

GREEN POWER
Feeds Your Engine



2nd VegOil

**Demonstration of
2nd Generation Vegetable Oil Fuels in
Advanced Engines**

**Workpackage WP4
Engine Oil Development**

**Deliverable N° 4.9:
Conclusions on Engine Lubricant**

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1 Introduction

Two engine lubricants have been developed for evaluation in the 2nd VegOil project. These engine lubricants meet the ACEA E7 and E9 performance categories. Details of the engine lubricant composition are contained in Deliverables 4.1, 4.3 and 4.11.

The engine lubricants chosen to be researched as part of the 2nd VegOil project were:

- OS240946 = a lubricant which is capable of meeting the ACEA E9-2008 specification
- OS241936 = a lubricant which is capable of meeting the ACEA E7-2008 specification

Both engine lubricants selected for evaluation were SAE 15W-40 multigrade viscosity grade. The reason for the selection of these multigrade lubricants over monograde lubricants (e.g. SAE 40) was that multigrade lubricants are suitable for use in both cold temperature and hot temperature environments, whilst monograde lubricants are suitable for use only in hot temperature environments. As the field trials were to be conducted through the winter months the use of a monograde lubricant would have been inappropriate.

The ACEA 2008 nomenclature and specifications for E7 and E9 lubricants is detailed in Appendix A in deliverable 4.1.

The composition of the engine lubricant formulations (e.g. engine lubricant additives, viscosity modifiers and base oil type) used in the 2nd VegOil project are detailed in Table 1.

Table 1 Engine Lubricant Formulations to be used in 2nd VegOil Project

Lubrizol Oil Code		ACEA E7 Engine Lubricant	ACEA E9 Engine Lubricant
		OS241936	OS240946
Viscosity Grade		15W-40	15W-40
ExxonMobil AP/E 150N	Group I Base Oil	59.4	-
ExxonMobil AP/E 600N	Group I Base Oil	20	-
Chevron 220R (220N)	Group II Base Oil	-	71.1
Chevron 600R (600N)	Group II Base Oil	-	6.1
Lubrizol® 4986E	Engine Lubricant Additive	12.6	-
Lubrizol® 40007	Engine Lubricant Additive	-	16.5
Lubrizol® 7077	Viscosity Modifier	7.7	-
Lubrizol® 7075F	Viscosity Modifier	-	6.1
Lubrizol® 6662	Pour Point Depressant	0.3	0.2

The Product Data Sheets for Lubrizol® 4986E, Lubrizol® 40007, Lubrizol® 7077 and Lubrizol® 7075F are shown in Deliverable 4.11, Appendix B. These Product Data Sheets list the

performance qualifications for the engine lubricant additives and provides information on the viscosity modifiers.

Sufficient quantities of each lubricant were supplied to the relevant project partners throughout the project (refer to Deliverables 4.11a, 4.11b and 4.11c). The relevant project partners have supplied Lubrizol with used engine lubricant samples throughout the duration of the 2nd VegOil project.

This deliverable report specifically details the results from all the tractors operating in Austria, Germany, France and Poland. Table 2 details the tractor unit identification, operating location and the engine lubricant used in that tractor.

Table 2 Tractor Unit Identification, Operating Location and Engine Lubricant Used

Operating Country	TRACTOR UNIT NAME	Engine Lubricant OS NUMBER
Germany	L06930N613519	OS240946
France	L07530N613532	OS240946
Austria	L07430R604221	OS240946
Germany	CD6068R066040	OS240946
Poland	L06830G612350	OS241936
Poland	L06830K512170	OS241936
Poland	L06830K596568	OS241936
Poland	L06830K614003	OS241936
Poland	L07430K494001	OS241936
Germany	L06930N586574	OS241936
Austria	L07430R604472	OS241936
Austria	L07530N613561	OS241936
France	L06830P606579	OS241936
France	L07530K616305	OS241936

The used engine lubricant samples were taken at approximate 250 hour intervals (when the engine lubricant was changed for fresh lubricant) apart from tractors running in Germany with identifications of L06930N586574 and L06930N613519. As reported in Deliverable 4.12 these tractors operated under a different engine lubricant sampling regime and engine lubricant drain interval.

