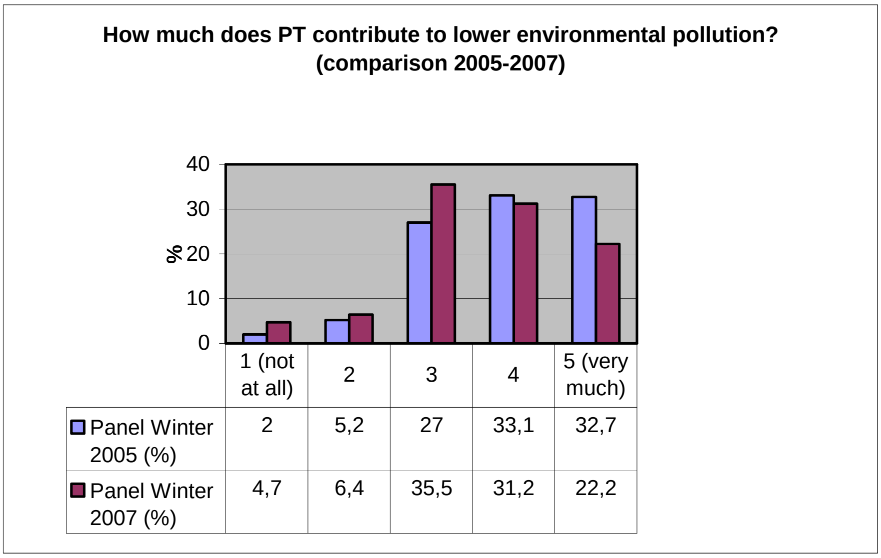

Figure 11: Excerpt from the surveys on PT perception in Ljubljana in 2005 and 2007. In spite of the positive opinion about relation between PT and the environmental protection effects, biodiesel can not be applied in the buses due to its higher costs compared to D2, however such an opinion can be used as a driver for making available mode choices in terms of using less polluting PT instead of individual cars.

C3 Achievement of quantifiable targets

No.	Target	Rating
1	Large scale deployment of biodiesel in LPP buses	0
2	Whole chain from production to use of biodiesel at small farms	★★★
3	Improvement of the quality of biodiesel produced at Pinus	★★
4	Awareness level about alternative fuels	★

0 = Not Achieved NA = Not Assessed ★ = Substantially Achieved (at least 50%) ★★= Achieved in full ★★★= Exceeded

C4 Up-scaling of results

Concerning the use of biodiesel in the bus fleet it is clear that this is not recommendable for old buses Euro 0 (due to high costs for preparing and maintaining/servicing the fleet). Also, winter time may be problematic in terms of causing non-operability of buses due to parafine crystallization in biodiesel below -7 °C. Otherwise, introduction of biodiesel is environmentally beneficial. For proving this benefit we recommend data collection on emissions and bus operation in real life, i.e. taking into account specifities of the PT network, occupation of buses, weather conditions etc., as described in "C2.3 Comments to evaluation". Up-scaling potential is also related to biodiesel production and quality improvement at Pinus and at small farms. The latter means popularisation and distribution and not single production capacity increase over 5000 tonnes per year.

C5 Appraisal of evaluation approach

It is important to emphasis the role of the measure leader in the evaluation process, the coherence, and the consistency of the activities comprising the measure. Since measure 5.4.L is/was a collection of different, actually non-linked activities it was difficult to maintain a common picture of the measure itself, and related evaluation activities. Nine legal entities were involved in the design, development, implementation and promotion of the measure (AIS, CoL, FME, LPP, Petrol, Pinus, REC, Sava, Teol), which made the coordination of the work and synthesis of the results rather difficult. Such situation also makes evaluation activities disintegrated, i.e. each component of the measure needs to be evaluated separately. In addition, particular activities in the measure have their specific goals and targets, which are not interconnected and merged into a common goal. Also measure leader has been changed three times during the project which influenced continuity of the measure implementation. General insight into the measure shows that in the Inception and Mid report it is described in a somewhat scattered way.
If have a chance to undertake evaluation again it would be beneficial to spend more time on involving measure leaders in the evaluation design and data collection. It would be also useful if the measure is divided into three measures.

