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Revision of European Ecolabel Criteria for Lubricants

Preliminary report

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Abstract

The objective of this project is to revise the existing EU Ecolabel criteria relating to Lubricants (Commission Decision 2011/381/EU¹). This preliminary report is intended to provide the background information for the revision of the criteria. The study has been carried out by the Joint Research Centre's Institute for Prospective Technological Studies (JRC-IPTS) with technical support from LEITAT. The work is being developed for the European Commission's Directorate General for the Environment.

The EU Ecolabel criteria form key voluntary policy instruments within the European Commission's Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan and the Roadmap for a Resource-Efficient Europe. The Roadmap seeks to move the economy of Europe onto a more resource efficient path by 2020 in order to become more competitive and to create growth and employment. The EU Ecolabel promotes the production and consumption of products with a reduced environmental impact along the life cycle and is awarded only to the best (environmental) performing products in the market.

An important part of the process for developing or revising Ecolabel criteria is the involvement of stakeholders through publication of and consultation on draft technical reports and criteria proposals and through stakeholder involvement in working group meetings. This document provides the background information required for the working group meeting, scheduled to take place in February 2017.

This preliminary report addresses the requirements of the Ecolabel Regulations N° 66/2010 for technical evidence to inform criteria revision. It consists mainly on the following 3 sections: an analysis of the scope, definitions and description of the legal framework (Task 1); a market analysis (Task 2); and an overview of existing technical lifecycle assessment studies, revealing the significant environmental impacts of tourist accommodation (Task 3). Combined with input from stakeholders, this information will be used to present an initial set of criteria proposals (1st Technical Report).

¹ Commission Decision No 2011/381/EU of the European Parliament and of the Council of 24 June 2011 establishing the ecological criteria for the award of the EU Ecolabel to lubricants, available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011D0381>

Glossary of relevant lubricants

Bearing lubricants: lubricants which provide a thin film between the contact areas in a bearing to reduce friction dissipate heat and inhibit corrosion on balls and raceways.

Chainsaw Oil: is a lubricant specially formulated to protect the chain and bar of chainsaw against wear, rust and corrosion.

Compressor Oil: lubricant designed to reduce heat and friction, minimize downtime and consume less energy of air, gas and refrigeration compressors.

Gear Oil: is a lubricant specifically for transmissions, transfer cases and differentials in industrial equipment, cars, trucks and other machinery. Apart from the important function of lubricating the sliding rolling contacts, the oil also fulfils the task of cooling and removing friction heat.

Grease: is a lubricant created when a lubricating fluid is thickened with other materials until it is a solid or semisolid consistency.

Heat transfer fluid: Oil or other liquid used for the transfer of heat.

Heat treatment fluid: lubricants and related products used in the process of hardening metallic materials.

Hydraulic Fluid: are the medium by which power is transferred in hydraulic machinery as hydraulic brakes, power steering systems, transmission and industrial machinery.

Internal combustion engine oil: essentially, engine oils are used as a separating film to reduce the friction between moving parts, thereby decreasing heat and reducing wear. However, engine oils can also serve the purpose of dispersing contaminants, controlling sludge, inhibiting corrosion, improving sealing and extending your engine's life.

Metalworking fluid: any lubricant emulsion, usually mineral oil based that facilitates metal cutting or shaping with two main functions: lubrication and heat dissipation. Basic types of metalworking lubricants are: cutting and tapping fluids, drawing compounds, etc.

Mould release lubricant: a mixture used to prevent other materials from bonding to surfaces. The mould lubricant facilitates removal of the moulded object from the mould, protects the surface of the mould, and reduces or eliminates the need for cleaning it.

Pneumatic tools oil: lubricants designed to extend the life of pneumatic tools.

Slideways oil: lubricant which provides a stable, adhesive lubricating film

Spindle bearings oil: light-bodied oil used principally for lubricating textile spindles and for light, high-speed machinery.

Stern tube grease: provide outstanding lubrication and rust/corrosion protection. The oils' lubricating film resists water, keeping stern tube systems protected for extended periods of time and under severe operating conditions.

Temporary protection against corrosion lubricants: products the main function of which is to ensure temporary protection, the word "temporary" being relevant not to time-limit product efficiency but to the capacity for removal of the product after a certain time. It excludes products that are applied for other purposes but also ensure temporary

protection. Vapour-phase inhibitors and other chemical products that differ from petroleum products in behaviour are also excluded.

Turbine oil: oil used to lubricate the bearings and auxiliary machinery on steam and hydraulic turbines, in turbopumps, and in air, gas, and refrigeration turbocompressors. Turbine oils are also used as lubricants and working fluids in various types of closed-cycle industrial machinery.

Two-Stroke engine oil: Is lubricating oil that is mixed with gasoline and used for 2-stroke engines.

Wire rope lubricants: lubricant specially formulated for lubrication and protection of wire ropes and cables.

Previous revision: summary and suggested issues to be addressed in current revision.

This chapter summarises the adaptations made in the last revision and the issues left to be addressed in this revision gathered in one of the output reports of the past revision². It is expected to cover some of the issues in the preliminary report, technical reports and in the technical discussions.

The following adaptations were proposed in the past revision:

- *The scope of product group has been extended to: tractor transmission oils, stern tube greases and stern tube oils, wire rope lubricants and industrial and marine gear oils*
- *New category for Industrial and Marine gear oils has been defined.*
- *Stating on the application form intentionally added or formed substances from 0.1% to 0.010% (w/w)*
- *Decrease of fraction allowed in the lubricant from 0.1% to 0.010% for substances of very high concern and stated on several EU lists and annexes.*
- *Exclusion of nanomaterials*
- *The total fraction of substances not assessed on aquatic toxicity and biodegradation below 0.5% (w/w)*
- *Fraction of very toxic substances in hydraulic fluids decreased from 1% to 0.10%*
- *Allowed to use results of seawater tests on aquatic toxicity and biodegradation*
- *Fraction of inherently and non-biodegradable substances for greases from 15 and 10% respectively to 25% together*
- *Inclusion in the criteria the LuSC-list and the valid letter of compliance for substances and/or commercial additive packages*
- *Limiting fraction of monomer in a polymer*
- *LogK_{ow} calculation methods for organic substances simplified*
- *Removal of biodegradation exception for thickeners in greases*

Several other small changes in the criteria were added e.g. allowing standard tests that are also allowed within the EU chemical policy regulations.

The following issues were touched upon during the revision but were left to the next revision by the stakeholders, either because the proposed criterion was not feasible at that moment or the impact at this moment was not known:

- *To include impurities in the stated substances on the application form present above 0.010% and for which criteria these impurities could apply.*
- *Reducing the fraction of sensitising substances to 0.10%*
- *It is also urged to develop an on-line application method including software that leads you through the application form.*
- *Quantifying the reduction in CO₂-emission and possible other sustainability parameters? To calculate a possible reduction in CO₂-emission it is not only required to agree on the methodology but also to the values to be used in the*

² Revision of the EU Ecolabel criteria for Lubricants. Summary of the modifications.
Hildo Krop / IVAM UvA BV

applied methodology. A good start could be the methodology described in the EU biofuels directive. It is therefore urged to develop a methodology to agree both on the calculation method of GHG emission reduction and its parameter values before the second revision. This also falls in line with a recent article on the possible use of the carbon footprint as a toolkit in the EU Ecolabel (Baldo et al, The Carbon Footprint measurement toolkit for the EU ecolabel, Int J LCA, 2009, 591-596))

- *CO₂-emission may also be reduced by a better lubrication or longer lifetime. Can these parameters be quantified and included in the future methodology on Greenhouse gas reduction for lubricants and if so, how.*
- *Is it possible to circumvent established minimum technical performance tests by proven fitness for purpose?*
- *What substance data will be published by ECHA and in what way do they diminish the substance data requirements of the EEL?*
- *Experiences with the LuSC-list*
- *Is it possible to include the IMO-GESAMP list into the LuSC-list?*

TASK 1: Scope and definition

1. Introduction

The aim of first section of the report (Task 1, scope and definition) is to provide an overview of existing technical categories, relevant legislation, standards and stakeholders feedback with regard the scope and definition, received in the first questionnaire released at the beginning of this revision, and to propose on that basis the scope and definition of the product for the revised criteria. Recommendations for the changes in the scope and definition are proposed in the final section of Task 1. During the revision, practicability and feasibility of the proposed changes will be assessed in the light of other relevant information (market data, technical analysis, feedback from stakeholders, etc...) and further modifications might be proposed in a later stage after evaluation of further information and discussions at the AHWG meetings.

The focus of this task is to explore (1) the definitions of the product group (including a comparison of the existing EU Ecolabel definition against other labels where 'Lubricants' have a written definition), (2) the existing scope and the proposal to enlarge the scope for the revised criteria for lubricants and (3) the potential to harmonise the lubricant categories with ISO 6743³.

Brief definition of the different lubricants mentioned in the report can be found in the Glossary of relevant lubricants

³ UNE-EN ISO 6743-4:2015: Lubricants, industrial oils and related products (class L) – Classification.

2. Existing legislation and standards

An overview of several environmental regulations (mainly EU wide) and labelling schemes related to lubricants is presented in below sections.

2.1. Main regulatory framework

- **Regulation (EC) No 66/2010⁴** of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel. The European Union Ecolabel is a voluntary environmental labelling system. It enables consumers to recognize high quality eco-friendly products. This Regulation aims to improve the rules on the award, use and operation of the label.
- **REACH regulation. Regulation (EC) No 1907/2006⁵ of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)**, establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EC) N° 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC.

REACH does not allow marketing of a chemical substance if it does not have appropriate Registration, which has to be carried out by every legal entity that manufacture or import from outside of the European Union substances on their own, in mixtures or in articles in quantities of 1 tonne or above per year. REACH places responsibility on industry to manage the risks that chemicals may pose to human health and environment, as well as to provide safety information that would be passed down the supply chain. The companies that do not undertake this procedure, will not be able to produce, sell or use their products and would consequently be forced to stop their activity.

In addition to Registration, REACH regulates other procedures such as the management of the risk and hazardous properties of the substances, Authorisation of Substances of Very High Concern (SVHC) and the Restriction on the manufacturing, placing on the market and use of certain dangerous substances, mixtures and articles when an unacceptable risk to human health or the environment exists. The restricted substances (on their own, in a mixture or in an article) and the consequent restriction conditions are listed in Annex XVII of REACH Regulation (Restriction list⁶).

⁴ Regulation (EC) No 66/2010 of the European Parliament and of the Council on the EU Ecolabel, available online at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:027:0001:0019:en:PDF>

⁵ Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC, available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006R1907-20150601&from=EN>

⁶ Substances restricted under REACH (Annex XVII): <http://echa.europa.eu/addressing-chemicals-of-concern/restrictions/substances-restricted-under-reach>

Regarding to the Authorization procedure, it requires an authorisation for the placing on the market and the use of certain substances that may cause serious and often irreversible effects on human health and the environment. These substances are identified as Substances of Very High Concern (SVHC: carcinogenic, mutagenic and/or toxic for reproduction; persistent, bioaccumulative and toxic or very persistent and very bioaccumulative; or of equivalent level of concern) and are listed in Annex XIV of REACH Regulation (Authorization list⁷). REACH aims at ensuring that the risks resulting from the use of SVHCs are controlled and that the substances are replaced where possible. A Member State, or ECHA⁸ on request of the European Commission, can propose a substance to be identified as an SVHC. A manufacturer, importer or downstream user can apply for the authorisation. Applications for authorisation are submitted to ECHA. At the end of the authorisation process, which includes a public consultation and the development of opinions by ECHA's Committees on Risk Assessment and Socio-economic Analysis, the European Commission decides on the granting or refusing of authorisations.

The identification of a substance as SVHC and its inclusion in the Candidate List⁹ is the first step of the authorisation procedure. Companies may have immediate legal obligations following such inclusion which are linked to the listed substances on its own, in mixtures and articles.

- **Regulation (EC) No 440/2008**¹⁰ of 30 May 2008 laying down test methods pursuant to Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

- **CLP regulation. Regulation (EC) No 1272/2008**¹¹ **of the European Parliament and of the Council of 16 December 2008 on Classification, Labelling and Packaging of substances and mixtures (CLP)**, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 .

The CLP Regulation ensures that the hazards presented by chemicals are clearly communicated to workers and consumers in the European Union through classification and labelling of chemicals. It entered into force in January 2009 and the method of classifying and labelling it introduced is based on the United Nations' Globally Harmonised System (GHS). After June 2015 the CLP Regulation replaced fully the: Dangerous Substance Directive (67/548/EC) and the Dangerous Preparations Directive (1999/45/EC).

⁷ Authorisation list (Annex XIV): <http://echa.europa.eu/addressing-chemicals-of-concern/authorisation/recommendation-for-inclusion-in-the-authorisation-list/authorisation-list>

⁸ European Chemicals Agency: <http://echa.europa.eu/>

⁹ Candidate List of SVHC for Authorisation: <http://echa.europa.eu/web/guest/candidate-list-table>

¹⁰ Regulation (EC) No 440/2008 of 30 May 2008 laying down test methods pursuant to Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0440&from=EN>

¹¹ Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006, available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008R1272-20150601&from=en>

Before placing chemicals on the market, the industry must establish the potential risks to human health and the environment of such substances and mixtures, classifying them in line with the identified hazards. The hazardous chemicals also have to be labelled according to a standardised system so that workers and consumers know about their effects before they handle them. Thanks to this process, the hazards of chemicals are communicated through standard statements and pictograms on labels and safety data sheets (SDS). CLP regulation also sets requirements for the packaging of hazardous chemicals.

▪ **Regulation (EU) No 528/2012¹² of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products.** The Biocidal Product Regulation (**BPR**) concerns the placing on the market and use of biocidal products, which are used to protect humans, animals, materials or articles against harmful organisms like pests or bacteria, by the action of the active substances contained in the biocidal product. It aims to improve the functioning of the biocidal products market in the EU, while ensuring a high level of protection for humans and the environment. All biocidal products require an authorisation before they can be placed on the market, and the active substances contained in that biocidal product must be previously approved. It will repeal and replace the Biocidal Products Directive (Directive 98/8/ The BPR Regulation will maintain the two-step process of approval of the previous Directive, while providing for the possibility that some biocidal products are authorised at the Union level:

- 1) Evaluation of the active substance at the Union level and,
- 2) Product authorisation at Member State level.

▪ **Directive 2008/1/EC¹³** of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (**IPPC**). According to the IPPC Directive, permit conditions must be based on Best Available Techniques (BAT). The BAT Reference Documents (BREFs) are the result of the exchange of information for the guidance of decision makers involved in the implementation of the IPPC Directive. BAT Reference Document for the Refining of Mineral Oil and Gas. BAT Reference Document on Surface Treatment of Metals and Plastics has a chapter on "minimisation and optimisation of coating from previous mechanical treatments – oil and grease".

▪ **Directive 1999/13/EC¹⁴** of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations.

▪ **Directive 1999/44/EC¹⁵** of 25 May 1999 on certain aspects of the sale of consumer goods and associated guarantees.

¹² Regulation (EU) No 528/2012 of the European Parliament and of the Council concerning the making available on the market and use of biocidal products, available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02012R0528-20140425&from=EN>

¹³ Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (IPPC), available online at: <http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:024:0008:0029:en:PDF>

¹⁴ Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations, available online at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0013:EN:HTML>

- **Directive 2008/98/EC**¹⁶ of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Waste Framework Directive). Waste oils are hazardous waste and are governed by the Waste Framework Directive, especially by Article 21. This Directive lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use.
- **Directive 89/391/EEC**¹⁷ of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (Occupational Safety and Health Framework Directive).
- **Directive 98/24/EC**¹⁸ of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).
- **Directive 2000/60/EC**¹⁹ of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive).
- **Decision No 2455/2001/EC**²⁰ of the European Parliament and of the Council of 20 November 2001 establishing the list of priority substances in the field of water policy and amending Directive 2000/60/EC.
- **Directive 2006/11/EC**²¹ of the European Parliament and of the Council of 15 February 2006 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community.

¹⁵ Directive 1999/44/EC of 25 May 1999 on certain aspects of the sale of consumer goods and associated guarantees, available online at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0044:EN:HTML>

¹⁶ Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, available online at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF>

¹⁷ Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work, available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01989L0391-20081211&from=EN>

¹⁸ Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31998L0024&from=EN>

¹⁹ Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive), available online at: http://ec.europa.eu/environment/water/water-framework/index_en.html

²⁰ Decision No 2455/2001/EC of the European Parliament and of the Council of 20 November 2001 establishing the list of priority substances in the field of water policy and amending Directive 2000/60/EC, available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001D2455&from=ES>

²¹ Directive 2006/11/EC of the European Parliament and of the Council of 15 February 2006 on pollution caused by certain dangerous substances discharged into the aquatic environment of the

- **Directive 94/62/EC**²² of 20 December 1994 on packaging and packaging waste. This Directive aims to prevent or reduce the impact of packaging and packaging waste on the environment. It contains provisions on the prevention of packaging waste, on the re-use of packaging and on the recovery and recycling of packaging waste.
- **Directive 99/31/EC**²³ of 26 April 1999 on the landfill of waste. The objective of the Directive is to prevent or reduce as far as possible negative effects on the environment, in particular on surface water, groundwater, soil, air, and on human health from the landfilling of waste by introducing stringent technical requirements for waste and landfills.
- **Directive 2009/119/EC**²⁴ imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products. This directive is aimed at mitigating supply risks through a stockholding system. The minimum stockholding capacity is calculated based on average daily inland consumption of the previous year.

National regulations

A variety of national regulations promoting bio-based lubricants have been reported²⁵:

- French law 2010-788 (12/7/2010) prohibits, in natural areas classified as “sensitive”, the use of fossil based lubricants which can be easily substituted with biodegradable non-ecotoxic lubricants that meet the criteria for the European Ecolabel (2005/360/EC directive).
- In Germany, Austria, and Switzerland regulations are in place that forbid the use of mineral oil-based lubricants around inland waterways and in forest areas. In addition, the German federal government has introduced a program called “Market Introduction Program (MIP) Biolubricants and Biofuels” for the reimbursement of costs associated with substituting mineral oil-based lubricants for lubricants based on renewable resources with a mass content greater than 50%.
- In Italy, there is a tax on mineral oils and products that contain them.
- Belgium has enacted legislation that requires bio-lubricants to be used in all operations that take place near non-navigable waters.

Community, available online at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:064:0052:0059:EN:PDF>

²² Directive 94/62/EC of 20 December 1994 on packaging and packaging waste. OJL 365, 31.12.1994, p. 10-23, available online at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31994L0062:EN:HTML>

²³ Directive 99/31/EC of 26 April 1999 on the landfill of waste, available online at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999L0031&from=EN>.

²⁴ Directive 2009/119/EC imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products, available online at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:265:0009:0023:EN:PDF>

²⁵ J. Salimon1, N. Salih and E. Yousif, Biolubricants: Raw materials, chemical modifications and environmental benefits, Eur. J. Lipid Sci. Technol. 2010, 112, 519–530

In the Netherlands, the Dutch Ministry of Spatial Planning, Housing and the Environment issued a policy and action program in favour of bio-lubricants in 1996. Tax incentives affecting bio-lubricants are operated, which allows for the accelerated depreciation of environmental investments.

2.2. Labelling schemes related to lubricants

An overview of environmental schemes for lubricants is presented in this section. There are several national ecolabels that include the category of lubricants in their scope. They are shown in Table 1.

Some important environmental schemes do not cover lubricants. For instance, the International Environmental Product Declaration System²⁶ currently does not include the lubricants category. The Product Category Rules²⁷ expired; the last version was approved in 2002 with a validity of 3 years.