2 Chemical and Physical Testing Performed on Used Engine Lubricant Samples

Lubrizol has analysed the used engine lubricant samples supplied by the relevant project partners using various industry standard used lubricant analysis techniques:

- Total Base Number (TBN by ASTM method D4739)
- Total Base Number (TBN by ASTM method D2896)
- Total Acid Number (TAN by ASTM method D664)
- Kinematic Viscosity (tested at 100°C by ASTM method D7279)
- Wear metals measured by Inductive Coupled Plasma (ICP)
- High Temperature High Shear viscosity (as measured by CEC Test method L-36-A-90)
- Percentage soot measured by Thermogravimetric Analysis (TGA)
- Oxidation and Nitration (by method DIN51 453)

Detailed analysis of the used engine lubricant samples is documented in Deliverable 4.8.

3 Conclusions from Chemical and Physical Testing of Used Lubricant Samples

The measured Total Base Number (by ASTM D4739 and ASTM D2896) shows that the basic reserve of the engine lubricant is being depleted due to the acidic nature of the combustion gases, however this change in basic reserve is considered to be acceptable as is demonstrated by only a small increase in the Total Acid Number (measured by D664).

The measured Kinematic Viscosity at 100°C (measured by ASTM D7279) and High Temperature High Shear viscosity (measured by CEC test method L-36-90) shows that throughout the field trial the kinematic viscosity of the engine lubricants has stayed within the SAE J300 specification for SAE 40 engine lubricants and the high temperature high shear viscosity has changed very little compared to the fresh engine lubricant. One lubricant sample did show a very low viscosity, but no attributable cause could be identified and contamination of the sample could not be ruled out. This highlights that the engine lubricants viscosity has stayed within the formulated viscosity grade throughout the field trial. The viscosity index of the used lubricant samples has been calculated according to ASTM D2270. The results are shown in Appendix B. The viscosity index has not changed significantly between the fresh lubricant and used lubricant samples. The viscosity performance of both engine lubricants is therefore considered satisfactory.

The copper wear levels (as measured by ICP) showed that six samples exceeded the John Deere warning limit of 20ppm (max.). However the samples that showed high copper either came from the tractor which had the low viscosity result (which could have caused the high copper wear) or from tractors which were operating on an extended engine lubricant drain cycle. It is recommended that John Deere investigate all of the tractors after the completion of the field trial for signs of excessive copper wear. It is also recommended that John Deere review the engine lubricant drain interval because the high copper results could indicate that the engine lubricant oil drain interval may need not be able to be extended to 500 hours.

The iron level follows a similar trend to copper with a reasonably low level of iron wear for all samples apart from the sample from Poland (which had the low viscosity) and the tractors operating in Germany on the extended lubricant drain interval. The level of iron wear for all samples fall within the John Deere warning limit of 0.5ppm / hour max.

Overall both engine lubricants have performed satisfactorily during the field trial. It is recommended that John Deere investigate the tractors which gave high copper levels for signs of excessive copper wear after the completion of the field trial. It is also recommended that an appropriate engine lubricant drain interval is defined for tractors running on the 2nd VegOil fuel.



In summary the engine lubricants developed for the 2nd VegOil project seem appropriate for the in the demonstration of 2nd generation vegetable oil fuels in advanced engines when the lubricant drain interval is 250 hours.