Regarding evaluation of large scale biodiesel bus implementation it is preferred if on-street evaluation is made about emissions of pollutants in different operation (load) and weather regimes/conditions (for details see D3).

C6 Summary of evaluation results

The key results are as follows:

- **Key result 1** – LPP now knows better which buses to purchase in the future and how to comprise PT fleet in Ljubljana. Justification could be based also on cost and environmental arguments. Existing 100 Euro 0 buses are to be replaced by new Euro 4 buses. About 30 will run on D2 while the others will partly run on biodiesel, partly on CNG, and small part will be hybrid.
- **Key result 2** – biodiesel production in Ljubljana is not appropriate due to expected urban changes and occupation of industrial zones in the city. Namely, the industrial zone where Teol is allocated changed during last 20 years in a way that some other industries left this location; their infrastructure and objects have been taken over and renewed by new owners, and new activities – in general services instead of previous production – has been introduced. Teol is now an exception in terms of production activity at this location/industrial zone. In addition, surroundings of the industrial zone changed significantly in a way that more vulnerable objects/activities are now present (commercial and recreational areas). Nevertheless, production elsewhere (at Pinus) could be improved as to meet high quality standards for products.
- **Key result 3 -** cost-effective production of biodiesel at small farms is feasible, however, it is better to make esterification of crude oil elsewhere, i.e. at industrial plants (see file "Transferability_example_BK(1).doc" for details.
- **Key result 4 -** Strategic environmental assessment (SEA) is helpful in following-up changes on a more general/strategic/land-use level; see Key result 2. Measures are sometimes detached from the "big picture" and SEA should maintain the associations between the two. For example, if a measure implementation would cause a certain urban change or impact on

land-use at a city level, then SEA is inevitable to show which alternative for the implementation seems the best, i.e. most cost-effective and environmentally beneficial, including the alternative of not implementing the change. In the case of 5.4L this has been proved for the planned production of biodiesel in the city centre (Teol). SEA showed both inadequacy of the site (due to planned long-term urban changes in that part of the city), and existing inoperability of the industrial infrastructure at the site which would require additional investments if biodiesel production is to be established. Managers of Teol recognised these issues as financial and environmental/spatial/urban obstacles in implementing the project. In this context SEA is particularly beneficial when considering and explaining good and weak points of the measures and their impact on higher (e.g., city or urban transport policy) level.

D Lessons learned

D1 Barriers and drivers

D1.1 Barriers

- **Barrier 1** – LPP personnel in charge of implementing 5.4L (measure leader) has been changing during the project three times. Also partners were joining and leaving the project measure during its implementation. This contributed to disintegration of the work and difficulties in its management. There was an impact also for the data collection and evaluation activities.
- **Barrier 2** – The measure was rather complex, consisting of components which were not interrelated: deployment of biodiesel at LPP buses, industrial biodiesel production, biodiesel production at small farms, improvement of the quality of biodiesel already produced. Such a situation caused a number of organisational and management issues, including difficulties in coordination, reporting, evaluation. It would be better to have three or four separate measures instead of a single.
- **Barrier 3 –** there was a financial problem regarding making adequate number of chemical analysis of biodiesel produced at small farms. Initially, i.e. at the planning stage of the measure lack of attention has been paid regarding these analyses. As a consequence biodiesel produced was analysed just several times during the project which did not allow continuous and prompt information about the quality of the product.
- **Barrier 4 –** pilot scale equipment (up to 100 L vessels) and mostly manual operations (dosage of reagents, mixing) have been applied in biodiesel production (esterification) at small farms. Due to this it was difficult to maintain/achieve constant quality of the product as well as same level of process efficiency. In future experiments proper process line should be established.
- **Barrier 5** – motivation for biodiesel production at small farms could have been increased if regular demonstration activities of the whole process would have been applied, not only for pressing rape seeds. However, barriers for such demonstrations were lack of space – the pilot scale laboratory was too small – as well as a lack of process equipment for esterification.

D1.2 Drivers

- **Driver 1** – harmonisation of a company policy and measure goals. At the start of a project it is crucial to check, whether measure goals contribute to the implementation of the business policy of a partner involved in the project. If this is not clear either goals of the measure are to be adapted or business policy should be updated. In this way motivation for the project is achieved and maintained at the partner side.