Table 1 Summary of ecolabels and environmental schemes applicable to lubricants

PROGRAM NAME	LOGO	REGION	DATE OF REVISION	NUMBER OF CERTIFIED PRODUCTS
Nordic Ecolabel		Denmark, Finland, Iceland, Norway and Sweden	withdrawn	
Blue Angel		Germany	2014	89
Eco Mark Japan		Japan	2012	ND
Korea-Ecolabel		Korea	2012	ND

²⁶ The International EDP System: <http://www.environdec.com/en/>

²⁷ The International EDP System, PCR-Lubricants:

http://www.environdec.com/en/PCR/Detail/?Pcr=5658&show_login=true&new_user=true

USDA, CERTIFIED BIOBASED PRODUCT		U.S.A	2002	214
Swedish Standard		Sweden	2016	142
Environmentally Acceptable Lubricants (EAL)		U.S.A	2011	ND
OSPAR		European Union	-	ND

- **Nordic Ecolabel²⁸:**

Nordic Ecolabel or Swan was the first international labelling program for lubricants, covering Norway, Sweden, Finland, Iceland, and Denmark. Nordic Swan was set up under the Nordic Council of Ministers in 1989 with the purpose of providing an environmental labelling scheme that would contribute to a sustainable consumption. It was originally introduced for hydraulic oils, two-stroke oils, and transmission and gear oils. However it the label for lubricants has been recently withdrawn. It is mentioned in background document of the EU Ecolabel for lubricants²⁹ that the lack of success of this scheme is not clear. Some claim that the problem lies in the high renewability requirements while others point out to the high costs related to the procedure of gaining the eco-label.

- **Blue Angel³⁰:**

One of the first national labelling schemes for lubricants was the German Blue Angel (Blauer Engel) label. This scheme was first put in place in 1978. The lubricants were considered under the Blue Angel since 1988, with criteria developed for several lubricant classes, including hydraulic fluids, lubricating oils, and greases; in order to qualify for certification, a lubricant must possess the following characteristics: biodegradability, low toxicity to aquatic organisms, non-bioaccumulative, and not containing dangerous ingredients (such as carcinogenic or toxic substances). A product must, at the same time, pass a number of technical performance characteristics that make it fit for its use. Biodegradability can be demonstrated using OECD tests 301B-301F to measure ultimate biodegradability or CEC L-33-A-934 to measure primary biodegradability. What makes

²⁸ Nordic Ecolabel: <http://www.nordic-ecolabel.org/>

²⁹ Background Document. Development of criteria for the award of the European Eco-label to lubricants. D.Theodori, R.J.Saft, H.Krop, P. van Broekhuizen. Amsterdam, 09 March 2004.

³⁰ Blauer Engel: <https://www.blauer-engel.de/>

Blue Angel different from other lubricant labelling programs is the requirement for ultimate biodegradability. Blue Angel certification does not have any requirements for using renewable raw materials and, consequently, lubricants based completely on petroleum-sourced components can receive Blue Angel certification. Currently, 83 products bear 'Blauer Engel' label.

- **Eco Mark Japan³¹:**

The categories covered are hydraulic oil, 2-cycle engine oil, grease and other lubricating oil. For every product life stage the label considers the resource consumption, discharge of greenhouse gases, discharge of the ozone layer depleting substances, discharge of atmospheric pollutants, discharge of water pollutants, discharge/disposal of wastes, use/discharge of hazardous materials and others.

- **Korea-Ecolabel³²:**

Korea-Ecolabel covers lubricants that are released to the environment after use. This label considers the following environmental criteria: biodegradability, toxicity and bioaccumulation for the lubricant categories of greases, anti-rust lubricating oils, hydraulic oils, and lubrication oils that are discharged after use.

- **USDA (United States Department of Agriculture), Certified Biobased Product³³:**

USDA, Certified Biobased Product is a label for products that have biobased content on their composition, derived from plants and other renewable agricultural, marine, and forestry materials. The certification covers 187 product categories: including construction, cleaning, automotive, lubricants, and personal care products. Depending on the lubricant category is considered a minimum biobased content: the percentage goes from 30% to 90%.

- **EU Ecolabel³⁴:**

The EU Ecolabel for lubricants was established in 2005 and it includes hydraulic fluids, greases, and total loss lubricants such as two-stroke oils. This labelling scheme consists of seven criteria, covering biodegradation, aquatic toxicity, and bioaccumulation, the exclusion of certain types of toxic substances, the content of renewable raw materials and a minimum technical performance.

Other initiatives

- **Swedish Standard³⁵:**

The Swedish Standard Institute (SIS) develops Swedish standards and also contributes to the development of International standards. It was developed as a collaborative

³¹ Japan Environmental Association (JEA). Eco Mark Office: <http://www.ecomark.jp/english/>

³² KEITI: Korea Environmental Industry & Technology Institute:

<http://el.keiti.re.kr/enservice/enindex.do>

³³ United States Department of Agriculture:

<http://www.biopreferred.gov/BioPreferred/faces/pages/PurposeOfLabel.xhtml>

³⁴ EU Ecolabel: <http://ec.europa.eu/environment/ecolabel/>

³⁵ SIS: Swedish Standard Institute: <http://www.sis.se/en/>

project between government and industry. SIS program has a large number of lubricants: currently 142 lubricants. It includes standards for hydraulic fluids³⁶ and for greases³⁷. The evaluation involves testing for biodegradability and aquatic toxicity, as well as sensitizing properties of a lubricant formulation and its components (Habereeder et al., 2008³⁸). Biodegradability is evaluated using ISO 9439³⁹. Depending on the lubricant class, it has also varying requirements regarding content of renewable materials.

- **Environmentally Acceptable Lubricants⁴⁰:**

In November 2011, the U.S. Environmental Protection Agency (EPA) formulated a document describing the Environmentally Acceptable Lubricants (EAL) as lubricants that have been demonstrated to meet standards for biodegradability, toxicity and bioaccumulation potential, in such a way that through its use, the likelihood of adverse effects to the aquatic environment is minimized.

In December 2013, the Vessel General Permit⁴¹ (VGP) entered into force. VGP requires the use of an EAL for all oil-to-sea interfaces for vessels longer than 79 feet unless technically unfeasible, imposing strict limits on incidental discharges (including lubricants) for vessels operating within three nautical miles of U.S. coastlines and in the Great Lakes.

Some applications covered by the VGP include: controllable pitch propellers, thruster hydraulic fluids, lubrication discharges from paddle wheel propulsion, stern tubes, rudder bearings, wire rope and mechanical equipment subject to immersion. Meeting the VGP standard means the lubricant must bear three characteristics:

- **Biodegradable**, a minimum of 60% biodegradation within 28 days for 90% of the lubricant formulation (75% if it's grease). The final product may contain up to 10% of components not meeting this 60% requirement and up to 5% of non-biodegradable (up to 25% for greases)
- **Minimally toxic**, the final product must pass acute and chronic toxicity tests or, alternatively, each constituent can be evaluated in order to measure the Lethal Concentration (LC) and the No Observed Effect Concentration (NOEC)⁴².
- **Non bioaccumulative**: To qualify as non bioaccumulative a substance must not be able to build up to toxic levels.

In general, three kinds of lubricant are EPA EAL compliant: Vegetable oils, polyglycols, and synthetic esters.

³⁶ Science Partner, Technical Research Institute of Sweden:

<https://www.sp.se/en/index/services/Hydraulic%20fluids/Sidor/default.aspx>

³⁷ Science Partner, Technical Research Institute of Sweden:

<https://www.sp.se/en/index/services/Lubricating%20grease/Sidor/default.aspx>

³⁸ Habereeder, T., Moore D., Lang M. (2008). Chapter 26, Eco Requirements for Lubricant Additives. In: Lubricant Additive Chemistry and Applications, 2nd Edition. CRC Press. Boca Raton, FL.

³⁹ ISO 9439: Water quality – Evaluation of ultimate aerobic biodegradability of organic compounds in aqueous medium – Carbon dioxide evolution test

⁴⁰ Environmentally Acceptable Lubricants, November 2011. United States Environmental Protection Agency Office of Wastewater Management. Washington, DC 20460.

⁴¹ Vessel General Permit for discharges incidental to the normal operation of vessels, 2013.

⁴² Warne Michael St J., van Dam R. (2008). NOEC and LOEC data should no longer be generated or used. Australasian Journal of Ecotoxicology, **14**, 1-5

On top of this, there are manufacturers offering innovative approaches to the issue of marine spills, for instance the seawater polymer bearings. Certainly, seawater is an EAL and VGP EPA compliant lubricant⁴³.

- **OSPAR⁴⁴:**

The OSPAR regulations address environmental performance of chemicals in terms of persistence and marine toxicity. For persistency two parameters are evaluated: bioaccumulation (OECD 117⁴⁵ or OECD 107⁴⁶) and biodegradation in seawater over a 28-day period (OECD 306⁴⁷). Marine toxicity is assessed against four different North Sea species. The testing is done for each component and a third-party laboratory must carry it out. The OSPAR Convention (Convention for the Protection of the Marine Environment of the North-East Atlantic⁴⁸) is the current legal instrument guiding international cooperation on the protection of the marine environment; it combines and updates the 1972 Oslo Convention on dumping waste at sea and the 1974 Paris Convention on the land-based sources of marine pollution.

The standards for environmental compliance, defined within the OSPAR Harmonized Mandatory Control Scheme (HMCS) regulations, do require testing on each component for biodegradation, bioaccumulation, and toxicity; these standards are considered to be the most appropriate for measuring the overall impact of a substance (not just its persistence).

- **CEN standards^{49,50}**

CEN is developing standards that will support the growth of the bio-based products market by increasing transparency and boosting consumer confidence.

CEN/TC 19 - Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin has produced a Technical Report (CEN/TR 16227) on terminology and characterisation of bio-lubricants and bio-based lubricants. This TR has been used as a basis for developing a European Standard (EN 16807) which contains requirements on biodegradability, aquatic toxicity, content of biomass and performance.

⁴³ Seawater is an acceptable Environmentally Acceptable Lubricant for Propeller Shafts. January 8, 2015. <http://www.cleanerseas.com/seawater-commercially-viable-eal-propeller-shafts/>. Retrieved 26-03-2016

⁴⁴ OSPAR Commission. Protecting and conserving the North-East Atlantic and its resources: <http://www.ospar.org/>

⁴⁵ OECD Guidelines for the Testing of Chemicals. Partition Coefficient (n-octanol/water), HPLC Method

⁴⁶ OECD Guidelines for the Testing of Chemicals. Partition Coefficient (n-octanol/water): Shake Flask Method

⁴⁷ OECD Guidelines for the Testing of Chemicals. Biodegradability in Seawater,

⁴⁸ OSPAR Convention: <http://www.ospar.org/convention/text>

⁴⁹ CEN/TR 16227:2011, Liquid petroleum products - Bio-lubricants - Recommendation for terminology and characterisation of bio-lubricants and bio-based lubricants

⁵⁰ EN 16807:2016, Liquid petroleum products — Bio-lubricants — Criteria and requirements of bio-lubricants and bio-based lubricants

3. Scope and definition analysis

A preliminary analysis of the product group scope and definition has been conducted with the aim to assess its comprehensiveness, to evaluate the possibility to enlarge the scope (include a broader range of lubricants available on the market) and to understand if the current definitions need to be amended in order to make them clearer or more practical.

3.1. Overview on existing scope and definition

With regard to the definition of lubricant, Article 2 of the existing Commission Decision¹ defines a lubricant as follows:

i. *'lubricant' means a preparation consisting of base fluids and additives;*

This definition is quite broad, however, the words base fluids and additives, and additional relevant terms are also defined aiming to narrow the definition.

ii. *'base fluid' means a lubricating fluid whose flow, ageing, lubricity and anti-wear properties, as well as its properties regarding contaminant suspension, have not been improved by the inclusion of additive(s);*

iii. *'substance' means a chemical element and its compounds in the natural state or obtained by any production process, including any additive necessary to preserve the stability of the products and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition;*

iv. *'thickener' means one or more substances in the base fluid used to thicken or modify the rheology of a lubricating fluid or grease;*

v. *'main component' means any substance accounting for more than 5 % by weight of the lubricant;*

vi. *'additive' means a substance or mixture whose primary functions are the improvement of the flow, ageing, lubricity, anti-wear properties or of contaminant suspension;*

vii. *'grease' means a solid to semi-solid mixture which consists of a 'thickener' and may include other ingredients imparting special properties in a liquid lubricant.*

Nevertheless there exist more complex lubricant compositions, which do not consist on base fluids and additives but on emulsions (e.g. metal working fluids, demoulding agents...) or on solid state compounds (e.g. fine powders to reduce friction), and therefore are not covered by the existing EU Ecolabel definition based on composition.

In relation to the existing scope, an initial assessment of the background documents⁵¹ from previous revision has been done with the aim to understand the current types of

⁵¹ Theodori, D., Saft, R.J., Krop, H., van Broekhuizen, P. (2004). Development of criteria for the award of the European Eco-Label to lubricants: Background Document.

lubricants covered by the EU Ecolabel. The product group of lubricants is divided into five sub-categories based on the following considerations:

- The **success** of the lubricants categories in **others national Ecolabels**, e.g. the number of licenses obtained.
- Focus on Loss lubricants and high risk (of accident) lubricants.

Loss lubricants: lubricants physically exposed to the surroundings, their entry into environment is unavoidable and they are irretrievable.

High risk lubricants: lubricants used in confined systems which are susceptible to accidental losses.

- The **minimum technical performance** criteria: considering fit for use criteria as an option to decrease the risk and to increase the acceptance of the biolubricants in the market.
- The **market potential**: the inclusion of lubricants with a high market share can contribute to higher penetration of EU Ecolabel lubricants.

The different types of lubricants, differentiating in accordance with application field and operating conditions, were analysed according to the above-mentioned considerations to define the scope and categories of existing criteria. The categories of lubricants included on the current scope of the Commission Decision 2011/381/EU¹ (Article 1) are the following:

- *Category 1: Hydraulic fluids and tractor transmission oils*
- *Category 2: Greases and stern tube greases*
- *Category 3: Chainsaw oils, concrete release agents, wire rope lubricants, stern tube oils and other total loss lubricants*
- *Category 4: Two-stroke oils*
- *Category 5: Industrial and marine gear oils*

Considering only the loss or high risk lubricants, approximately the 84.1% of the lubricants market is not included on the current EU Ecolabel scope (Figure 1). If is considered a total market of 37.1 million tons (MT) (2015), the total of lubricants that could be spilled accidentally on the environment are 31.2 MT. Although the possibility of spillage is lower, the amount of impact generated could be important⁵². Moreover, environmental impacts of a lubricant product can be caused in any life stage of its life cycle (e.g. during raw material extraction or at the end of life), and not only from its potential release to the environment.

⁵² Lubricants Market Analysis and Segment Forecast to 2022, Grand View Research, Inc.

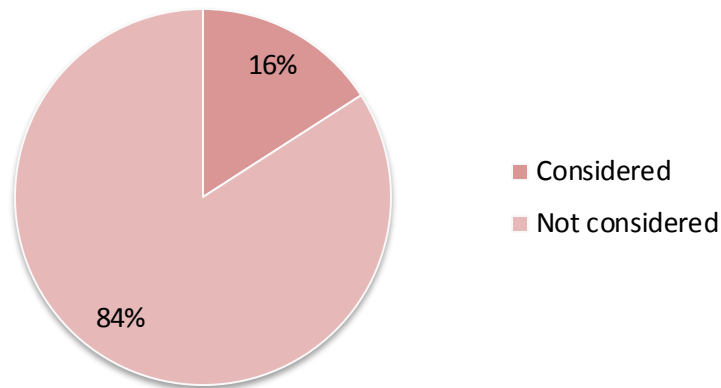


Figure 1: Global product demand considered or not in the present EU Ecolabel

In addition, the existing scope seems not to be always clear, for instance:

- In category 1 hydraulic fluids are mentioned, and additionally tractor transmission oils are specifically listed too, which in fact belong to hydraulic fluids group (understood as a medium used to transmit power in hydraulic machinery),
- In category 2 it is stated that greases are to be considered. Additionally, stern tube grease is specifically mentioned. It is not completely clear why this specific type of greases is mentioned. Does it mean that tractor greases are not to be considered? If they are, should also tractor greases be specifically mentioned?

3.2. Definitions from other voluntary labelling schemes

Table 2 provides an overview of the scope and definitions of other available voluntary labelling schemes for lubricants.

Table 2: Definitions and product categories of others voluntary labelling schemes

Labelling schemes	Scope	Definitions
Nordic Ecolabel*	<p>Nordic Swan classifies the lubricants focused on the potentially negative effect on the environment during normal use, unforeseen leakages or other accidents:</p> <ul style="list-style-type: none"> • Lubricants used in open systems (chain oil, mould oil, 2-stroke oil, lubricating grease and metal cutting fluid) • Lubricants used in semi-closed systems (hydraulic oil, metal cutting fluid) • Lubricants used in closed systems (gear or transmission oils) 	<p>The lubricants product group encompasses lubricating oils which have a lubricating and pressure transferring effect. The most common constituent substances in lubricating oils are:</p> <ul style="list-style-type: none"> • Base oil: the following base oils are used in lubricating oils: Virgin mineral oil, white oil, severely hydrotreated oil, synthetic oil, synthetic esters, polyalphaolefines (PAO), dibasic acid esters, polyol esters, alkylated aromatics, polyalkylene glycols, phosphate esters, vegetable oil, animal oil, rerefined mineral oil, or a mixture of some of these. • Additives: Additives are essential in lubricants for reinforcing the performance of base oils and for suppressing their deficiencies. They perform many and varied functions such as friction reduction, protection of metal surfaces, heat transfer, engine seal protection, and separation and suspension of contaminants. The principal functional classes of additives are antioxidants, dispersants, neutralizing agents, pour point depressants, viscosity modifiers, friction modifiers and antifoam agents.
Blue Angel	<p>Lubricants for areas in which lubricant loss occurs during their intended use:</p> <ul style="list-style-type: none"> • Lubricants that primarily escape into the environment during their intended use e.g. point and rail lubricants and lubricants for open bearings, guides or sealing purposes (incl. stern tube greases) • Lubricants for the glass industry • Concrete release agents for use in formwork • Release agents for use in asphalt paving work <p>Hydraulic fluids (pressure fluids) particularly in environmentally sensitive hydraulic systems and tractor transmission oils</p> <p>Chain lubricants for motor saws</p> <p>Gear lubricants for industry and shipping</p>	<p>Lubricant: a preparation consisting of base fluids and additives.</p> <ul style="list-style-type: none"> • Base fluid: a substance that is used as the base for lubricants. This means a lubricating fluid or base fluid whose flow, ageing, lubricity and anti-wear properties, as well as its properties in terms of contaminant suspension, have not been improved by the inclusion of additives. • Additive: A substance or mixture whose primary function is e.g. the improvement of the flow, ageing, lubricity, anti-wear properties or of contaminant suspension.

	Greases	
Eco Mark Japan	Hydraulic oil 2-cycle engine oil Grease Other lubricating oil	Base oil: is the main component of lubricating oil. With general lubricating oil, mineral oil is mainly used; examples of base oil for lubricating oil with high biodegradability include vegetable oil, synthetic ester, PAG (polyalkylene glycol), etc. Additive: added to base oil to give new properties to produce or complement insufficient properties. There are various types according to purpose.
Korea- Ecolabel	Greases Anti-rust lubricating oils Hydraulic oils Lubrication oils that are discharged after use	Lubricating oil that are discharged after use: those lubricating oils which are discharged into environmental after ends of their usage thus difficult to be recovered (chainsaw oils, water soluble cutting oils).
Swedish Standard	Hydraulic fluids Lubricating greases	-

* Although lubricants product group has been withdrawn under the Nordic Swan label, it was found relevant to include the scheme in the overview of labels.

3.3. Further relevant information

In relation to the definition, from the different available voluntary labelling schemes, it can be seen that there is no universal definition for the term "lubricant". Some of them define a lubricant as *"a preparation consisting of a base fluid with additives"*; while others, like Nordic Ecolabel, also refer in the definition to lubricant's functions.