Appendix A

List of Acronyms

ACEA – European Automobile Manufacturers Association

E7 – An engine lubricant which meets the ACEA E7 engine lubricant specification

E9 – An engine lubricant which meets the ACEA E9 engine lubricant specification

Appendix B Tabulated used Engine Lubricant Analysis for OS241936

Country	UNIT NAME	UNIT AGE	Lubricant OS NUMBER	Kinematic Viscosity at 100°C measured by D7279 (cSt)	Kinematic Viscosity at 40°C measured by D7279 (cSt)	Viscosity Index	Fe measured by ICP (ppm)	Cu measured by ICP (ppm)	TAN measured by D664 (mg KOH/g)	Soot measured by TGA (%)	High Temperature High Shear measured by L-36 A-90 (cP)	TBN measured by D2896 (mg KOH/g)	TBN measured by D4739 (mg KOH/g)	NITRATION measured by FTIR (A/cm)	OXIDATION measured by FTIR (A/cm)
Fresh Lubricant	Fresh Lubricant	-	OS241936	14.55	109	137	-	-	2.99	-	4.12	7.47	9.59	-	-
Poland	L06830G612350	380	OS241936	14.83	95.5	163	8	3	2.68	0.249	3.9	3.5	9.4	1.4	3
Poland	L06830G612350	580	OS241936	14.3	99.2	148	19	2	3.05	0.164	4	4.26	9.95	0.5	4.7
Poland	L06830G612350	600	OS241936	13.05	97	132	11	2	2.34	0.125	4.06	5.23	9.64	0.5	4.6
Poland	L06830G612350	850	OS241936	9.49	61.22	137	60	23	3.71	0.655	3.1	2.63	7.2	0.9	3.5
Poland	L06830K512170	286	OS241936	13.84	100.1	140	17	2	3.85	0.185	4	6.79	9.51	0.3	6.9
Poland	L06830K512170	850	OS241936	14	104	136	13	3	2.79	0.161	4.1	6.49	10.01	0.4	5.8
Poland	L06830K596568	350	OS241936	14.5	101	148	16	4	2.45	0.11	4	4.53	10.02	0.5	4.7
Poland	L06830K596568	600	OS241936	13.3	100	131	17	3	2.63	0.146	4	4.36	9.93	0.1	3.6
Poland	L06830K596568	601	OS241936	13.9	103	136	9	1	2.72	0.155	4.13	5.81	10.11	0	3.1
Poland	L06830K596568	850	OS241936	13.9	103	136	10	3	2.67	0.088	4	5.35	9.93	0.5	5.2
Poland	L06830K614003	244	OS241936	13.5	99.1	136	17	4	2.51	0.045	4	6.87	9.98	0.3	4.7
Poland	L06830K614003	497	OS241936	13.7	101	136	12	3	2.19	0.155	4.09	6	10.23	0.2	4.7
Poland	L06830K614003	747	OS241936	14.9	101	154	13	4	2.27	0.111	4	3.97	9.76	0.4	4
Poland	L07430K494001	860	OS241936	13.7	99.2	139	15	2	3.59	0.098	4	5.62	9.88	1.1	5.3
Germany	L06930N586574	69	OS241936	14	103	138	12	3	2.83	0.074	4	7.87	9.08	0	3.1
Germany	L06930N586574	133.4	OS241936	13.9	104.4	134	24	4	3.3	0.15	4	7	9.41	0.2	3.7
Germany	L06930N586574	137	OS241936	13.9	103	136	25	4	3.51	0.156	4.1	6.9	9.62	0.2	4
Germany	L06930N586574	219	OS241936	14	105.7	134	8	2	3.56	0.04	4.1	7.46	9.12	0.1	3.6
Germany	L06930N586574	290	OS241936	13.9	104	135	32	3	4.03	0.246	4.1	5.72	9.31	0.5	5.2
Germany	L06930N586574	469	OS241936	13.95	105.2	134	10	5	3.05	0.247	4	7.28	9.12	0.4	5
Germany	L06930N586574	550	OS241936	13.9	104	135	15	3	2.89	0.137	4.1	6.59	9.25	0.2	2.7
Germany	L06930N586574	596	OS241936	13.9	103	136	18	2	3.06	0.137	4.1	6.26	9.3	0.3	3.5