- **Driver 2** – Involved partners should have some experience on the subject of the measure. Sharing knowledge among partners is motivating. Different forms of sharing this knowledge is a strong driver for the project.
- **Driver 3** – Research activities in the project (creating new knowledge) contribute to the identification of the involved parties with the project, its goals and expected benefits. Also improvements, which are the results of the measurement implementation, contribute to positive identification of the involved parties with the project.
- **Driver 4** – chain reasoning that biodiesel produced at Pinus will be used for testing engine/bus performance and its emission of pollutants contributed to the dedication of the partners on one side and interest to achieve as quality product as possible. Also training of Pinus staff to be able to perform analytical control of the quality of raw material and biodiesel was crucial.
- **Driver 5** – introduction of the state-of-the-art analytical methods for biodiesel production control was very motivating.

D2 Recommendations

- **Recommendation 1 -** A measure leader should have a key role in the evaluation process. Measure leader should be involved in the evaluation design and data collection. In this way the coherence, and the consistency of the activities comprising the measure are organised and implemented in a way that contributes to evaluation which is also consistent, coherent, clear and transparent.
- **Recommendation 2** – Mesure should be straightforward in its primary core. Complexity, especially due to linking non-consolidated ideas and sub-measures should be avoided.
- **Recommendation 3** - Evaluation manager, measure leader and project leader at city level should meet regularly to monitor and actively manage the activities on a particular measure.
- **Recommendation 4** – Based on testing Euro 0 buses in Ljubljana it is not recommendable to run these buses on biodiesel. Environmental benefits are negligible while costs are considerable.
- **Recommendation 5** – Biodiesel or rather rape seed oil as a raw material for biodiesel can be economically produced at small farms. This stands if cake after pressing is used as fodder.
- **Recommendation 6** – Small farmers should have prior training in the basics of process engineering if they want to apply esterification for biodiesel production. They also need to consider that return rate of the investment in process equipment is between 5 and 7 years.
- **Recommendation 7 -** when applying biodiesel quality improvement approach as in Pinus one should note that investigation of possible benficial use of waste which are produced during testing should be found.

D3 Future activities relating to the measure

It is planned to perform additional test on biodiesel use in PT buses for the purpose of specifying more accurately the environmental benefits for the city of Ljubljana. Additional measurements and data collection is envisaged. A set of new equipment for these measurements includes GPS with 5m antenna cable and Can interface, and the DL2 Data Logging system. Data will be collected on:

- position of the bus
- rpm (engine & gearbox)
- bus speed
- gear

- acceleration up to 50 km/h
- braking (settling) 50-10 km/h

The test will be performed on three representative bus lines in the city: bus line 6 (flat, one of the most occupied), bus line 14 (less occupied however has steep sections), and bus line 3 (less occupied, runs through suburbs). The equipment will be either moved from bus to bus or one bus will first run on line 6, then on line 14, and finally on line 3. The test will start in September 2008.

Based on collected data combined with the specific emission data at specific operating condition of the bus the integration will be made on total emission at selected locations in the city of Ljubljana. After applying the approach for all 21 bus lines in the city the overall picture will be available on the improvement after large-scale introduction of B100 into PT fleet in Ljubljana.

Final comment: Higher costs than expected for buses preparation and maintenance during operation (doubled frequency of servising is needed), higher fuel cost, as well as buses inoperability in winter conditions at temperatures below -7 °C are the reasons that LPP can not afford deployment of B100 on 100 buses. Therefore the LPP management decided to rather apply hybrid buses in Ljubljana than biodiesel

Presently high return of biodiesel production at small farms (see the basis on Figure 3) might drive up production and therefore increase the price of rape seed and reduce the market price of biodiesel. This would certainly be in support of the endeavours of extending biodiesel use especially in agriculture. Whether this would also facilitate wider production of biodiesel at small farms as to significantly contribute to the supply of biodiesel at open market in Slovenia is rather a question of future orientation of farmers than just a question of a profit. One should know that Slovenian farmers are rather conservative and do not change their habits easily. On the other hand, and traditionally, Slovenian farmers are oriented to cattle breeding (hilly countyside) rather than to industrial plants production.

Work on 5.4L was extreemly beneficial in terms of learning for all involved parties from Ljubljana/Slovenia.