Literature reviewed showed that sometimes the definition of lubricant is very narrow. It is, for instance, defined as a *"substance introduced to reduce friction between surfaces in mutual contact"*⁵³. In other cases, the definition is wider stating that *"Lubricants are products used to lubricate and they provide reduction of friction and wear, as well as the function of transmitting forces, cooling, pulse damper, sealing effect, and corrosion protection"*⁵⁴. Virtually all the sources consulted agree that a lubricant is composed of: **base fluid** and **additives**. However there exist more complex lubricant compositions, which do not consist on base fluids and additives but on emulsions (e.g. metal working fluids, demoulding agents...) or on solid state compounds, and therefore are not covered by the existing EU Ecolabel definition based on composition.

With regard the classification, there is no single and simple way to classify lubricants and different stakeholders classify them according to different features, as briefly presented below. (For brief definition of relevant lubricants, see the Glossary of relevant lubricants)

➤ Depending on their state:

Liquid and solid (for specific applications) lubricants dominate the market, though air based lubricants are also known, for instance in fluid bearings.

The most common lubricants are the liquid ones. The classical base oil used in them since decades, is the mineral oil, which is a liquid by-product of refining crude oil to make gasoline and other petroleum products. It is usually a transparent and colourless liquid with a density of 0.8 g/ml, composed mainly of alkanes and cycloalkanes in the range C15-C40. There are three types of mineral oil: 1) alkanes, based on n-alkanes; 2) naphthenic oils, based on cycloalkanes; and 3) aromatic oils, based on aromatic hydrocarbons.

Solid lubricants are either used as coating layers (PTFE, polytetrafluoroethylene) used to make cooking utensils non-stick surface, or they are used as true solid lubricants, typically at high temperatures (graphite, boron nitride, molybdenum disulphide, and tungsten disulphide).

The American Petroleum Institute (API⁵⁵) classifies the lubricant base oils into five groups: Group I, Group II, and Group III have different levels of saturated hydrocarbons and sulphur content. Group IV are the polyalphaolefines (PAO), and Group V comprises all other lubricant base oils not included in the previous 4 groups, like naphthenic oils, polyalkylene glycols (PAGs) and esters.

➤ Depending on the area of application:

⁵³ Kuzmina, O., Hallett, Jason P. (2016). Application, Purification and Recovery of Ionic Liquids. Elsevier.

⁵⁴ CHEMIE.DE Information Service GmbH: <http://www.chemie.de/lexikon/Schmierstoff.html> retrieved 20-6-2016.

⁵⁵ American Petroleum Institute: <http://www.api.org/>

- Automotive
 - Engine oils
 - Automatic transmission fluid
 - Gearbox fluid
 - Brake fluid
 - Hydraulic fluid
- Tractor (one lubricant for all systems)
- Other motors (2-stroke engine oils)
- Industrial
 - Hydraulic oils
 - Air compressor oils
 - Food grade lubricants
 - Gas compressor oils
 - Gear oils
 - Bearing and circulating system oils
 - Refrigerator compressor oils
 - Steam and gas turbine oils
 - Metalworking fluids
- Aviation
 - Gas turbine engine oils
 - Piston engine oils
- Marine
 - Crosshead cylinder oils
 - Stern tube lubricants
 - Trunk piston engine oils

- Depending on the formulation and solubility in water: oil based and water based products.

Majority of oil based lubricants contain typically around 90% of base oil (mineral oil) and up to 10% of additives. Besides mineral oil, vegetable oils, synthetic esters, silicones, fluorocarbons, ionic liquids, Multiply Alkylated Cyclopentane (MAC) and others are used sometimes as base oils. A large number of additives are used to modify performance or physical characteristics: antioxidants, detergents, anti-wear, corrosion inhibitors, friction modifiers, anti-foaming agents, extreme pressure, viscosity index improving agents, demulsifying / emulsifying agents, complexing agents, thickeners, stickiness improving agents (in metalworking fluids), to highlight some of the most used.

- Depending on the origin of the base oil: **renewable** or not: biolubricants, renewable; and lubricants with a **fossil** base oil source.

The process of collecting used lubricants and their treatment and re-refining has significantly increased in recent years, fostering the use of **recycled oils** as a valuable resource in lubricants industry. However, the difficulty to determine the amount of recycled oils in the final lubricant formula represents an issue which would need further consideration in the revision of the EU Ecolabel.

- According to market intelligence reporting, lubricants are classified under the following three categories:
 - **Industrial** (process oils, general industrial oils, metalworking fluids, industrial engine oils, and others)

- **Commercial automotive** (heavy duty engine oil, hydraulic & transmission fluid, gear oil, grease)
- **Consumer automotive** (passenger vehicle & motor oil, automatic transmission fluid, gear oil, grease)

The International Organization for Standardization (ISO) has developed a standard for the classification of lubricants: **ISO 6743 "Lubricants, industrial oils and related products"** which establishes a general system of classification, which applies to lubricants, industrial oils and related products, designated by the prefix letter "L" (see Table 3). Within class L, 18 families of products are defined, according to the application areas, so as to cover, as much as possible, all the applications where lubricants, industrial oils and related products are used.

ISO 6743 helps to classify the lubricants into families. Each family is also divided into sub-families which are identified by application or applied chemistry (i.e. Family H- Hydraulic Fluids, Family-HH Hydraulic fluid based on mineral oils). ISO 6743 not only covers lubricants but it also classifies other related products, for instance fluids based on mineral oils such as rust preventive oils (Family R).

Table 3: General system of Lubricant classification following ISO 6743

Classification	
ISO 3448:1992	Industrial liquid lubricants – ISO viscosity classification
ISO 6743-1:2002	Lubricants, industrial oils and related products (class L) -- Classification -- Part 1: Family A (Total loss systems)
ISO 6743-2:1981	Lubricants, industrial oils and related products (class L) -- Classification -- Part 2: Family F (Spindle bearings, bearings and associated clutches)
ISO 6743-3:2003	Lubricants, industrial oils and related products (class L) -- Classification -- Part 3: Family D (Compressors)
ISO 6743-4:2015	Lubricants, industrial oils and related products (class L) -- Classification -- Part 4: Family H (hydraulic systems)
ISO 6743-5:2006	Lubricants, industrial oils and related products (class L) -- Classification -- Part 5: Family T (Turbines)
ISO 6743-6:1990	Lubricants, industrial oils and related products (class L) -- Classification -- Part 6: Family C (Gears)
ISO 6743-7:1986	Lubricants, industrial oils and related products (class L) -- Classification -- Part 7: Family M (Metalworking)
ISO 6743-8:1987	Lubricants, industrial oils and related products (class L) -- Classification -- Part 8: Family R (Temporary protection against corrosion)
ISO 6743-9:2003	Lubricants, industrial oils and related products (class L) -- Classification -- Part 9: Family X (Greases)
ISO 6743-10:1989	Lubricants, industrial oils and related products (class L) -- Classification -- Part 10: Family Y (Miscellaneous)
ISO 6743-11:1990	Lubricants, industrial oils and related products (class L) -- Classification -- Part 11: Family P (Pneumatic tools)
ISO 6743-12:1989	Lubricants, industrial oils and related products (class L) -- Classification -- Part 12: Family Q (Heat transfer fluids)
ISO 6743-13:2002	Lubricants, industrial oils and related products (class L) -- Classification -- Part 13: Family G (Slideways)
ISO 6743-14:1994	Lubricants, industrial oils and related products (class L) -- Classification -- Part

	14: Family U (Heat treatment)
ISO 6743-15:2007	Lubricants, industrial oils and related products (class L) -- Classification -- Part 15: Family E (Internal combustion engine oils)
ISO 6743-99:2002	Lubricants, industrial oils and related products (class L) -- Classification -- Part 99: General

3.4. Initial proposal in the first questionnaire

The preliminary analysis of the existing EU Ecolabel for lubricants indicate that there is a need to explore further during the current revision process the following aspects:

- 1) A revised **definition** of lubricant, which comprises **all product types covered** in the scope,
- 2) An **harmonisation** of the lubricant classes covered with the **ISO 6743 classification** aiming to establish unambiguously what are the types of lubricants considered under each category, so that companies can apply for the correct one from the first moment,
- 3) A **potential to enlarge the scope** to cover higher market share and to allow companies to improve the environmental performance for the different types of lubricant formulations.

A first questionnaire related to the current scope, definition and an initial proposal based on above mentioned aspects has been prepared for the stakeholders (see questionnaire in APPENDIX I and feedback in Chapter 3.5). Contact with relevant stakeholders, such as competent bodies, manufacturers and retailers are essential to evaluate the valid criteria and potential amendments. This section summarises main outputs of this questionnaire.

With regard the definition, the questionnaire included a proposal to amend the current definition of lubricant which currently states that a lubricant is "*a preparation consisting of base fluids and additives*".

A revised definition which includes the lubricant functionality was proposed for consideration in the first questionnaire:

"a substance or mixture capable of reducing friction and wear when introduced between two surfaces which are in relative movement".

In relation to the scope, there is a wide range of products available on the lubricants market. Nevertheless, only a few of them are covered by the different voluntary labelling schemes. For instance mould release, metalworking fluids and rust preventive oils are examples of products excluded from the EU Ecolabel, although they are included in other voluntary labelling schemes. Moreover, environmental impacts of a lubricant product can be caused in any life stage of its life cycle (e.g. during raw material extraction or at the end of life), and not only from its potential release to the environment. For this reason it was initially suggested in the questionnaire to extend the scope as much as possible, including accidental loss lubricants.

The present EU Ecolabel scope does not cover a whole range of products that are present on the market (Table 4).

Table 4: Existing scope and relation with ISO categories

Existing EU Ecolabel			Consistency with ISO 6743
	Lubricant types	minimum technical performance	
Not covered under the current scope	-	-	Families EM, Q, R, U
Category 1	Hydraulic fluids	ISO 15380 Table 2-5	Family H-E
	Tractor transmission oils	Fit for purpose	Family H-V
Category 2	Greases	Fit for purpose	Family X
	Stern tube greases		Families: C-KG, C-KL, M-HG, M-AI and P-AE
Category 3	Chainsaw oils,	Technical performance criteria according to RAL-UZ 48 of the Blue Angel	Family A-C
	Concrete release agents	Fit for purpose	Family B
	Wire rope lubricants,		Family A-B
	Stern tube oils		Family A-B
	Other total loss lubricants		Families: A-Y & A-N
Category 4	Two-stroke oils	NMMA TC-W3 for marine ISO 13738:2000 for Terrestrial	Family EG
Category 5	Industrial gear oils	DIN 51517	Family C
	Marine gear oils		

It has been therefore proposed in the questionnaire to extend the scope to include other lubricant types that are not currently covered and to harmonise the lubricants covered with the nomenclature used in classification to the ISO 6743 "Lubricants, industrial oils and related products" to define each single family seeking harmonisation with this commonly used standard.

Categories proposed to be studied for potential inclusion on the revised scope, according to the standard ISO 6743, are:

- Family B mould release (currently only concrete release agents are considered)
- Family D Compressors
- Family E internal combustion engine oils (extending to 4T)

- Family F spindle bearings, bearings and associated clutches
- Family G slideways
- Family M metalworking
- Family P pneumatic tools
- Family Q heat transfer fluids
- Family R temporary protection against corrosion
- Family T turbines
- Family U heat treatment

Other advantage of having this classification refers to the possibility to set clearer minimum technical performance requirements, i.e. to define a standard test per family or sub-family. In addition, several categories suggested to be included, for instance mould release and metalworking fluids, are included in other voluntary labelling schemes. In the proposed system of classification (according ISO 6743), the minimum technical performance of the products should be designated in a uniform way and categorized according to each family group with a standard test, whenever possible. This revision would like to propose a standard test for each family group in order to harmonise the current tests employed and fit a minimum technical performance of each family group.

Other proposals

Water based products

In addition, although the present EU Ecolabel scope does not explicitly exclude water based products, certain criteria or assessment request of the current set might not be applicable to these products, leading to an indirectly exclusion of these products. Water based products are readily available for hydraulic fluid and metal cutting fluid categories. It has been proposed in the first questionnaire to include water based products, due to the fact that their demand is increasing.

Indoors/outdoors differentiation proposal

The wide range of lubricant applications has a consequence that products, which belong to the same family, can be applied at very different conditions. It is possible that a product can be used in a closed area, like a factory (e.g. in machines) or in an open-air area. Initially, in the questionnaire, it was proposed for consideration whether to distinguish between criteria depending if the lubricants are used indoors and outdoors. The impact generated in indoor areas could be solved with an adequate risk management; for this reason the possibility to generate an environmental impact is lower than if the discharge is produced in outdoor areas.

3.5. Questionnaire feedback analysis

It is considered very important to identify any issues of relevance for the revision at early stage; therefore a first questionnaire was sent out to all parties who expressed their interest in the revision at the very beginning of the process. First general questions were aimed to understand what type of stakeholders took part in the survey; e.g. if a stakeholder have applied before for the EU Ecolabel for lubricants or, for instance, if their products have been previously rejected.

A total number of 44 stakeholders answered the questionnaire. The most representative share of the stakeholders constitutes manufacturers of lubricants (32 stakeholders, i.e.

above 73% of all stakeholders who participated). Others stakeholders that answered the questionnaire are: competent bodies (3 stakeholders, 7% of the respondents), suppliers of raw materials (7 stakeholders, 16% of the stakeholders). The remaining 4% (2 stakeholders) were not assigned to any of these groups (others).

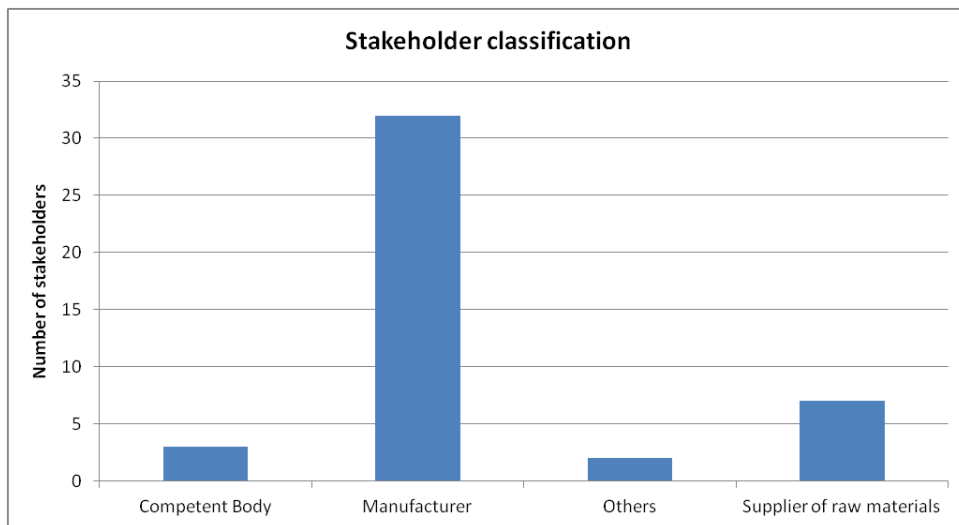


Figure 2: Classification of stakeholders by interest or type of organization

Another question referred to the relation to the current EU Ecolabel. The stakeholders have been divided between:

- Actively involved with the EU Ecolabel criteria development process,
- Obtained an EU Ecolabel license,
- Participated in the process of applying for a license,
- Considered to apply for a license,
- None of the above.

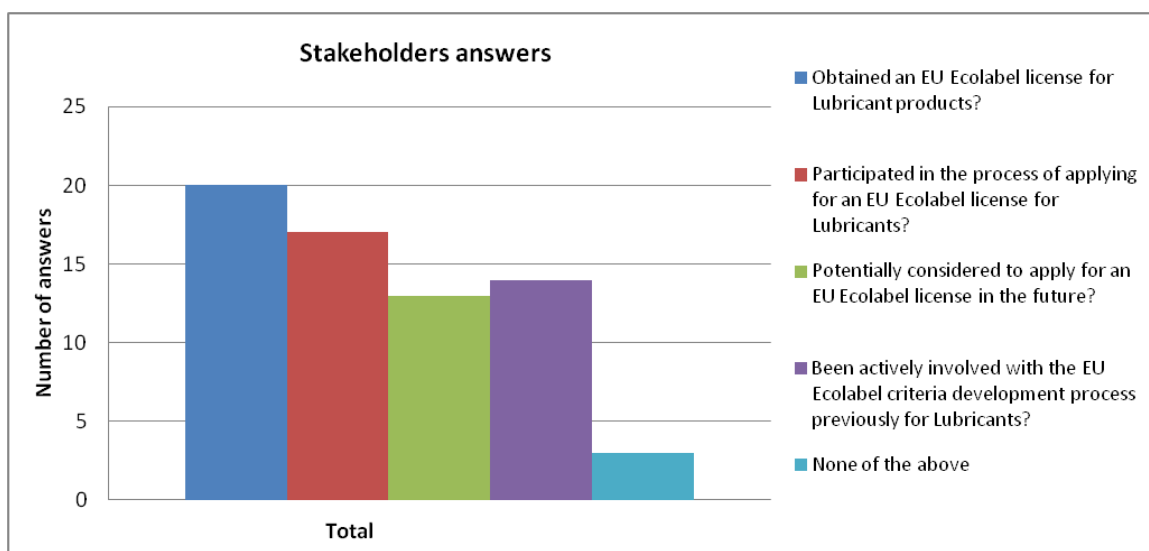


Figure 3: Involvement of the stakeholders with the EU Ecolabel

48% of the respondents obtained the Ecolabel license and 31% consider applying for the EU Ecolabel license in the future.

Definition

The definition proposed in the questionnaire is accepted by 21 stakeholders. However, 7 of them think that the definition could be improved and added comments or proposed new definitions. A stakeholder stated that they are fine with revising the definition because the old definition excluded solid lubricants. However, they think that the proposed definition is too narrow. In their view in order to include hydraulic fluids it should also mention that the purpose of the substance or mixture may also be the transmission of power.

Comments generally revealed that the functionality of a lubricant is very broad, for this reason some stakeholders consider that it is important not to limit the uses of the lubricant in the definition. They highlighted that the lubricant function is not only reducing friction, but it could also be to keep friction constant or at a high level, remove heat, or transmitting power.

In addition, a stakeholder mentioned that sometimes the fine powders (carbon) can also be used to smooth two surfaces to reduce the friction.

A stakeholder stated that there are rust preventive fluids that use similar technology as lubricants (base fluids + additive). They claimed that the definition should cover rust preventive fluids.

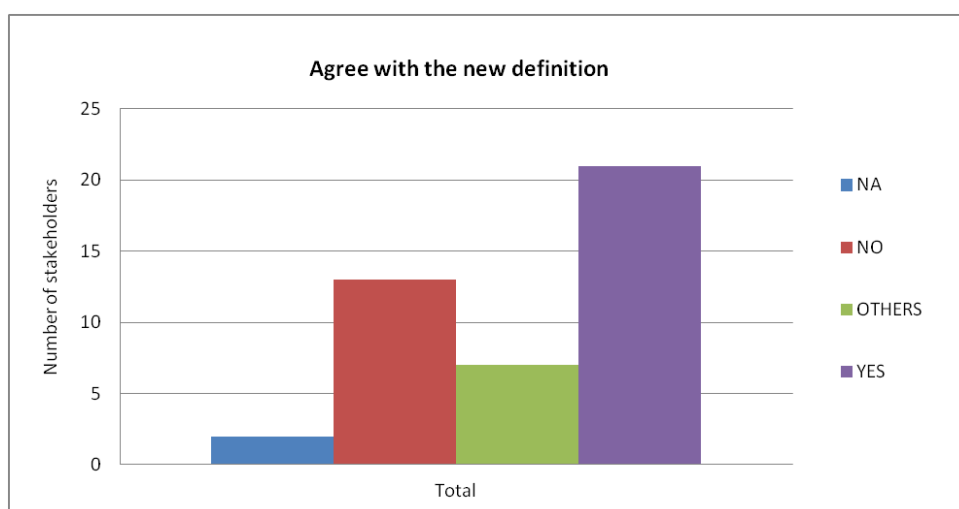


Figure 4: General stakeholder's agreement with the current definition. (NA: no answer; NO: disagree with the new definition; OTHERS: proposals for definitions; YES: agree with the new definition)

Scope and ISO harmonisation

In order to analyse the answers related to the scope, the organizations that have been involved with the EU Ecolabel previously, have been particularly considered. This refers to respondents who answered positively to the following questions: "Obtained an EU Ecolabel license for lubricant products?" and "Participated in the process of applying for an EU Ecolabel license for lubricants?". Considering this sample (26 stakeholders), 21 of the stakeholders did not have difficulties to understand the existing scope. Few stated that the formulation is not easy to understand for first-time applicants. They indicated that they also had problems with the choice of categories under which their products fall, due to the fact that same products could fit into two categories.