Germany	L06930N586574	660	OS241936	14.05	106	134	29	2	3.46	0.245	4.2	5.57	9.23	0.5	5.3
Germany	L06930N586574	741.2	OS241936	14.15	105	137	38	3	2.8	0.173	4.1	4.77	9.19	0.5	4.2
Germany	L06930N586574	802.5	OS241936	14.1	106.7	134	45	3	2.99	0.381	4.2	4.22	9.05	0.9	8.6
Germany	L06930N586574	853.5	OS241936	14.2	106	136	58	6	1.17	0.418	4.2	4.05	8.81	0.8	6.2
Germany	L06930N586574	904.1	OS241936	14.2	107	135	62	34	3.43	0.401	4.27	3.04	8.9	0.8	6.2
Germany	L06930N586574	950.6	OS241936	14.25	106	137	60	38	4.26	0.393	4.28	3.22	9.19	0.3	7.9
Germany	L06930N586574	1018	OS241936	14.2	106	136	67	74	4.61	0.454	4.27	2.87	8.6	0	7.5
Germany	L06930N586574	1018.1	OS241936	14.3	106	138	67	75	3.78	0.466	4.28	2.91	9.2	0.1	9
Germany	L06930N586574	1052	OS241936	13.9	103	136	6	6	3.42	0.02	4.06	7.33	9.49	0	9.5
Germany	L06930N586574	1101.7	OS241936	13.74	102.01	135	7	7	3.24	0.03	4	6.62	9.62	0.1	2.5
Germany	L06930N586574	1150	OS241936	13.7	101.54	135	9	7	3.24	0.203	4	6.18	9.77	1.3	0
Germany	L06930N586574	1268	OS241936	13.77	102.01	136	18	8	3.06	0.265	4	5.14	9.71	0.2	4.7
Germany	L06930N586574	1306	OS241936	13.83	103.1	135	23	9	3.29	0.366	4.1	4.77	9.7	0.3	4.1
Germany	L06930N586574	1317	OS241936	13.29	100.58	130	26	10	2.99	0.277	4.1	4.32	9.39	0.4	5
Germany	L06930N586574	1403	OS241936	14.6	111.3	135	12	2	2.46	0.143	4.1	6.42	8.66	0.8	9.7
Germany	L06930N586574	1476	OS241936	14.41	108.76	135	17	3	1.78	0.257	4.1	5.89	9.09	0.9	10.3
Austria	L07430R604472	1995	OS241936	14.2	104	139	17	3	2.3	0.321	4.1	4.13	8.76	0.2	5.2
Austria	L07430R604472	2460	OS241936	13.9	101	139	10	1	3.9	0.095	4.1	6.38	9.43	0.2	4.9
Austria	L07430R604472	2750	OS241936	14	101	141	14	1	4.01	0.211	4.1	5.86	9.39	0.3	6.5
Austria	L07530N613561	873.3	OS241936	14.3	106	138	38	8	2.95	0.548	4.22	6.11	10	0.5	8
Austria	L07530N613561	1018	OS241936	14	104	136	20	2	3.01	0.331	4	5.19	9.73	0.3	4.4
Austria	L07530N613561	1040	OS241936	13.8	104	133	23	3	3.21	0.347	4.1	4.77	9.83	0.3	4.4
Austria	L07530N613561	1352	OS241936	14.24	105.22	138	38	6	2.71	0.358	4.2	4.87	9.67	0	0.9
France	L06830P606579	384	OS241936	13.8	103	135	14	4	2.45	0.156	4.1	5.69	9.98	0.5	4.9
France	L06830P606579	1039	OS241936	14.25	108	134	35	4	2.86	0.322	4.25	4.34	9.42	0.2	7.1
France	L06830P606579	1290	OS241936	12.25	87.37	135	39	14	2.41	0.155	3.6	5.71	9.92	0.4	1.3
France	L06830P606579	1561	OS241936	13.33	97.18	136	20	10	3.07	0.183	3.9	5.35	9.62	0.4	4.8
France	L06830P606579	1809	OS241936	13.82	103.55	134	16	3	3.22	0.194	4.1	5.68	10.07	0.5	4.4
France	L07530K616305	1010	OS241936	13.7	101	136	26	11	2.37	0.199	4	5.44	10.08	0	5.2
France	L07530K616305	1250	OS241936	13.75	100.4	138	20	3	3.01	0.178	4	4.98	9.6	0.2	5.3
France	L07530K616305	1500	OS241936	13.71	102.19	135	30	5	3.51	0.215	4.1	5.48	9.77	0.3	4.7