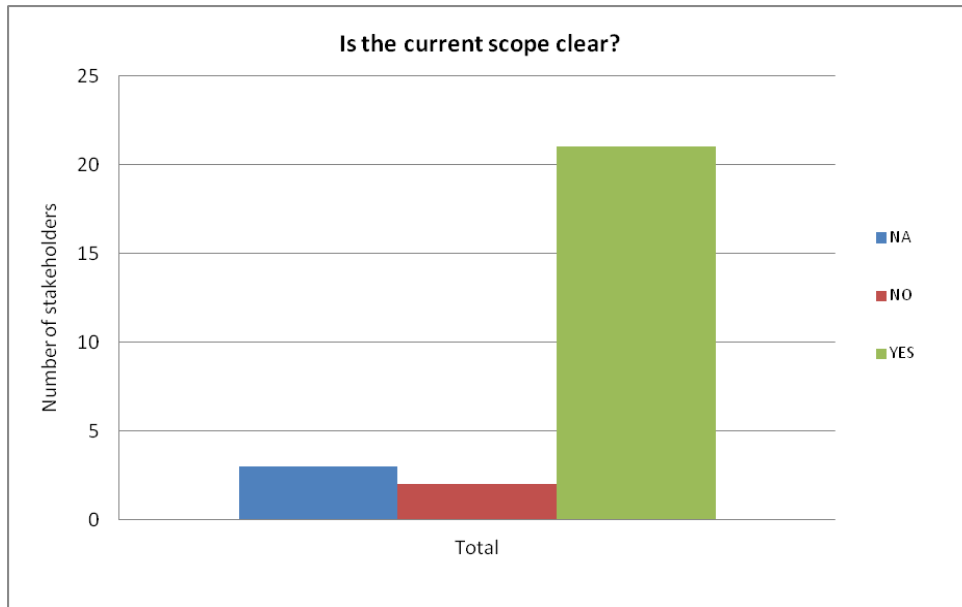


Figure 5: Answers related to the understanding of the current scope of the EU Ecolabel. (NA: no answer; NO: the current scope is not clear; YES: the current scope is clear)

The below figure shows the answers of the stakeholders by type of organization:

- I stands for lubricant industries independent of petroleum industries,
- P for lubricant industries bound to petroleum industries,
- RM for the suppliers of raw materials,
- O for others (Competent Bodies, for example).

In all categories, stakeholders consider that the alignment with the ISO 6743 will be better. However, there are comments that refer to potential difficulties of using this classification, due to the different categories included. Some stakeholders commented on the questionnaire that a first classification according to the environmental impact would be clearer, adding the ISO 6743 families as sub-classifications.

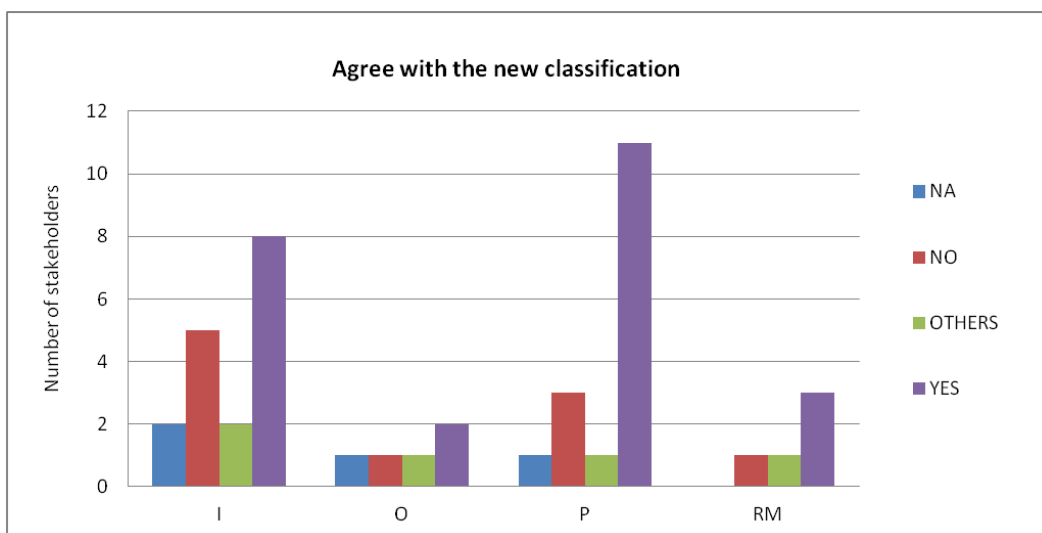


Figure 6: Stakeholder's agreement with the current classification depending on the type of stakeholder. (NA: no answer; NO: disagree with the new classification; OTHERS: proposals for classification; YES: agree with the new classification)

Several stakeholders suggested that extending the scope to all ISO subcategories will make the criteria too complex. They suggested including only the base categories or families or grouping the subfamilies considering their impact to the environment. They stated that a classification according to ISO 6743 would be too large and complicated in one step. Thus, they would prefer a step-by-step process, i.e. identifying single further product groups relevant for the environment.

Regarding the question on inclusion of water based lubricants into the EU Ecolabel scope, 25 stakeholders agree with this proposal.

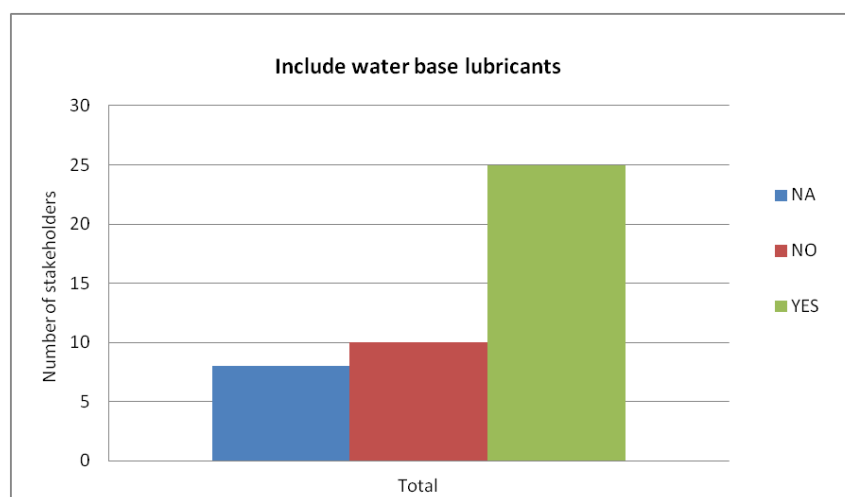


Figure 7: Stakeholder’s agreement with the new proposal of include water based lubricants. (NA: no answer; NO: disagree to include water base lubricants; YES: agree to include water base lubricants)

If the responses are analysed by types of stakeholders, although the 58% of the stakeholders agree to include water base lubricants (Figure 7), if the answers are analysed by type of stakeholders (independents of petroleum industries, bound to petroleum industries, suppliers of raw materials, and others), the proportion varies: 65% of the industries independents of petroleum industries agree to include the water base lubricants, whereas only 44% of the industries bound to petroleum industries are in favour of this extension of the scope Figure 8.

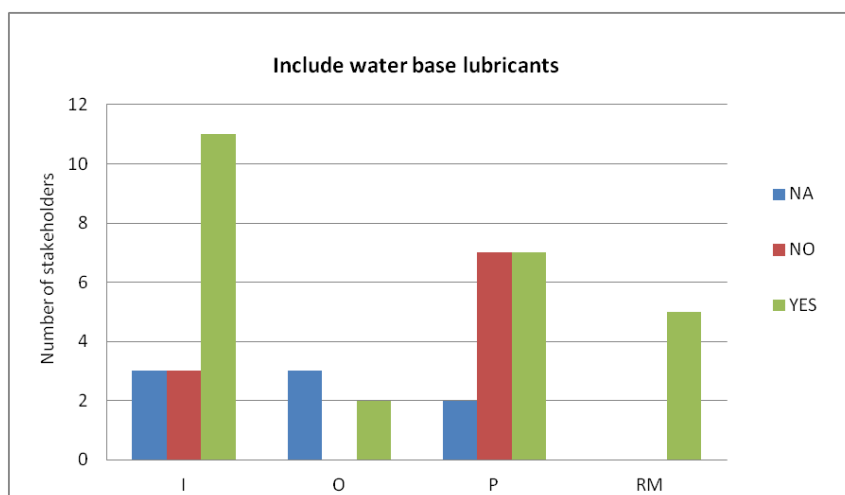


Figure 8: Stakeholder’s agreement with the new proposal of include water based lubricants. (NA: no answer; NO: disagree to include water base lubricants; YES: agree to include water base lubricants)

Regarding the consideration to differentiate between indoor and outdoor products, more than 50% of the stakeholders consider it unnecessary. The stakeholders are of opinion that sometimes it is difficult to distinguish between these application areas, and also that some lubricants cannot be classified in only one of the two target applications.

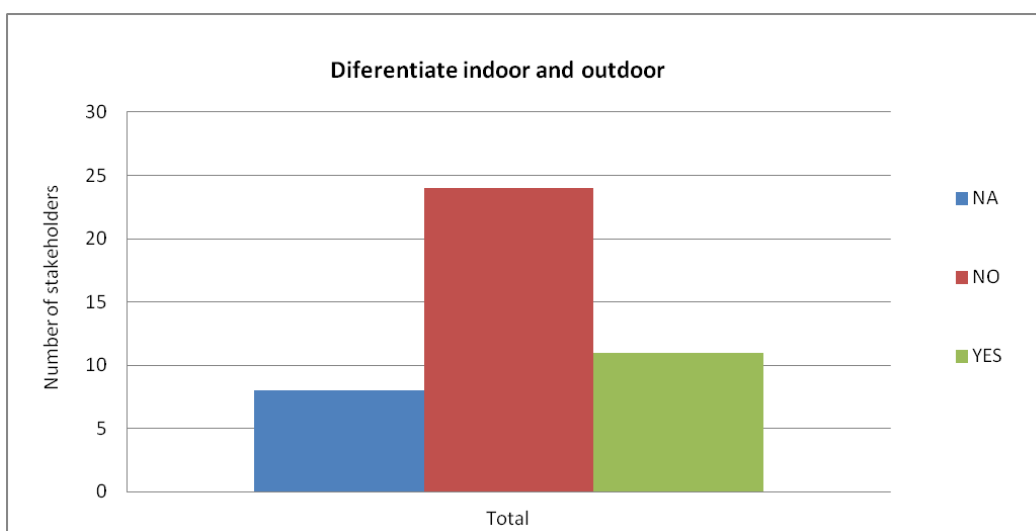


Figure 9: Stakeholder’s agreement with the new proposal to differentiate indoor and outdoor uses. (NA: no answer; NO: disagree to differentiate indoor and outdoor lubricants; YES: agree to differentiate indoor and outdoor lubricants)

4. Conclusions and recommendations on scope and definition for this revision

After analysing the existing labels for lubricants, the further research related to lubricants, the existing scope and the stakeholders input, the following considerations have been made in order to improve the current EU Ecolabel scope and definition.

Definition:

The product group name 'Lubricants' is proposed to be kept in the revised criteria set.

The current definition for lubricants is still proposed to be amended to be based on functionality in order to make it comprehensive enough to cover all products in the scope. However stakeholder's feedback has been considered and functionalities are suggested to be extended. In addition, the reference to the most common composition has been added to the initial proposal.

The following definition for lubricant is proposed in this initial stage of the revision:

Revised definition

"A lubricant means a substance or mixture capable of reducing friction, adhesion, heat, wear and corrosion when introduced between two solid surfaces in relative movement and capable to transmit power. The most common constituent substances are base fluids and additives"

The new definition takes into account main opinions of the stakeholders including:

- The inclusion of fine powders (carbon)
- Transmission power functionality (hydraulic fluids)
- Rust preventive oils, heat transfer fluids and transformer oils

With regard the complementary definitions, no changes are proposed at this stage; however the revised scope, the revised criteria, further research and discussions with stakeholders, might result in a proposal for amendments in a later stage of the revision process.

Complementary definitions

'base fluid' means a lubricating fluid whose flow, ageing, lubricity and anti-wear properties, as well as its properties regarding contaminant suspension, have not been improved by the inclusion of additive(s);

'substance' means a chemical element and its compounds in the natural state or obtained by any production process, including any additive necessary to preserve the stability of the products and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition;

'thickener' means one or more substances in the base fluid used to thicken or modify the rheology of a lubricating fluid or grease;

'main component' means any substance accounting for more than 5 % by weight of the lubricant;

'additive' means a substance or mixture whose primary functions are the improvement of the flow, ageing, lubricity, anti-wear properties or of contaminant suspension;

'grease' means a solid to semi-solid mixture which consists of a 'thickener' and may include other ingredients imparting special properties in a liquid lubricant.

ISO 6743 “Lubricants, industrial oils and related products”:

For the lubricant types to be covered in the scope during this revision it is suggested to harmonise to the nomenclature of the lubricant families used in the ISO 6743 classification aiming to establish unambiguously what are the types of lubricants considered under the scope and to set clearer minimum technical performance requirements (to define a standard test per family or sub-family).

Scope:

Existing scope only represents a **16% of the total lubricants market**. In the light of the feedback received, the initial proposal made in the questionnaire has been revised to take into consideration stakeholder's feedback.

It is therefore suggested to keep a focus on the **total loss** (lubricants physically exposed to the surroundings, their entry into environment is unavoidable and they are irretrievable) and **high risk** (of accident) **lubricants** (lubricants used in confined systems which are susceptible to accidental losses) and to extend the scope in order to cover a higher market share.

The following table shows the included and excluded families in the current EU Ecolabel and the level of potential lubricant loss during use.

Table 5: Included and excluded families following ISO 6743 classification in the current EEL and the general type of lubricant loss

ISO Family	ISO 6743-99 Description		Existing EU Ecolabel	Lubricant loss
A	Total loss systems		Included	Total
B	Mould release	Concrete	Included	Total
		Industrial	Excluded	Accidental
C	Gears		Included	Accidental/Partial
D	Compressors		Excluded	Accidental
E	Internal combustion engine oils	4-T stroke oil	Excluded	Accidental
		2-T stroke oil	Included	Total
F	Spindle bearings, bearings, and associated clutches		Excluded	Accidental/Partial
G	Slideways		Excluded	Partial
H	Hydraulic systems		Included	Accidental/Partial
M	Metalworking		Excluded	Accidental
P	Pneumatic tools		Excluded	Accidental/Partial
Q	Heat transfer fluids		Excluded	Accidental

R	Temporary protection against corrosion		Excluded	Total
T	Turbines	Stern tube	Included	Total
		Industrial	Excluded	Accidental/Partial
U	Heat treatment		Excluded	Accidental
X	Greases		Included	Accidental /Partial/Total

In addition, the environmental impacts of a lubricant product can be caused in any life stage of its life cycle (e.g. during raw material extraction or at the end of life), and not only from its potential release to the environment.

For this reason, it is considered reasonable to extend the scope to other lubricants not currently covered and that presents risk off accidental losses (**accidental loss lubricants**), and to **other risks lubricants** which are those lubricants associated to other environmental impacts than those associate to its potential release.

It is therefore suggested to explore the possibility to extend the scope to categories (according to the ISO) not covered by the existing EU Ecolabel. Several categories suggested to be further explored, for instance mould release (category B), metalworking fluids (category M) and rust preventive oils (category R) are included in other voluntary labelling schemes. Market shares and environmental impacts of each category, as well as feasibility of developing criteria for each category will determine during the revision the degree of extension of the scope in a later stage.

In addition, most of the current categories covered mostly encompass professional and industrial products. However, the EU Ecolabel is a label that mainly target consumers and it is therefore suggested to include categories of lubricants that are usually sold to **private end consumers** as well (e.g. automotive lubricants).

In relation to **water based lubricants**, there is a general interest from reflected in stakeholder's opinion (Figure 7), that supports their inclusion into the scope of the revised EU Ecolabel.

Water-based lubricants are mainly used under the category of Metal Working Fluids and Mould Release agents (water-in-oil emulsions). This category is estimated in almost 2MT globally, from which half million ton is the estimated market in Europe.

There is evidence of the use of water-based chemistries for other categories as Hydraulic fluids (HF), however these lubricants are classically made of oil and additives and there is not reliable market data on the share of water based hydraulic fluids. Even though, there have been attempts to prove the goodness of water-based HF, with pros and cons, they seem not to take-off in the market place.

- Water-based HF pros: easier to clean accidental spills, cost saving at the plant level (does not take into account. They are not flammable).
- Water-based HF cons: can freeze in winter, which can mean expensive maintenance costs, tendency to get contaminated with bacteria, which forces to

use antibacterial agents. Must be very closely monitored to ensure the system stays within the tolerance limits. Several components in the system (pumps, valves, actuators) must be adapted to a water containing environment.

It is initially suggested to explore further the possibility to set criteria applicable to water based lubricants for those categories where water based option is available.

With regard to **indoor/outdoor differentiation**, after the analysis of the stakeholder's comments, it is understood that the differentiation between indoor and outdoor lubricants is not considered necessary and straight forward due to the difficulty to assign clearly a product to a specific category.

It is important to note that considering potential difficulties to enlarge the scope in one step, the number of categories and the type of lubricant family(ies) to be included in the scope and each category is subject to the research presented in the following sections of this report: technical and market analysis; and to the stakeholders discussions and further research during the revision process. Further details on the scope extension are presented in section 4.7.

TASK 2: Market report

1 Introduction

The aim of this section of the report (Task 2, market analysis) is to provide the market information needed for the revision of the EU Ecolabel for Lubricants (Commission Decision 2011/381/EU⁵⁶). Considering that the EU Ecolabelled lubricants are marketed also outside the EU, and that applicants from third countries (e.g. US) have applied for this EU Ecolabel, the data gathered under this section reflect the EU and global markets. The following chapters will provide an overview on the global lubricants market, its current size in volume as well as in value. Key market figures will be presented in this section, aiming to enable a quantitative assessment of the economic relevance of the different lubricant products at micro and macro level. In addition, information will be provided on the market dynamics for this product group in order to identify relevant trends, drivers, innovations, and market segmentation, both, at European and at global (world) level, in coming years until 2022.

The classification of lubricants according the market where they are going to be used will be also reviewed, from a global and from a regional perspective. The main current drivers for this product range and the forecast for 2022 are given. Finally, a specific overview is given on the still small but growing biolubricants market.

⁵⁶ 2011/381/EU: Commission Decision of 24 June 2011 on establishing the ecological criteria for the award of the EU Ecolabel to lubricants

2 Ecolabel licenses and products today

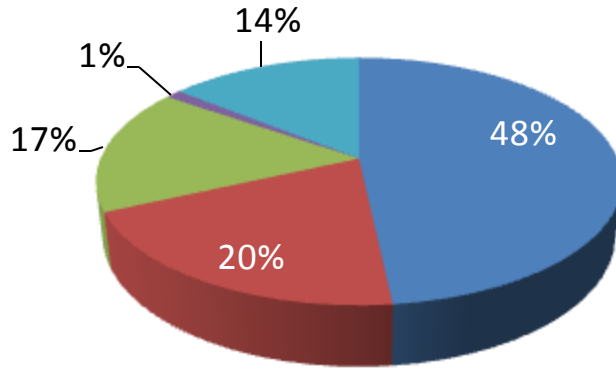
Recent data from the EU Ecolabel Helpdesk Team revealed that 97 licenses have been awarded with a flower. In total, 363 products have become available on the market (EU and third countries). The following figure reflects the competent bodies involved and the share of licenses evaluated by them:

CB	Licences	Products
Austria	3	4
Belgium	1	12
Czech Republic	2	9
Finland	1	4
France	10	69
Germany	48	160
Netherland	12	47
Poland	2	3
Spain	1	3
United Kingdom	17	52

Figure 10 Competent bodies that assessed current licenses (source: The EU Ecolabel Helpdesk Team (September 2016))

Among others, the companies that have applied the flower are: *NYCO, TOTAL Lubrifiants, Zeller-Gmelin GmbH&Co.KG, BASF SE, CARL BECHEM GMBH, Klüber Lubrication München SE & Co. KG, Fuchs Europe Schmierstoffe GmbH, KAJO-Chemie GmbH, ORLEN OIL Sp. z o.o., REPSOL LUBRICANTES Y ESPECIALIDADES S.A., CEPSA LUBRICANTES SA, PANOLIN AG, RS Clare, Vickers Oils, Lubrizol, Shell International Petroleum Company Ltd, etc...* in EU and *Royal Purple LLC* in US.

Competent Bodies has been consulted in order to know the categories distribution. Information has been obtained for 176 products. Most successful category correspond to hydraulic oils, however there is a growing number of greases and other categories being qualified for the flower. See the shares in the following figure:



- 1 - hydraulic fluids and tractor transmission oils
- 2 - greases and stern tube greases
- 3 - chain saw oil, concrete release agents, wire rope lubricants, stern tube oils and other total loss lubricants
- 4 - two-strokes oils
- 5 - industrial and marine gear oils

Figure 11 Awarded products by categories

3 Global lubricant market

This section analyzes the economic data regarding the product group under study. The scope of the analysis is global, encompassing: Europe, North America, Asia Pacific, Central and South America, Middle East and North Africa. The data have been provided by a Market Research Institute in the US (<http://www.grandviewresearch.com/>). All the market results cover all lubricant types, including biolubricants, which represent only a small share of the market as it'll be shown in chapter 5.

3.1. Overview, main trends, and growth perspective

The global demand for lubricants was 36.4 MT in 2014 and it is expected to reach 43.9 MT by 2022, growing at a CAGR⁵⁷ of 2.4%. In value terms, the market had a value of 35.7 billion USD in 2014 and it is expected to reach 68.5 billion USD in 2022, growing at a CAGR of 7.3% (see

⁵⁷ CAGR = Compound Annual Growth Rate

Table 6 and Table 7).

From a regional point of view, the global market is usually segmented into five regions:

- **Europe:** EU, Eastern Europe
- **North America:** US, Canada, Mexico
- **Asia Pacific:** China, India, Japan, Korea, Thailand, Indonesia, Australia, New Zealand, among others
- **Central & South America:** Brazil, Argentina, Paraguay, Chile, and Colombia, among others
- **Middle East & Africa:** United Arab Emirates, Saudi Arabia, Oman, South Africa, among others

Table 6 Global lubricants demand by region 2014 and 2022 in MT

	2014	2022
World	36.4	43.9
Europe	7.3	8.3
North America	7.6	8.6
Asia Pacific	15.3	19.4
Central & South America	2.5	3.2
Middle East & Africa	3.6	4.5

Table 7 Global lubricants demand by region 2014 and 2022 in billion USD

	2014	2022
World	35.7	68.5
Europe	7.4	13.0
North America	7.6	13.6
Asia Pacific	14.9	30.8
Central & South America	2.6	5.1
Middle East & Africa	3.3	6.0

A key factor of the development of the global lubricants market is expected to be the fast industrialization of the BRICS countries (Brazil, Russia, India, China, and South Africa). The positive outlook of the global automotive industry, with increasing consumer vehicles demand, in particular in China, India, and Brazil, will continue to be important in this respect.

More stringent environmental regulations as well as an increasing market penetration of bio-based lubricants will remain a key challenge for several market players and an opportunity for others (see chapter on Biolubricants (Chapter 5)).

Asia Pacific was in 2014 the largest regional market, accounting with over 40% of the global demand. Given the rapid industrialization in India, China, and Indonesia, it is expected to remain the fastest growing regional market.

The per-capita annual consumption of lubricants (Figure 12) presents significant opportunities for growth. In North America (Canada and United States) the consumption tops the 19 kg/person-year. In Europe, Middle East and Latin America consumption is between 5 and 10 kg, whilst Asia Pacific and Africa yearly consumption ranges between 2 and 4 kg (see Figure 12).

Increasing demand for engine oils, transmissions fluids, and gear oils in commercial and consumer automotives is expected to drive the global lubricants market growth. Economic growth in emerging markets of Asia Pacific has led to an enormous increase in automotive sales. Sales of passenger cars in these regions have witnessed booming sales in recent years. With increasing industrial output and high consumerism in these regions, logistics and commercial transportation are set to continue this growth path. This trend led to an increase in commercial vehicle sales, particularly heavy-duty trucks, light commercial vehicles, busses, and container trucks. Increasing number of automobile sales is expected to drive lubricants demand over the period 2015-2022.

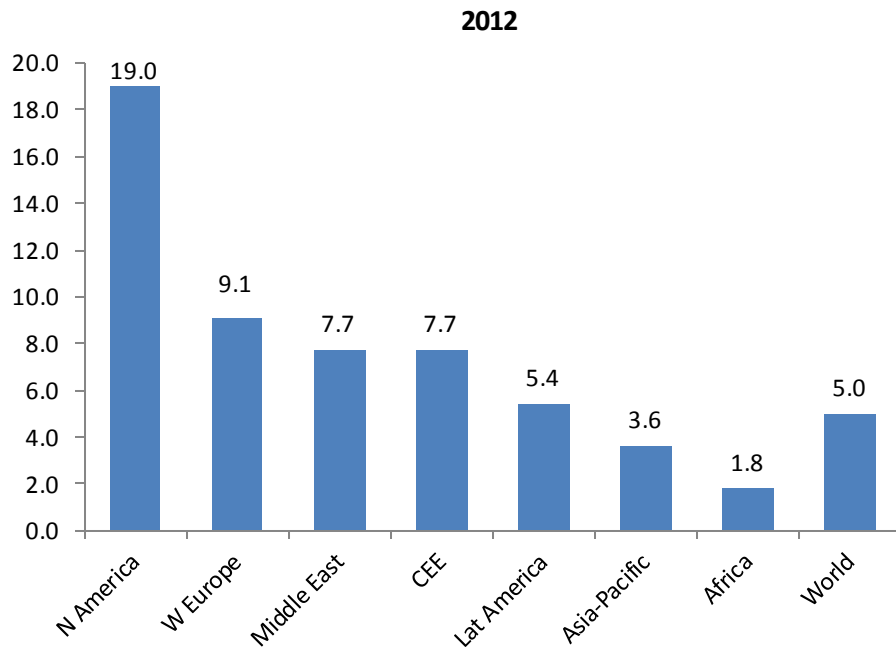


Figure 12 Per capita lubricants consumption by region in 2012 [kg/person-year]

Global lubricants revenue dropped in 2012-2013. This drop in revenue was attributed to a sharp drop in crude oil prices, which led to a drop in base oil prices for that particular year. A similar trend was observed in 2014 when crude oil prices fell even lower.

Increasing importance for industrial machinery maintenance in the manufacturing sector as a tool to minimize operational costs has led to a shift towards condition-based maintenance instead of breakdown maintenance. Additionally, increasing industrial output particularly in metal forming, foundry, plastics, machining, and mining industries of China and India have led to capability expansions by many companies. Demand for lubricants in these industries is expected to significantly grow over the forecast period. Lubricants such as industrial engine oils, metalworking fluids (metal cooling fluids and cooling oils) and process oils are expected to witness immense growth over the forecast period till the year 2022.

3.2. Classification

Lubricants are commonly manufactured from base fluids and additives. The vast majority of lubricants use as base fluid the mineral oil, which is derived from petroleum sources, such as crude oil, shale oil, and coal-bed methane (CBM). After the refining process, these mineral oils can be of different types, paraffinic oils, naphthenic oils, and aromatic oils. A few lubricants, though clearly on the rise, do not use mineral oil as base oil, but vegetable oil instead; these vegetable oils are primarily triglyceride esters derived from plants. All the information given in chapters 2, 3, and 4 of this Task 2, Market report, refer to all lubricant types, either using mineral oil (the majority in the market), or using vegetable oil. Due to the growing importance of vegetable oil based lubricants, these will be further explained in chapter 5, biolubricants.

These base fluids, in combination with additives, generate lubricants presenting a wide spectrum of applications across various industries, as automotive, aviation, general manufacturing, and marine transportation.

As it has been presented in the previous section of this report (Task 1, scope and definition), the lubricant products can be classified in a number of ways according to:

- The application: industrial, automotive,
- The composition: biolubricants (renewable), based on mineral oils (fossil origin),
- The physical form: oil, grease,
- The area of application: land, marine,
- The base oil used: The American Petroleum Institute (API) distinguishes among five groups (I, II, III, IV, and V)⁵⁸.

The market usually classifies the lubricants into three main groups:

- Industrial,
- Commercial Automotive,
- Consumer Automotive.

The industrial group represents the largest group and their products are frequently grouped into five categories: Process oils, General Industrial oils, Metalworking fluids, Industrial engine oils, and others.

As mentioned in Task 1 section, the International Organization for Standardization (ISO) has developed a standard for the classification of lubricants: **ISO 6743**⁵⁹, for lubricants, industrial oils, and related products.

While the current EU Ecolabel scope clusters lubricants within 5 categories:

- Category 1: Hydraulic fluids and tractor transmission oils
- Category 2: Greases and stern tube greases
- Category 3: Chainsaw oils, concrete release agents, wire rope lubricants, stern tube oils and other total loss lubricants
- Category 4: Two-stroke oils
- Category 5: Industrial and marine gear oils

In order to know the market shares of the current EU Ecolabel categories, the ISO 6743 categories, as well as the common market categories, in order to considering the potential to harmonize with the standard, three tables have been created, linking both classifications (i.e. ISO 6743, and EU Ecolabel), with the market classification (for which the market data are available); the results are presented in following tables (Table 8, Table 9 and Table 10).

⁵⁸ API base oil categories are, in just a few words: Group I (solvent refined), Group II (hydrotreated), Group III (hydrocracked), Group IV (polyalphaolefines, PAOs), and Group V (all other base oils not included in Groups I through IV, such as PAO or esters)

⁵⁹ ISO 6743: Lubricants, industrial oils and related products – Classification

Explanations to abbreviations used can be found in Acronyms & Abbreviations section.

For an optimal understanding, each table has to be read **from left to right**, as the left columns are key drivers for each table.

Table 8 is organized taking the market categories into account. Column 1 lists the 13 different market categories: 5 industrial, 4 commercial automotive and 4 consumers automotive. Column 3 lists the tonnage for each category, which is well known from the market research report. The fourth column lists the corresponding ISO 6743 categories. It is rare to find these correspondences unambiguously. For instance, **Engine oil** (ISO category E), can be found in three different market categories: a) as part of the industry general oils, b) as heavy duty engine oil within the Commercial automotive, and c) as passenger vehicle motor oil, within the Consumer automotive. **Industrial process oils** are related to three different ISO categories: Compressors (D), Pneumatic tools (P), and Heat transfer fluids (Q), while they are not in the current Ecolabel categories, so that a 'No' entry can be found in the fifth column, Ecolabel. **Greases** are a unique ISO category (X), though greases can be found within three different market categories: a) Consumer automotive greases, b) Commercial automotive greases, and c) greases used in the industry, which are counted within the Industrial others. Accordingly, the 'X' letter can be found three times in column 4. In the fifth column (Ecolabel) sometimes **brackets** are used: no brackets means the specific Ecolabel category does unambiguously correspond to the market size in MT; an Ecolabel category within brackets means the market size for that specific category is unknown. As an example, the entry Grease can be found three times: two times without brackets, for the automotive market categories, where the market size is unambiguously known. The third entry, with brackets, means the greases used in the industrial sector are unknown, as this market group is contained within the 'Industrial others'.

MWF are another example: it is a single market category, with a size of 1,91MT, listed as Industrial MWF (see Table 8), and it does correspond to 2 ISO categories, M (metal working) and B (mould release); both ISO categories B and M make up the 1,91 MT market size. On the other side MWF are not listed in the current Ecolabel scheme as such, though a specific group of mould release agents are listed in the Ecolabel, the concrete release agents. This explains how this mixed situation of MWF is expressed differently in the different tables: third row in Table 8, rows 2 and 9 in table Table 9, and row 6 in Table 10.

Table 8 Market classification for lubricants

	Market	Global MT (2015)	ISO 6743	Ecolabel category
Industrial	Process oils	4.57	D,P,Q,U	No
Industrial	General industrial oils	4.97	G,H,C	1-Hydraulics 5-Gear IND
Industrial	MWF	1.91	M,B	No
Industrial	Industry engine oils	1.58	E,Z,T	No
Industrial	Others	1.65	F,R,X,Y,A	(2-Grease) (3-Chainsaw)
COM-A	Heavy Duty Engine Oil	7.22	E	No
COM-A	Hydraulic & Transmission Fluid	2.15	H	1-Hydraulics

COM-A	Gear oil	2.22	C	No
COM-A	Grease	0.53	X	2-Grease
CON-A	Passenger Vehicle & Motor Oil	7.46	E	No
CON-A	Automatic Transmission Fluid	1.11	H	1-Hydraulics
CON-A	Gear oil	1.33	C	No
CON-A	Grease	0.40	X	2-Grease
TOTAL		37.10		-

Table 9 ISO 6743 classification for lubricants, industrial oils and related products

ISO Family	ISO 6743-99 Description	Ecolabel category	Market group	Volume (MT)
A	Total loss systems	3	IND - Others	Included in IND - Others 1.65
B	Mould release	(3 – Concrete release)	IND - MWF	Included in MWF (1.91)
C	Gears	(5)	IND – General oils COM-A – Gear oil CON-A – Gear oil	3.55 + Part of General industrial oils 4.97
D	Compressors		IND-Process oils	4.57
E	Internal combustion engine oils	No	IND Engine oils COM-A – HDEO CON-A - PVMO	16.26
F	Spindle bearings, bearings, and associated clutches	No	IND - Others	1.65 (Except Industrial Greases)
G	Slideways	No	IND-General industry oils	Included in General Industrial Oils (4.97)
H	Hydraulic systems	(1)	IND – General industry oils COM-A – H&TF CON-A - ATF	3.26+? ⁶⁰
M	Metalworking	No	IND – MWF	1.91 ⁶¹
P	Pneumatic tools	No	IND - Process oils	Included in IND-Process oils (4.57)
Q	Heat transfer fluids	No	IND - Process oils	Included in IND-Process oils 4.57
R	Temporary protection against corrosion	No	IND – Others	Included in IND – Others (1.65)

⁶⁰ A part of General industrial oils: 4.97

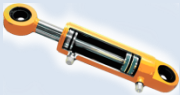
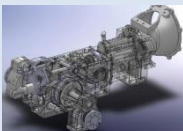
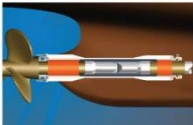

⁶¹ Includes also mould release agents in the 1.91.

T	Turbines	No	IND – Engine oils	Included in 1.58
U	Heat treatment	No	IND - Process oils	Included in 4.57
X	Greases	2	IND – Others COM-A – Grease CON-A - Grease	0.93+? ⁶²
Y	Miscellaneous			
Z	Cylinders & steam machines	No	IND – Engine oils	Included in Industrial engine oils 1.58
TOTAL				37.10

Source: ISO 6743

Table 10 lists on the left column the 5 different Ecolabel Categories, 1 through 5. These 5 Categories have been split in the different product types, making a total of 11 product types. An image has been included for clarity, where possible.

Table 10 Ecolabel classification for lubricants

	Ecolabel Category		ISO 6743	Market	Global MT (2015)
	1	Hydraulic fluids	H	COM-A CON-A General industrial oils	3.26+ Part of General industrial oils 4,97
	1	Tractor transmission oils	H	General industrial oils	
	2	Greases	X	COM-A Grease CON-A Grease Other industrial lubricants	0.93 + Part of Other industrial oils 1.65
	2	Stern tube greases	X	Other industrial lubricants	
	3	Chainsaw oils	A	Other industrial lubricants	Included in 'Other industrial lubricants'

⁶² A part of Other industrial oils: 1.65.

	3	Wire rope lubricants	A	Other Industrial oils	1.65.
	3	Stern tube oils	A	Other industrial lubricants	
	3	Other total loss lubricants	A	-	-
	3	Concrete release agents	B	Metalworking fluids	Included in MWF: 1.91.
	4	Two-stroke oils	(E)	Industrial engine oils	Included in Industrial engine oils 1.58
	5	Industrial and marine gear oils	C	IND General oils	Included in General industrial oils 4.97
				Industrial process oils	4.57
			M	Metalworking fluids	1.91
			E	Industrial engine oils	1.58
				Other industrial lubricants	1.65
			E	COM-A HDEO	7.22
			H	COM-A H&TF	2.15
			C	COM-A Gear oil	2.22
			E	CON-A PV&MO	7.46
			H	CON-A ATF	1.11
			C	CON-A Gear oil	1.33
TOTAL					37.10

In the first section of this report, TASK 1: scope and definition, it is recommended for this revision:

1. To harmonise with the nomenclature of the lubricant families used in the ISO 6743 classification aiming to establish unambiguously what are the types of lubricants considered under the scope and to set clearer minimum technical performance requirements.

2. To extend the scope in order to cover a higher market share. It is therefore suggested to explore the possibility to extend the scope to categories (according to the ISO) not covered by the existing EU Ecolabel. Several categories suggested to be further explored, for instance mould release (category B), metalworking fluids (category M) and rust preventive oils (category R) are included in other voluntary labelling schemes. Market shares and environmental impacts of each category, as well as feasibility of developing criteria for each category will determine during the revision the degree of extension of the scope in a later stage.

An estimation of the market share for the categories to be studied for potential inclusion on the revised scope, is presented below:

Family B mould release (currently only concrete release agents are considered) Family M metalworking	1.91MT
Family D Compressors Family P pneumatic tools Family Q heat transfer fluids	4.57MT
Family E internal combustion engine oils release (currently only two-stroke oils are considered)	16.26MT
Family F spindle bearings, bearings and associated clutches Family R temporary protection against corrosion	1.65MT
Family G slideways Family T turbines	Unknown (part Hydraulic systems 8.23MT)
Family U heat treatment	Unknown

3.3. Raw materials

Since 2011, global **lubricant base oil** average prices were observed as having a downward trend similarly to crude oil price trend. Lube oil base stock prices are mainly dependent on 1) the crude oil pricing and 2) the global supply-demand scenario.

With regard to the global crude oil average spot prices were observed to have a relatively stable supply-demand scenario between 2011 and 2013. Average crude oil prices recovered from the global economic downturn in 2009 and they reached USD 79.5 per barrel in 2010. Growing oil demand from downstream segments along with limited global oil production led to high crude oil prices globally. Average crude oil spot prices during 2011 reached USD 106.5 per barrel, rising further to 107 in 2012. The oversupply as well as the low demand from downstream sectors has led, however, to a steep fall in crude oil spot prices in 2014.

In relation to the lubricant base oil supply -demand scenario, most of the base stock capabilities are centered in Middle East and Asia Pacific, whilst Europe and North America are major importers.

Falling crude oil prices along with large inventory stocks with net importers have led to a steep fall of average lube oil prices. Average lube oil prices fell from an all time high of USD 1 275 per ton in 2011 to 976 per ton in 2014.

Again this background, average lube oil base stock prices are expected to witness a significant hike over the next six years on account of expected recovery of global demand-supply along with increasing dependence on synthetic lubricants. These prices are expected to follow a similar trend as that of global average crude oil spot prices.

3.4. Main manufacturers

Major producers of base oil can be grouped into two categories: those **linked to an oil company** and those that are not linked to an oil company, often tagged as **independent manufacturers**.

In the global lubricants base oil market four Companies account for almost 45% of the share (Shell, ExxonMobil, BP/Castrol, and Chevron). See Figure 13.