Appendix B Tabulated used Engine Lubricant Analysis for OS240946

Country	UNIT NAME	UNIT AGE	Lubricant OS NUMBER	Kinematic Viscosity at 100°C measured by D7279 (cSt)	Kinematic Viscosity at 40°C measured by D7279 (cSt)	Viscosity Index	Fe measured by ICP (ppm)	Cu measured by ICP (ppm)	TAN measured by D664 (mg KOH/g)	Soot measured by TGA (%)	High Temperature High Shear measured by L-36 A-90 (cP)	TBN measured by D2896 (mg KOH/g)	TBN measured by D4739 (mg KOH/g)	NITRATION measured by FTIR (A/cm)	OXIDATION measured by FTIR (A/cm)
Fresh Lubricant	Fresh Lubricant	97	OS240946	16.1	123	140		0	2.83		4.3	6.93	7.9		
Germany	L06930N613519	145	OS240946	14.5	118.4	124	7	2	3.6	0.092	4.1	6.48	8.07	0.1	0
Germany	L06930N613519	199	OS240946	14.35	113	129	12	3	3.75	0.026	4.1	6.09	8.11	0.1	0
Germany	L06930N613519	251	OS240946	14.3	107	136	16	4	4.01	0.243	4.1	5.66	8.11	0.2	0
Germany	L06930N613519	309	OS240946	14.3	108.1	135	24	5	3.12	0.279	4.1	5.17	4.76	0.4	0
Germany	L06930N613519	355	OS240946	14.3	107	136	27	5	3.28	0.348	4.1	4.83	8.06	0.4	0.2
Germany	L06930N613519	407	OS240946	14.6	110	136	7	1	3.08	0.106	4.2	6.13	7.9	0.1	0
Germany	L06930N613519	458	OS240946	14.5	110	135	11	1	3.32	0.157	4.1	5.46	7.92	0.3	0.5
Germany	L06930N613519	503	OS240946	14.5	109	136	12	2	2.56	0.181	4.2	5.11	7.88	0.4	0.2
Germany	L06930N613519	554.6	OS240946	14.5	109	136	17	2	2.91	0.283	4.2	4.57	7.7	0.6	0.7
Germany	L06930N613519	614	OS240946	14.6	109	138	22	2	3.38	0.326	4.2	4.23	7.84	0.8	1.1
Germany	L06930N613519	669	OS240946	14.55	110	136	25	3	2.83	0.312	4.2	3.97	7.93	0.9	1.8
Germany	L06930N613519	724	OS240946	14.55	109	137	29	3	2.72	0.43	4.2	3.37	5.84	1.1	2.4
Germany	L06930N613519	773	OS240946	14.6	109	138	28	4	3.27	0.452	4.34	3.05	7.87	1	2.8
Germany	L06930N613519	827	OS240946	14.6	109	138	33	5	2.26	0.474	4.38	2.7	7.61	1.1	4.3
Germany	L06930N613519	877	OS240946	14.6	109	138	38	20	3.8	0.447	4.38	2.36	7.05	0.8	4.7
Germany	L06930N613519	940	OS240946	14.55	105	143	42	59	4.14	0.523	4.4	2.87	7.48	0	6.9
Germany	L06930N613519	1049	OS240946	15.14	108	147	16	13	2.72	0.298	4.2	4.57	8.49	0	1.7
Germany	L06930N613519	1054	OS240946	14.58	110.43	135	8	11	2.76	0.281	4.2	5.27	8.66	0	
Germany	L06930N613519	1171	OS240946	14.58	110.27	136	11	5	2.55	0.148	4.1	6.4	8.54	0	
Germany	L06930N613519	1221	OS240946	14.54	109.58	136	12	5	3.29	0.213	4.2	5.84	8.56	0.1	0.1
France	L07530N613532	1072	OS240946	14.4	108	136	26	2	2.33	0.374	4.2	4.73	7.33	0.5	1.4
France	L07530N613532	1654	OS240946	14.72	110.28	138	28	3	2.88	0.848	4.4	4.54	8.5	0.6	0.6
Austria	L07430R604221	904	OS240946	14.8	112	136	6	3	2.06	0.074	4.25	5.5	8.43	0.1	0.3
Austria	L07430R604221	975	OS240946	14.65	111	136	9	3	1.98	0.238	4.3	5.72	8.23	0.2	0.8
Austria	L07430R604221	1097	OS240946	14.25	111	130	7	3	2.27	0.195	4.2	5.23	8.53	0.1	0.3
Austria	L07430R604221	1245	OS240946	15	113	138	13	5	2.37	0.373	4.3	3.88	8.55	0.4	2
Austria	L07430R604221	1375	OS240946	14.1	111	128	7	2	3.14	0.184	4.2	4.85	8.51	0.2	1.3
Austria	L07430R604221	1496	OS240946	14.9	115.57	133	12	3	2.36	0.304	4.3	4.77	8.34	0.4	0.4
Austria	L07430R604221	1640	OS240946	14.48	109.93	135	8	1	2.96	0.059	4.2	5.57	8.56	0	
Germany	CD6068R066040	85	OS240946	14.9	114.7	134	3	3	2.3	0.125	4.29	6.09	8.71	0	1.7
Germany	CD6068R066040	134	OS240946	14.6	110	136	10	8	2.82	0.246	4.24	6.64	9.11	0	
Germany	CD6068R066040	185	OS240946	14.5	107	139	11	7	2.71	0.132	4.1	0.31	8.42	0	
Germany	CD6068R066040	790	OS240946	14.32	106.77	137	20	8	2.71	0.182	4.2	4.35	8.23	0.1	