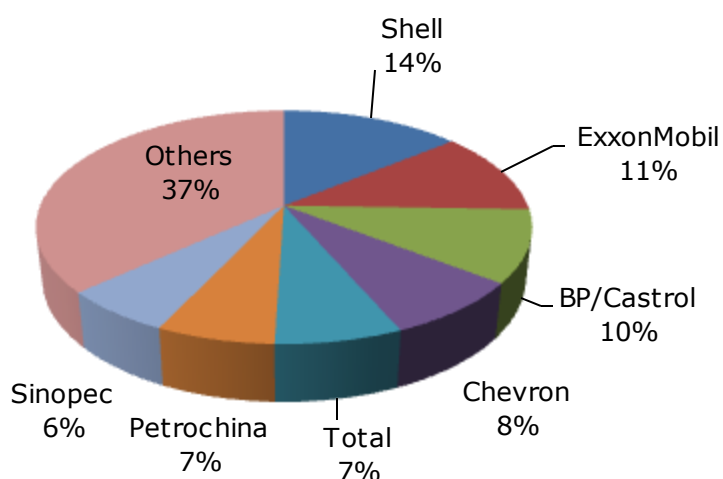


Figure 13 Global manufacturing companies of lubricants in 2013

Total, Petrochina, and Sinopec make up for another 20% of share; other companies among the top lubricant producers are Fuchs, Pennzoil, and Amsoil Inc. Among the top ten global players, Fuchs is the only independent one.

A few major oil companies, BP, Shell, Ashland Inc., and ConocoPhillips have established their own subsidiaries, Castrol, Pennzoil, Valvoline, and Kendall, respectively. The remnant one third of the market is much more fragmented, with around 600 lubricant manufacturers worldwide.

The additives manufacturers are most often chemical or specialty chemical companies, among them, BASF, Lanxess, Evonik, or Dow.

In order to gain competitive advantage, several big players, as Shell, ExxonMobil, or Kendall, have developed proprietary refining technologies for lubricant production, specifically and mainly for the motor oil, the prevalent segment in the market.

Another strategy to gain and retain market share is to have supply agreements for specific applications. These agreements with major end-users ensure steady sales of lubricants. Companies as Total, Shell, Amsoil, or Castrol, have entered into exclusive

supply agreements with Tata Motors, BMW, Ford, and Vestas Wind Systems, to supply their lubricant brands.

4 Lubricant market segmentation

This section studies in more detail the characteristics of the lubricant market, including the single segments. Global lubricants market shares by product type in the year 2014 and its development in the forecasted period till the year 2022 are presented in Table 11.

Table 11 Global lubricants market share by product 2014 and 2022

%	2014	2022
Industrial	39.6	39.5
Commercial Automotive	32.7	32.2
Consumer Automotive	27.7	28.3

The **industrial lubricants** are the largest product segment. Increasing consumption of general industrial lubricants and process oils in industrial machinery such as centrifuge, rotary compressors, air compressors, and machine bearings is expected to drive industrial lubricants demand over the period forecasted in this report.

Over the recent past, there has been an increase in industrial output in emerging economies such as China, India, Russia, Brazil, and South Africa. Industrial output rose particularly in core manufacturing sectors such as metal forming, foundry, consumer appliances, and plastics along with the mining industry. This trend has led to an increase in the use of lubricants such as process oils, metalworking fluids, industrial oils, and engine oils. A stable industrial output in the mentioned markets is expected to continue to drive industrial lubricants demand over the next 6 years.

Commercial automotive lubricants accounted for 32.7% of the total market volume in 2014. This product segment is largely driven by high consumption of engine oils in heavy duty vehicles such as trucks and busses. Growing demand for commercial automotives for transportation is expected to drive commercial automotive lubricants demand. Commercial automotive lubricants are projected to account for 32.2% by 2022.

Consumer automotive lubricants were 27.7% of the total market volume in 2014. The product segment is expected to gain market share and to account for 28.4% of the market volume by 2022. Growing passenger car sales in emerging economies of Asia Pacific and South America are expected to drive the demand for automotive lubricants, such as engine oils, transmission fluids and gear oils.

Growth in automotive sales across the globe, primarily driven by emerging markets, is expected to drive consumer automotive lubricants demand over the next years. Growing income levels and rising living standards in developing nations and emerging markets, has been driving the sales of passenger cars and motorcycles. This trend is expected to drive consumer automotive lubricants consumption over the next years. Engine oils and transmissions fluids are expected to witness considerable demand in consumer automotive lubricants over the next 6 years, given the universal application in automobiles of different kinds.

4.1. Industrial lubricants

Global industrial lubricants demand was 13.9 MT in 2012 and it reached 14.0 MT in 2013, keeping the same volume in 2014; it is expected to reach 17.3 MT in 2022, growing at a CAGR of 2.4% from 2015 to 2022 (see Table 12). Increasing industrial production in emerging markets of Asia Pacific and Latin America is expected to be a major factor driving industrial lubricants demand. Industries that are projected to witness high growth include mining, unconventional energy and chemicals. This trend is expected to further strengthen industrial lubricants demand in industrial engines, compressors, hydraulics, bearings, and centrifuges.

Table 12 Global industrial lubricants market volume estimates and forecast 2015-2022.

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	14.68	14.97	15.29	15.64	16.01	16.42	16.85	17.3	2.4%
Value USD (B)	15.66	16.79	18.01	19.28	20.62	22.06	23.58	25.19	7.0%
Volume Europe (MT)	3.66	3.72	3.78	3.84	3.91	3.99	4.08	4.17	1.9%
Europe USD (B)	4.41	4.63	4.87	5.12	5.38	5.65	5.95	6.26	5.1%

The consumer industrial lubricants can be divided into five different groups: process oils (PO), general industrial oils (GIO), metalworking fluids (MWF), industrial engine oils (IEO) and others.

General industrial oils were the largest product segment for industrial lubricants at 4.88 MT in 2014. Process oils followed general industrial oils at 4.48 MT in 2014. Metalworking fluids was the third largest product for industrial oil but it is expected to witness highest growth over the forecast period. Figure 14 presents the shares of different groups within the industrial lubricants category, while the respective volumes are given in Figure 15.

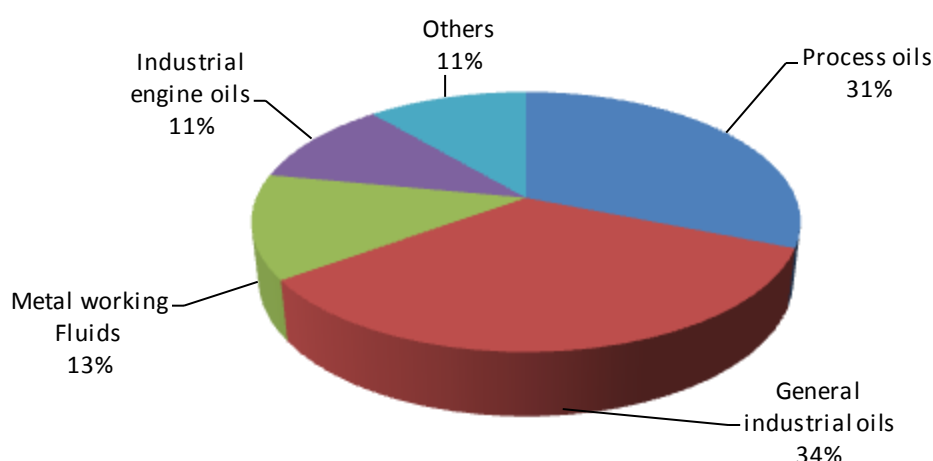


Figure 14 Global industrial lubricant market volume by product in 2014 (MT)

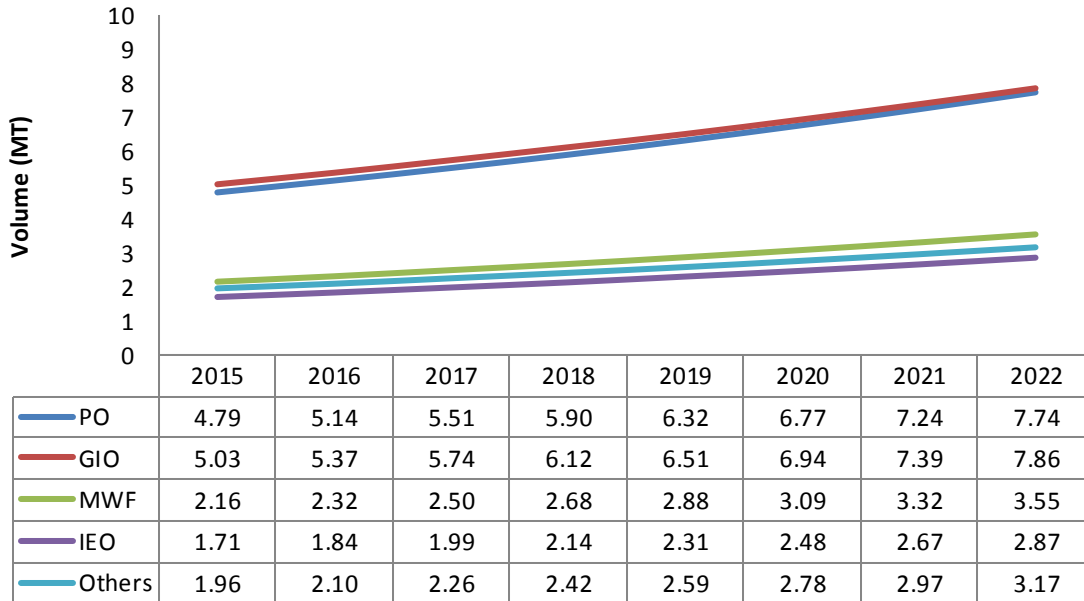


Figure 15 Global industrial lubricants market volume by product, 2015-2022 (MT)

Process oils

Process oils are used widely in chemical and other industries, either as raw material component or as an aid to improve manufacturing processes, for instance the Pneumatic tools oils. Main industries include: Cosmetics, Polymers, Defoamer, Textile, Cable fill, or Tire industry.

Global process oil demand was 4.31 MT and 4.35 MT in 2012 and 2013 respectively. In terms of revenue, the market was USD 4.52 B and USD 4.23 B in 2012 and 2013 respectively. In 2014 the demand was 4.48 MT and is expected to reach 5.39 MT by 2022, growing at a CAGR of 2.4% from 2015 to 2022. Europe market was 1.16 MT in 2015 and is expected to reach 1.32 MT by 2022 (see following table).

Table 13 Global industrial process oils market volume estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	4.57	4.66	4.76	4.87	4.99	5.11	5.25	5.39	2.4%
Value USD (B)	4.79	5.14	5.51	5.90	6.32	6.77	7.24	7.74	7.1%
Volume Europe (MT)	1.16	1.17	1.19	1.22	1.24	1.26	1.29	1.32	1.9%
Europe USD (B)	1.34	1.42	1.49	1.56	1.64	1.74	1.82	1.92	5.2%

General industrial oils

General industrial oils are regularly used for machinery maintenance in the industry in order to prevent industrial machinery from rust, wear & tear and other chemical corrosion problems. These include industrial hydraulic systems and Slideways.

Global general industrial oils demand was 4.71 MT and 4.75 MT in 2012 and 2013 respectively. In terms of revenue, the market was USD 4.82 B and USD 4.49 B in 2012 and 2013 respectively. In 2014 the demand was 4.88 MT and is expected to reach 5.80 MT by 2022, growing at a CAGR of 2.2% from 2015 to 2022. Europe market was 1.19 MT in 2015 and is expected to reach 1.33 MT by 2022 (see Table 14).

Table 14 Global general industrial oils market volume estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	4.97	5.06	5.16	5.27	5.38	5.51	5.65	5.80	2.2%
Value USD (B)	5.03	5.37	5.74	6.12	6.51	6.94	7.38	7.85	6.6%
Volume Europe (MT)	1.19	1.20	1.22	1.24	1.26	1.28	1.31	1.33	1.7%
Europe USD (B)	1.38	1.44	1.51	1.57	1.64	1.72	1.79	1.87	4.4%

Metalworking fluids

Metalworking fluids (also known as cutting fluids, cutting oils, or coolants) are designed specifically for metalworking processes, such as machining and stamping. They provide a double function: cooling and lubrication. They usually consist of water-in-oil emulsions that are usually diluted at 5-8% in water at the application point. In this report, mould release and pressure die casting (PDC) products, similar to MWF from a composition point of view, are counted within this product group. PDC products are used diluted 0.1-0.3% in water.

Global metalworking fluids demand was 1.79 MT and 1.81 MT in 2012 and 2013 respectively. In terms of revenue, the market was USD 2.02 B and USD 1.82 B in 2012 and 2013 respectively. In 2014 the demand was 1.87 MT and is expected to reach 2.29 MT by 2022, growing at a CAGR of 2.6% from 2015 to 2022. Europe market was 0.49 MT in 2015 and is expected to reach 0.56 MT by 2022 (see Table 15).

Table 15 Global metalworking fluids market volume estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	1.91	1.95	2.00	2.05	2.10	2.16	2.22	2.29	2.6%
Value USD (B)	2.16	2.32	2.5	2.68	2.88	3.09	3.31	3.55	7.4%
Volume Europe (MT)	0.49	0.49	0.50	0.51	0.52	0.54	0.55	0.56	2.1%
Europe USD (B)	0.62	0.66	0.69	0.73	0.78	0.82	0.87	0.91	5.6%

Industrial engine oils

Industrial engine oils are used to reduce friction and wear in industrial engines for powered equipment. With the majority of industrial engines running on diesel, there is a growing demand for engine oils with shear resistance and specific viscosity index. In this report, Turbine engine oils are also included in the industrial engine oils.

Industrial engine oils demand was 1.48 MT and 1.50 MT in 2012 and 2013 respectively. In terms of revenue, the market was USD 1.58 B and USD 1.49 B in 2012 and 2013 respectively. In 2014 the demand was 1.55 MT and is expected to reach 1.90 MT by 2022, growing at a CAGR of 2.7% from 2015 to 2022. Europe market was 0.40 MT in 2015 and is expected to reach 0.47 MT by 2022 (see Table 16).

Table 16 Global industrial engine oils market volume estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	1.58	1.62	1.66	1.70	1.74	1.79	1.84	1.90	2.7%
Value USD (B)	1.79	1.84	1.98	2.14	230	2.48	2.66	2.87	7.7%
Volume Europe (MT)	0.40	0.41	0.42	0.43	0.44	0.45	0.46	0.47	2.1%
Europe USD (B)	0.49	0.52	0.56	0.59	0.62	0.66	0.71	0.75	6.0%

Other industrial lubricants

Other industrial lubricants are the lubricants used in auxiliary units, bearings, spindle bearings, circulating systems, and food production machinery, which requires a special quality approved for food contact. In this report, industrial greases are included in the other industrial lubricants.

Other industrial lubricants demand was 1.57 MT and 1.58 MT in 2012 and 2013, respectively. In terms of revenue, the market was USD 1.82 B and USD 1.73 B in 2012 and 2013, respectively. In 2014 the demand was 1.62 MT and is expected to reach 1.94 MT by 2022, growing at a CAGR of 2.3% from 2015 to 2022. Europe market was 0.43 MT in 2015 and is expected to reach 0.48 MT by 2022 (see Table 17).

Table 17 Global other industrial oils market volume estimates and forecast 2015-2022.

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	1.65	1.68	1.72	1.76	1.80	1.84	1.89	1.94	2.3%
Value USD (B)	1.96	2.10	2.26	2.42	2.59	2.77	2.96	3.17	7.1%
Volume Europe (MT)	0.43	0.43	0.44	0.45	0.46	0.46	0.47	0.48	1.8%
Europe USD (B)	0.55	0.58	0.61	0.64	0.67	0.71	0.75	0.78	5.2%

4.2. Commercial automotive lubricants

Global commercial automotive lubricants demand was 11.50 MT in 2012 and it has increased during the last years, reaching 11.57 MT in 2013 and 11.90 MT in 2014. It is expected to achieve 14.12 MT in 2022, having a total growth at a CAGR of 2.2% from 2015 to 2022 (see Table 18). The growth of sales of consumer automotives like trucks, busses and other forms of passenger transport is expected to drive commercial automotive lubricants market during this period. Public transport improvement on emerging markets (e.g. China, India or Brazil) is expected to enhance the commercial

automotive demand in the coming years. In terms of revenue, the market was USD 11 979.4 M in 2014 and is expected to reach USD 22 748.1 M by 2022.

The first market for commercial automotive in 2014 was Asia Pacific with 5.33 MT, followed by North America with 2.42 MT; Europe was placed third with 1.94 million tons.

Asia Pacific market has also the most significant expected revenue growth, increasing at a CAGR of 8.3% between 2015 and 2022. Other regional markets with significant revenue growth include Central & South America and Middle East & Africa. In Europe, the revenue is expected to be at 3 559.1 USD Millions in 2022.

Table 18 Global commercial automotive lubricants market estimate and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	12.11	12.33	12.57	12.84	13.12	13.43	13.76	14.12	2.2%
Value USD (B)	14.03	15.07	16.18	17.35	18.58	19.89	21.28	22.79	7.1%
Volume Europe (MT)	1.96	1.98	2.00	2.02	2.05	2.07	2.11	2.14	1.2%
Europe USD (B)	2.59	2.71	2.83	2.97	3.10	3.25	3.40	3.56	4.6%

The commercial automotive lubricants can be segmented into four different groups: Heavy Duty Engine Oil (HDEO), Hydraulic & Transmission Fluid (H&TF), Gear Oil and Grease.

HDEO were the largest product segment for commercial automotive lubricants with a demand estimated at 7.08 MT in 2014. They are expected to be fastest growing commercial automotive lubricant at a CARG of 2.4% over the forecast period, reaching a product demand of 8.50 MT by 2022 (see Figure 16 and Figure 17).

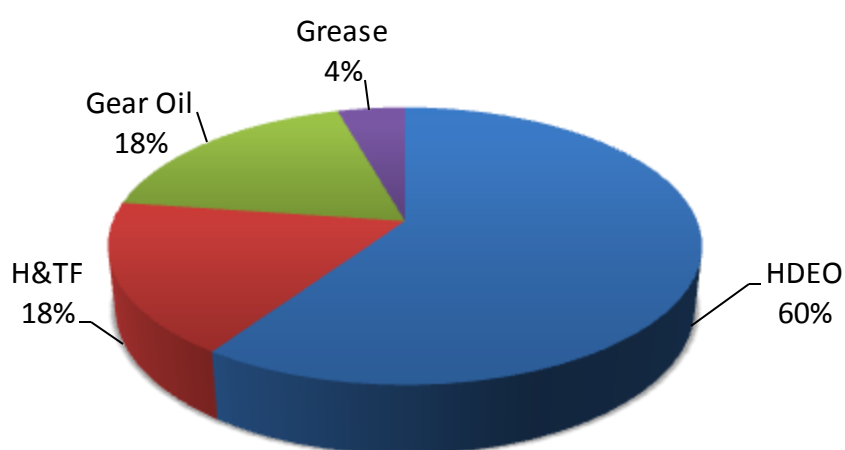


Figure 16 Global commercial automotive market volume by product in 2014 [%]

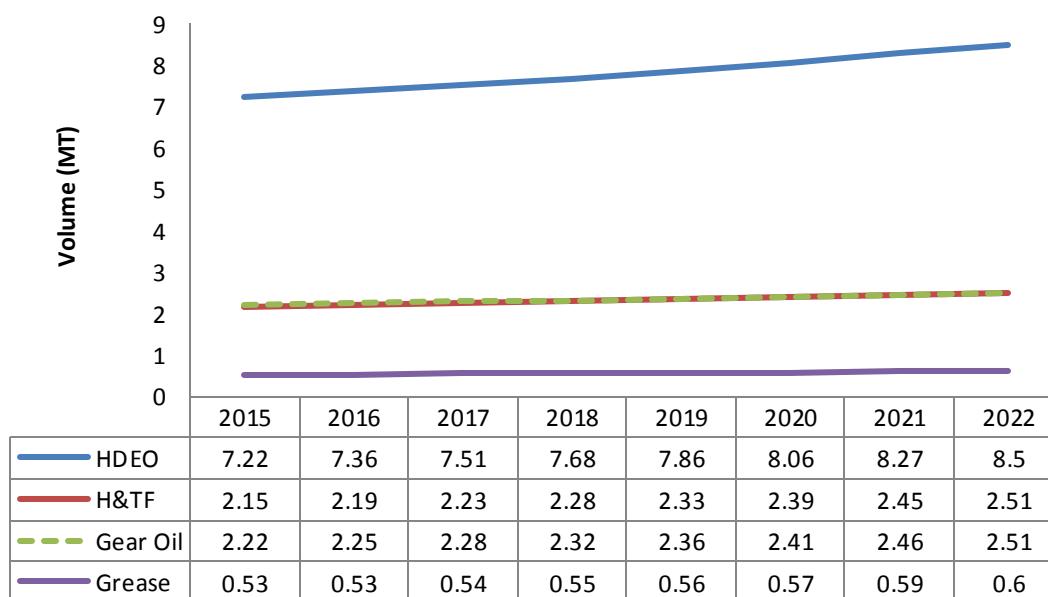


Figure 17 Global commercial automotive market volume by product, 2015-2022 (MT)

Heavy-duty engine oil

HDEO, also named heavy-duty motor oils, are the lubricants used in heavy duty vehicles, such as trucks and busses.

HDEO vehicle & motor oil demand was 6.88 MT and 7.08 MT in 2013 and 2014 respectively. In terms of revenue, the market was USD 7.32 B and USD 7.02 B in the same period of time. It is expected that hydraulic and transmission oils will have a CAGR of 2.8% from 2015 to 2022. European market was 1.11 MT in 2014 and is expected to reach 1.24 MT by 2022 (see Table 19).

Table 19 Global commercial automotive HDEO market estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	7.22	7.36	7.51	7.68	7.86	8.06	8.27	8.50	2.4%
Value USD (B)	8.23	8.87	9.54	10.26	11.01	11.82	12.68	13.59	7.4%
Volume Europe (MT)	1.12	1.13	1.14	1.16	1.18	1.19	1.21	1.24	1.4%
Europe USD (B)	1.45	1.52	1.59	1.67	1.75	1.84	1.93	2.03	4.9%

Hydraulic & Transmission Fluid

Hydraulic fluids are used in commercial vehicles such as trucks, busses, tractors, trailers, cranes, and other hydraulic lifts. These fluids are used as a medium by which power is transferred in hydraulic systems such hydraulic brakes, power steering systems and transmissions.

HTF demand was 2.04 M, 2.05 MT and 2.11 MT in 2012, 2013 and 2014 respectively. In terms of revenue, the market was USD 2.23 B, USD 2.11 B and USD 2.01 B in that same

time period. They are expected to have a CAGR of 2.3%. In terms of revenue, European market was USD 0.38 B in 2015 and is expected to reach USD 0.41 B by 2022 (see Table 20).

Table 20 Global commercial automotive HTF market estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	2.15	2.19	2.23	2.28	2.33	2.39	2.45	2.51	2.3%
Value USD (B)	2.36	2.54	2.72	2.92	3.13	3.35	3.58	3.83	7.2%
Volume Europe (MT)	0.38	0.38	0.38	0.39	0.39	0.40	0.41	0.41	1.3%
Europe USD (B)	0.47	0.49	0.51	0.54	0.56	0.59	0.62	0.65	4.8%

Gear oil

Gear oil is a lubricant made specifically for transmissions, transfer cases, and trucks. It is usually of higher viscosity to better protect the gears. Most gear oils contain Extreme Pressure (EP) and antiwear additives, which make these oils to be frequently associated with a strong sulphur smell.

Global gear oil demand was 2.13 MT in 2012 and it has continuously increased, reaching 2.14 MT in 2013 and 2.19 MT in 2014. It is expected to achieve 2.51 MT by 2022, having a total growth of 1.8% from 2015 to 2022. Europe market was 0.38 MT in 2014 and is expected to reach 0.40 MT by 2022. In terms of revenue, European market was USD 466.3 M in 2014 and is expected to reach USD 608.6 M by 2022, growing at a CAGR of 3.8% from 2015 to 2022 (see Table 21).

Table 21 Global commercial automotive gear oil market estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	2.22	2.25	2.28	2.32	2.36	2.41	2.46	2.51	1.8%
Value USD (B)	2.42	2.58	2.74	2.92	3.10	3.29	3.49	3.70	6.3%
Volume Europe (MT)	0.38	0.38	0.38	0.38	0.38	0.39	0.39	0.40	0.7%
Europe USD (B)	0.47	0.49	0.50	0.52	0.54	0.56	0.59	0.61	3.8%

Grease

Greases are semisolid lubricants that are applied to mechanisms that can only be lubricated infrequently and where lubricating oil would not stay in position. They usually consist of a soap emulsified with oil (mineral or vegetal).

Global grease demand in commercial automotive lubricants was 0.51 MT in 2012 and 2013 and 0.52 MT in 2014. In terms of revenue, the market was USD 976.0 M, USD 916.0 M and USD 872.4 M in 2012, 2013 and 2014 respectively. It is expected to reach 0.60 MT by 2022, growing at a CAGR of 1.8% from 2015 to 2022. In terms of revenue,

the market is expected to reach USD 1,625.0 million by 2022, growing at a CAGR of 6.9% from 2015 to 2022 (see Table 22).

The market in Europe was 0.09 MT in 2014 and is estimated a growing at a CAGR of 1.0% over the forecast period. In terms of revenue, the market in this region was USD 164.1 M and is expected to reach USD 277.6 M by 2022, growing at a CAGR of 4.4% over the period 2015-2022.

Table 22 Global commercial automotive grease market estimate and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	0.53	0.53	0.54	0.55	0.56	0.57	0.59	0.60	1.8%
Value USD (B)	1.02	1.09	1.17	1.25	1.34	1.43	1.52	1.63	6.9%
Volume Europe (MT)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	1.0%
Europe USD (B)	0.21	0.21	0.22	0.23	0.24	0.25	0.27	0.28	4.4%

4.3. Consumer automotive lubricants

Global consumer automotive lubricants demand was 9.64 MT in 2012 and it has continuously increased since then, reaching 9.74 MT in 2013 and 10.07 MT in 2014. It is expected to achieve 12.43MT by 2022, having a total growth of 2.7% from 2015 to 2022. Increasing passenger sales in emerging markets as Asia Pacific and Latin America are expected to be a major factor driving consumer automotive lubricants demand growth. Recovery of automotive industry in the United States is expected to further strengthen the market growth. In terms of revenue, the market was USD 10,447.5 million in 2014 and is expected to reach USD 20 597.0 million by 2022.

Asia Pacific was the first largest market with demand estimated at 4.48 MT in 2014, while in Europe the consumer automotive lubricants market was 1.70 MT. Growing passenger car and motorcycle sales particularly in China and India coupled with increase in automotive production in Japan and Taiwan are expected to drive the market growth over the forecast period.

Table 23 Global consumer automotive lubricants market estimate and forecast 2015-2022.

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	10.30	10.53	10.79	11.07	11.37	11.70	12.06	12.43	2.7%
Value USD (B)	12.30	13.27	14.31	15.41	16.58	17.84	19.17	20.60	7.6%
Volume Europe (MT)	1.72	1.74	1.76	1.79	1.82	1.85	1.88	1.95	1.5%
Europe USD (B)	2.35	2.43	2.55	2.67	2.80	2.93	3.07	3.22	4.8%

The consumer automotive lubricants can be segmented into four different groups: Passenger Vehicle & Motor Oil (PV & MO), Automatic Transmission Fluid (ATF), Gear oil and Grease (see Figure 18).

Passenger vehicle & motor oil was the largest product segment for consumer automotive lubricants with demand estimated at 7.28 MT in 2014. It is expected to be the fastest growing consumer automotive lubricant over the forecast period, reaching a product demand of 9.06 MT by 2022 (see Figure 19).

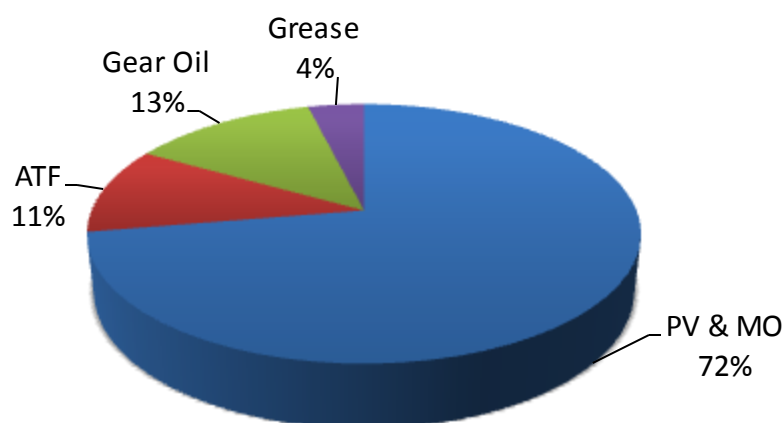


Figure 18 Global consumer automotive market volume by product in 2014 (%)

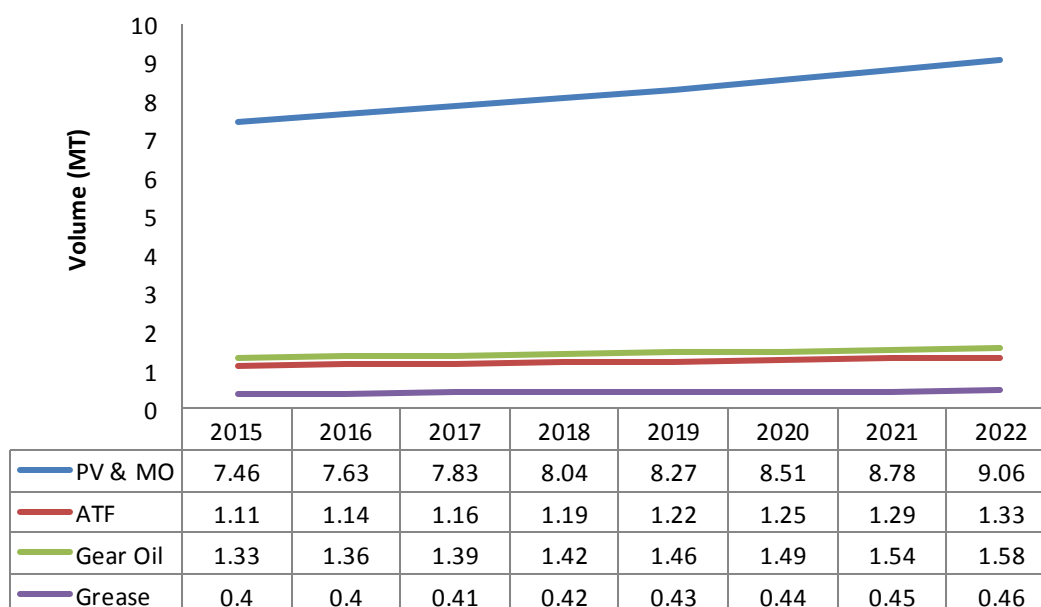


Figure 19 Global consumer automotive market volume by product, 2015-2022 (MT)

Passenger vehicle & motor oil

Global passenger vehicle & motor oil demand was 6.96 MT and 7.04 MT in 2012 and 2013, respectively. In terms of revenue, the market was USD 8.06 B and USD 7.63 B (to double check this value) in 2012 and 2013, respectively. In 2014 the demand was 7.28 MT and is expected to reach 9.06 MT by 2022, growing at a CAGR of 2.8% from

2015 to 2022. European market was 1.2 MT in 2014 and is expected to reach 1.41 MT by 2022 (see Table 24).

Table 24 Global passenger vehicle & motor oil market estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	7.46	7.63	7.83	8.04	8.27	8.51	8.78	9.06	2.8%
Value USD (B)	8.64	9.33	10.08	10.86	11.70	12.60	13.56	14.59	7.8%
Volume Europe (MT)	1.26	1.27	1.29	1.31	1.33	1.36	1.38	1.41	1.6%
Europe USD (B)	1.66	1.73	1.82	1.91	2.00	2.10	2.20	2.31	4.9%

Automatic transmission fluid

Automatic transmission fluids demand was 1.05 MT and 1.06 MT in 2012 and 2013 respectively. In terms of revenue, the market was USD 1.41 B and USD 1.33 B in 2012 and 2013. Global market was 1.09 MT in 2014 and is expected to reach 1.33 MT by 2022, growing at a CAGR of 2.6%. In terms of revenue, Europe market was USD 0.22 B in 2015 and is expected to reach USD 0.30 B by 2022 (see Table 25).

Table 25 Global consumer automotive ATF market estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	1.11	1.14	1.16	1.19	1.22	1.25	1.29	1.33	2.6%
Value USD (B)	1.50	1.61	1.74	1.87	2.01	2.17	2.33	2.50	7.6%
Volume Europe (MT)	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.20	1.4%
Europe USD (B)	0.22	0.23	0.24	0.25	0.26	0.27	0.29	0.30	4.6%

Gear oil

Global gear oil demand was 1.25 MT in 2012 and it has continuously increased, reaching 1.27 MT in 2013 and 1.30 MT in 2014. It is expected to achieve 1.58 MT by 2022, having a total growth of 2.5% from 2015 to 2022. Europe market was 0.22 MT in 2014 and is expected to reach 0.25 MT by 2022. In terms of revenue, Europe market was USD 0.23 B in 2014 and is expected to reach USD 0.39 B by 2022, growing at a CAGR of 4.4% from 2015 to 2022 (see Table 26).

Table 26 Global consumer automotive gear oil market estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	1.33	1.36	1.39	1.42	1.46	1.49	1.54	1.58	2.5%
Value USD (B)	1.37	1.48	1.59	1.70	1.82	1.95	2.10	2.23	7.2%
Volume Europe (MT)	0.23	0.23	0.23	0.23	0.23	0.24	0.24	0.25	1.2%

Europe USD (B)	0.29	0.30	0.31	0.33	0.34	0.36	0.37	0.39	4.4%
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Grease

Global grease demand in consumer automotive lubricants was 0.38 MT in 2012 and 2013. In terms of revenue, the market was USD 746.6 M and USD 702.4 M in 2012 and 2013 respectively. Grease market was 0.39 MT in 2014 and is expected to reach 0.46 MT by 2022, growing at a CAGR of 2.3% from 2015 to 2022 (see Table 27). In terms of revenue, the market was USD 670.9 M in 2014 and is expected to reach USD 1 278.4 M by 2022, growing at a CAGR of 7.2% from 2015 to 2022.

The market in Europe was 0.06 MT in 2014 and is estimated to grow at a CAGR of 1.2% over the forecast period. In terms of revenue, the market in this region was USD 128.4 M and is expected to reach USD 219.0 M by 2022, growing at a CAGR of 4.5% over the period 2015-2022.

Table 27 Global consumer automotive grease market estimates and forecast 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Volume Worldwide (MT)	0.40	0.40	0.41	0.42	0.43	0.44	0.45	0.46	2.3%
Value USD (B)	0.79	0.85	0.91	0.97	1.04	1.12	1.20	1.28	7.2%
Volume Europe (MT)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	1.2%
Europe USD (B)	0.16	0.17	0.18	0.18	0.19	0.20	0.21	0.22	4.5%

5 Biolubricants

The term 'biolubricant' is often not clearly defined. Some take it as synonym to bio-based lubricant. Others take it as a wider definition of 'lubricants that are biodegradable, non toxic to humans and aquatic environment'. In general, it is accepted they are totally or partially made from renewable resources. In the beginning of the development of biolubricants the focus was on the formulation of products based on pure vegetable oils. CEN/TC 19 produced a Technical Report (CEN/TR 16227) on terminology and characterisation of bio-lubricants and bio-based lubricants which has been used as a basis for developing a European Standard (EN 16807) containing requirements on biodegradability, aquatic toxicity, content of biomass and performance^{49,50}.

Over the last decay, the trend has been the use of synthetic ester types which may be partly derived from renewable resources. In the context of the development of the EU Ecolabel for lubricants in 2004²⁹, a distinction was made between: (i) plant and animal based lubricants and (ii) fully synthetic lubricants derived from mineral oil. It is normally assumed that lubricants with rapid biodegradability and low environmental toxicity overlap with plant and animal based lubricants, although this needs not necessarily to be the case.

Best applications for bio-based lubricants include machinery that spill the lubricant directly into the environment (the so-called 'total loss lubricants' include marine lubricants, two-stroke engines, chainsaw bars and chains, railroad flanges, cables, and

dust suppressants) and uses that may present risks of accidental releases in sensitive areas as water resources. However, for applications where long durability or other specific performance features are needed, a bio-based lubricant might not be the most suitable option due to its faster degradation.

The estimated global volume of biolubricants was 660.000 tonnes in 2015 and it is expected to reach 1 million tonnes in 2022 growing at a CAGR of 6.7%. The revenue of USD 2.06 Billions in 2015 is expected to reach USD 2.76 Billions in 2022. The demand for biolubricants and total lubricants in total and by region is compared in Table 28 and Figure 20.

Table 28 Biolubricants and Lubricants demand by region in MT (million tons)

	2015 Total Lubes	2015 Biolubes	2022 Total Lubes	2022 Biolubes
Europe	7.34	0.21	8.23	0.33
North America	7.70	0.23	8.64	0.36
Asia Pacific	15.72	0.13	19.39	0.21
Central & South America	2.61	0.06	3.15	0.09
Middle East Africa	3.72	0.03	4.47	0.05
World (million tons)	37.09	0.66	43.88	1.04

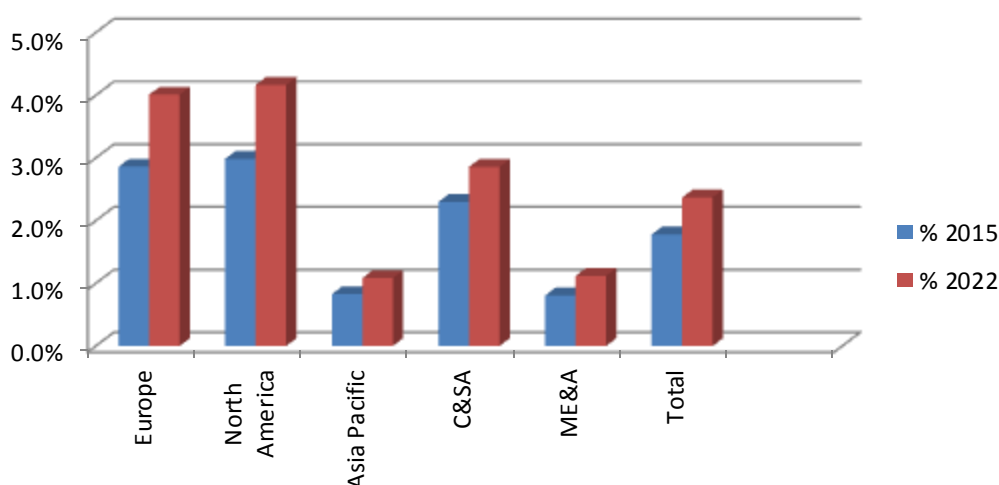


Figure 20 Global Biolubricants market volume by region in 2015 and 2022 forecast

Table 29 Biolubricants and Lubricants demand by region in billion USD.

	2015 Total Lubes	2015 Biolubes	2022 Total Lubes	2022 Biolubes
Europe	9.33	0.71	13.04	0.96
North America	8.85	0.77	13.57	1.04
Asia Pacific	17.29	0.36	30.83	0.44

Central & South America	2.95	0.15	5.10	0.20
Middle East Africa	3.58	0.08	6.01	0.12
World (million tons)	41.99	2.06	68.54	2.76

Several literature sources revealed an increasing demand due to their superior environmental properties in comparison to mineral oil based lubricants^{63,64}. Biolubricants have higher renewability content and they are biodegradable. Other often claimed advantages of biolubricants are the low maintenance, storage & disposal, better safety and constant viscosity with higher flash points and viscosity index as compared to mineral oil lubricants⁶⁵. Due to the renewable sourcing of biolubricants, there are several studies that claim their better positioning from GHG emissions point of view, as example the EPA funded LCA comparison between soybean biolubricants with mineral oil based lubricants for aluminum rolling⁶⁶. On the other hand, some bio-based lubricants have higher costs and are considered to have inferior performance than mineral-based products, which limits their development and competitiveness.⁶⁷

The current lack of European legislation enforcing the use of biolubricants is regarded as an important barrier for the promotion of biolubricants⁷⁶. A propitious regulatory scenario and higher consumer awareness in Europe and North America are expected to drive upwards the market for bio-based lubricants. At present, Asia-Pacific has a small share within the bio-based lubricants market; however, demand in the region is expected to increase slowly within the forecasted period. Stringent regulations imposed by government bodies towards environmental protection are anticipated to boost the demand for bio-based lubricants. As a result, regulatory support towards bio-based products, coupled with superior mechanical properties of biolubricants as compared to synthetic lubricants is expected to act as market restraint in the near future.

The demand for biolubricants divided by product type in 2015 and forecasted for 2022 is given in Table 30 while the demand by the end-use market is shown in Table 31.

Table 30 Global Biolubricants demand by product type

Global Biolubricants	2015 (kT)	2015 (Million \$)	2022 (kT)	2022 (Million \$)
Automotive oils	170.0	510.1	270.0	690.4
Hydraulic fluids	140.5	418.2	225.0	569.3

⁶³ <http://www.marketwired.com/press-release/biolubricants-market-witness-enhanced-demand-automobile-applications-till-2020-grand-2128157.htm>

⁶⁴ <https://globenewswire.com/news-release/2016/04/05/825824/0/en/Biolubricants-Market-To-Grow-At-A-CAGR-Of-6-8-From-2014-to-2020-Grand-View-Research-Inc.html>

⁶⁵ Environmentally preferable purchasing fact sheet: Biolubricants. Department of Ecology, State of Washington (<https://fortress.wa.gov/ecy/publications/documents/1307011.pdf>)

⁶⁶ https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.highlight/abstract/6613/report/F

⁶⁷ Bremmer, B. J. and L. Plonsker (2008). Bio-Based Lubricants: A Market Opportunity Study Update, United Soybean Board.

Process oils	134.0	404.5	212.5	543.1
Demoulding oils	74.0	225.9	115.5	299.8
Lubricating Grease	58.0	181.5	87.5	234.8
Chainsaw oil	40.0	147.5	62.0	195.1
Compressor oil	16.0	59.8	23.5	76.1
Turbine oil	13.0	49.7	19.0	63.3
Industrial gear oil	7.0	40.2	10.5	51.6
MWF	6.5	25.7	9.5	32.3
Total	659	2 063.3	1 062	2 755.9

Table 31 Global Biolubricants demand by end-use market

	2015 (kT)	2022 (kT)
Industrial	333.5	518.0
Commercial transportation	256.0	408.5
Consumer automotive	69.0	107.5
Total	658.5	1 034

Top growth areas for the biolubricant market are forecasted to be industrial gear, hydraulic, and process oils in North America. In Europe the three top growth areas forecasted are: hydraulic fluids, automotive, and process oils.

Table 32 Biolubricants market: Europe and North America in 2015 and 2022 forecast

Year	Europe (kT)		North America (kT)	
	2015	2022	2015	2022
Automotive oils	54.0	85.0	59.5	94.0
Hydraulic fluids	44.5	71.0	49.5	79.5
Process oils	43.0	68.0	47.0	74.0
Demoulding oils	23.5	36.5	26.0	41.0
Lubricating Grease	18.5	28.0	20.0	31.0
Chainsaw oil	12.5	19.5	14.0	22.0
Compressor oil	5.0	7.5	5.5	8.5
Turbine oil	4.0	6.0	4.5	7.0
Industrial gear oil	2.5	3.5	2.5	4.0
Metalworking fluids	2.0	3.0	2.5	3.5
Total	209.5	328	231	364.5

Table 33. Europe and global Bio-Lubricants Market Volume by Raw Material in 2015 and 2022 forecast

Raw Material	Europe (kT)		Global (kT)	
	2015	2022	2015	2022
Vegetable Oil	185.2	292.2	580.8	922.1
Animal Oil	24.8	35.7	77.4	112.2
Total	210.0	327.9	658.1	1,034.3

6 Conclusions on the market analysis

The main points regarding the analysis of the lubricant market are briefly given below:

- The **lubricant market** has worldwide **current size of about 37 MT**, with a forecast to reach the 44MT by 2022.
- It is divided in three main groups: Industrial, Commercial automotive, and Consumer automotive, being the latter the highest growth perspective in the next years, mainly driven by the Asia Pacific region.
- Table 8, Table 9 and Table 10 show that current Ecolabel scheme does cover only a part of the total lubricants market (approximately the 16%), mainly around the Hydraulic fluids and Greases.
- It is difficult, based on the licenses registered in the Ecolabel, to make estimation on the real market impact of the scheme; there is no information on the real tonnage of the EU Ecolabel lubricant products and its importance in the general market (its share) in the EU.
- The largest market categories in volume are currently not covered under the scope of EU Ecolabel: part of the ISO **Family E** internal combustion engine oils release (currently only two-stroke oils are considered), with more than 15 MT yearly is the most important one. Other categories, as **Family B** mould release (currently only concrete release agents are considered) and **Family M** metalworking according to market data under MWF category, with a worldwide tonnage of more than 1.8 MT; or **Family D** Compressors, **Family P** pneumatic tools and **Family Q** heat transfer fluids, according to market data under Process oils category with 4.57 MT per year, are also out of the existing EU Ecolabel scope.
- The estimated global volume of biolubricants was 660.000 tonnes in 2015 and it is expected to reach 1 million tons in 2022. A propitious regulatory scenario and higher consumer awareness in Europe and North America are expected to drive upwards the market for bio-based lubricants.
- From the point of view of reaching a broader share of lubricant market it is advisable to discuss the extension of the current EU Ecolabel scope in this criteria revision. In addition, several categories suggested to be further explored for its inclusion, for instance mould release (Family B), metalworking fluids (Family M) and rust preventive oils (Family R) are included in other voluntary labeling schemes.

TASK 3: Technical analysis

1 Introduction

The aim of the technical analysis is to provide information about potential impact of lubricants on the environment and human health. The entire life cycle of a lubricant has been assessed in order to recognize the life cycle stages with the highest environmental impacts and those with the highest improvement potential. In addition, analysis of the main hazardous substances used in the lubricant sector has been done, and an identification of their environment and human health impacts has been conducted.

In the first part of this technical analysis, a critical review of published LCA studies has been performed. 12 Life Cycle Assessment studies (LCAs) have been screened in order to evaluate the quality of the reports and classify them depending on four parameters: the scope, data, impacts evaluated and conclusions/findings. Supplementary information has been searched about the sustainability considerations in the different cycle stages in order to cover all key aspects of the life cycle of lubricants. Moreover, the software Ecoinvent 8.0. and its database have been used for analysing some of the cycle stages of lubricants.

According to the Regulation (EC) No 66/2010, the EU Ecolabel promotes products with reduced impacts during their entire life cycle. Article 6 highlights the importance of taking a whole life cycle perspective to the evaluation of the most significant environmental impacts, including:

- Impacts on climate change, nature and biodiversity
- Energy and resource consumption
- Generation of waste
- Emissions to all environmental media, pollution through physical effects
- The use and release of hazardous substances

Thus, the EU Ecolabel covers both aspects related to environmental impacts conventionally evaluated through the LCA methodology and other "non-LCA" aspects related to health and hazards inherent to the products.

Some impact assessment categories conventionally included in LCA studies are directly (e.g. human toxicity) or indirectly (e.g. ozone depletion) related also to health issues. However, the LCA methodology typically characterises environmental burdens attributed to inputs and outputs from the product system and it does not analyse the hazards associated to a product, as done for instance in risk assessment. In this sense, REACH and LCA have been integrated, to identify all relevant environmental and human health impacts.

In addition, it has been designed a prioritisation methodology in order to consider all the multidimensional (e.g. market, technical, environmental) aspects that influence this revision. The prioritisation methodology will serve as a basis to prepare a proposal of the revised scope attending to aspects described previously including market, technical and environmental aspects, as well as to help us to identify the environmental hotspots associated to the categories included in the scope in order to set the revised criteria that target the main relevant environmental hotspots associated to this product group.

Finally, the key areas of improvement and conclusions are included in the final chapter.

2 Environmental impact assessment

This chapter analyses the potential environmental impacts that lubricants can have during the different stages of their whole life cycle, i.e. from raw materials extraction and processing, manufacturing, transport, use and end-of-life.

A robust quantification of the overall environmental impact of lubricants would entail a detailed Life Cycle Assessment (LCA), with a scope covering manufacturing, use and fate at end of life, and with system boundaries encompassing petroleum, petrochemical, oleochemical and engineering industry activities. This would be a complex process, due to the very broad scope required, and also to some particular issues which are characteristic of the industry and the applications. One complication is that lubricants are typically manufactured as co-products in integrated product networks, based on petroleum refining, oleochemical refining or chemical processing.

Since different lubricant types differ greatly in their performance, a detailed knowledge of application performance is required in order to define an appropriate functional unit for comparison. LCA comparisons are made on the basis of equivalent outputs so a simple comparison of different lubricant types, based only on their resource requirements per kg or per liter, would therefore give misleading results.

Moreover tracing fate during use and at the end of life could be difficult, since lubricants are used so widely in many different products and applications. End of life treatment of industrial lubricants used at a single manufacturing site can be controlled and monitored, but following the fate of used particular engine oils is a more challenging problem. The eventual fate of a large proportion of overall lubricant production is not precisely known. Besides these limitations, industrial data from the sector is regarded as confidential to the product manufacturers or users, and not openly published.⁶⁸

A critical review of published LCA studies has been done, in order to extract the main areas of concern. For those life stages and aspects less covered by LCA studies, complementary information has been searched in order to have a complete environmental profile of this product category.

Supplementary information on sustainability considerations in the different cycle stages has been gathered in order to cover all key aspects of the life cycle of lubricants. A generic life cycle flowchart has been elaborated in order to illustrate the different stages of a lubricant product system. It should be noticed that environmental impacts can be related to all life stages from raw materials to the end-of- life; for this reason it is important to analyze all these stages in a holistic approach following life cycle approach as given in Figure 21.

⁶⁸ Steve Boyde. Green lubricants: Environmental benefits and impacts of lubrication. *Green Chemistry*, 2002, 4, 293–30. DOI: 10.1039/b202272a

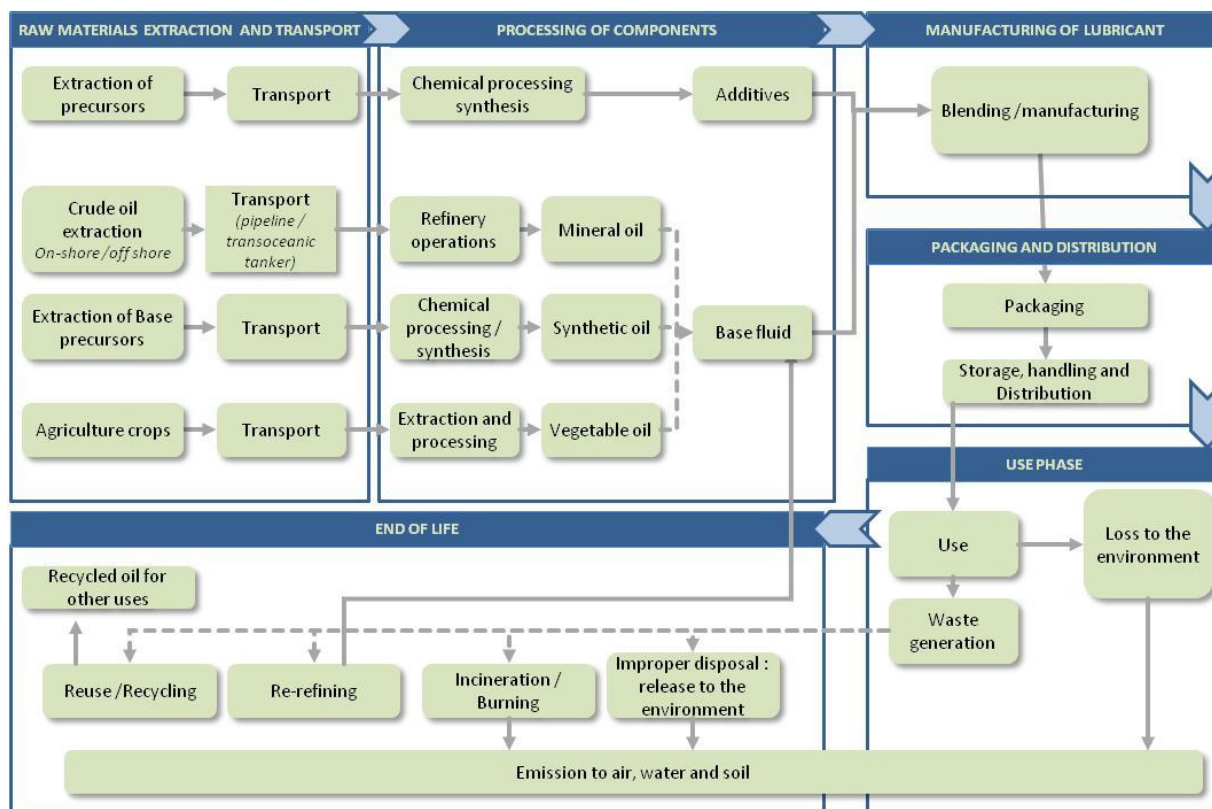


Figure 21: General flowchart of Life Cycle of a lubricant product

4.1. Life Cycle Assessment literature review: methodology

Several environmental studies were analysed during the previous revisions of the EU Ecolabel for lubricants. The analysis of the LCA studies performed during the last revision 2011 was focused on biolubricants, including the products used as base oils for biolubricants. From that analysis three main conclusions were drawn^{51,69}:

- The vegetable based lubricants are environmentally favourable with respect to the use of non-renewable energy and the related savings of CO₂ emissions from carbon capture and replacement. However, there are other GHG emission parameters associated to the vegetable based lubricants. .
- Vegetable based lubricants are less favourable when other environmental interventions are considered: land use, N₂O emitted, nutrients emitted from the fertilizers, and pesticides emitted.
- The consideration to include criteria on the unfavourable environmental issues of biolubricants would be interesting but the difficulty of controlling those makes it difficult.

However, for certain applications where long durability is needed and there is not spillage of the lubricant, a biolubricant might not be the best environmental option due to its degradation. There are barriers in the use of biolubricants in automotive engine

⁶⁹ Recommendations on the revision of the EU Ecolabel Criteria for Lubricants European ecolabel. Preliminary report prepared by: Hildo Krop - IVAM UvA BV, Demi Theodori - SMK January 2009

production plants and also in the re-use of this type of lubricants. On the other hand, some bio-based lubricants have higher costs and are considered to have inferior performance than mineral-based products, which limits their development and competitiveness.⁷⁰

The EU Ecolabel is a voluntary ecolabel award scheme intended to promote products within a specific product category with a reduced environmental impact during their entire life cycle. Article 6 of the EC 66/2010 EU Ecolabel Regulation describes the general requirements for EU Ecolabel criteria⁷¹. The environmental impacts which should be in particular considered are the impact on climate change, the impact on nature and biodiversity, energy and resource consumption, generation of waste, emissions to all environmental media, pollution through physical effects and use and release of hazardous substances. Having into consideration that it is intended to widen the scope to other lubricants categories a wider technical assessment is needed. In addition, the environmental impacts of a lubricant product can be caused in any life stage of its life cycle (e.g. during raw material extraction or at the end of life), and not only from its potential release to the environment.

For the current revision a comprehensive review of available LCA studies for lubricants has been done with the aim to identify the potential environmental impacts of lubricants along all life cycle stages aiming to allow a better understanding of their environmental performance and support the EU Ecolabel for awarding best options and practices. The number of studies identified is considered rather low.

Initially, a screening of available LCA studies has been performed aiming to select those studies that comply with methodological and quality standard in order to establish a robust basis for the criteria revision. The lack of detailed information about product composition makes difficult to study a product in a comprehensive way.

Studies identified have been selected with the following cut-off requirements:

- LCA studies are conducted according to the methodology ISO 14040.
- The scope is relevant for this revision, including LCA of base fluids.
- The impact assessment is broad or the indicators considered in the analysis are relevant.
- The conclusions are relevant for the revision.

From a preliminary review of the literature, 12 LCA papers and reports of potential relevance have been found and analysed. The second step has been the classification of the selected studies based on their relevance: a scoring system was used to evaluate the quality of the studies.

⁷⁰ Bremmer, B. J. and L. Plonsker (2008). Bio-Based Lubricants: A Market Opportunity Study Update, United Soybean Board.

⁷¹ Regulation (EC) No 66/2010 of the European Parliament and of the Council on the EU Ecolabel, available online at:

<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:027:0001:0019:en:PDF>

Two main regards are taken into account in life cycle assessment: the functional unit (FU) and the environmental impact categories included. A well-defined FU allows comparison between different studies.

Functional unit
"Produce 1 kg of base oil"

Although this is the functional unit most commonly used in studies, the functionality of lubricant products (i.e. kilometre covered in automobile applications) has been considered in some studies. This approach considering the application of the lubricating product would reflect more accurate results, although it is difficult to use for comparing different studies due to the wide range of different applications of lubricants.

On the other hand, in order to respond to the main requirements for EU Ecolabel criteria as mentioned in the EU Ecolabel Regulation⁴, it is considered that the key impacts categories of relevance for assessing the environmental impact of lubricant products in the present study should be:

Impact assessment categories
<ul style="list-style-type: none">• Global warming potential (kg CO₂ eq.)• Ozone layer depletion (kg CFC-11 eq.)• Acidification potential (H⁺ moles eq./ kg SO₂ eq.)• Human toxicity (kg 1,4-DB eq.)• Eutrophication potential• Aquatic ecotoxicity• Abiotic depletion

The scoring system was based on 4 parameters:

- Scope:
 - 5: Comparison of more than 2 different products (vegetable, mineral and synthetic oils; or three different vegetable bases)
 - 3: Comparison of 2 different products
 - 1: LCA of a product
- Data:
 - 5: High quality data: is representative from geographical and technical point of view. Also is up-to-date (data less than 5 years old)
 - 3: Average quality data: is representative from geographical and technical point of view. Data 5-10 years old
 - 1: Low quality data: less interest from a geographical and technical point of view. Data 10 or more years old
- Impact:
 - 5: Satisfactory broadness and high quality of impact assessment methods
 - 3: Not a large number of impact categories, but with a quality of impact assessment methods.
 - 1: Consideration of only one or two impact categories
- Conclusions:

- 5: Findings of the study are very relevant for the achievement of the goals of the analysis
- 3: Findings of the study are partially relevant for the achievement of the goals of the analysis
- 1: Findings of the study have minor relevance for the achievement of the goals of the analysis

Studies have been ordered by ranking overall score values and are presented in tables below. Studies obtaining an overall score of 12 points or above have been considered to present a satisfactory level of quality and are classified as relevant. The rest of the studies are classified as complementary.

Relevant LCA studies:

1	Item	Observation	Scoring
1	Title	Comparative LCA of biolubricants and mineral base lubricants ⁷²	-
2	Authors	Phoebe Cuevas	-
3	Reference and year	2010	-
4	Type of publication	LCA (Comparative and retrospective). ISO 14040	S _{SCOPE} = 3
5	Scope	The objective of this study is to compare the environmental impacts of rapeseed, soybean, and mineral based lubricants, develop the framework for a decision matrix and integrate LCA results into the decision matrix.	
6	Functional unit	1 kg of lubricant	
7	System boundaries	For bio-lubricants cultivation of rapeseed and soybean up to the production of the lubricant and for mineral based lubricant, from the crude oil recovery to lubricant production. Transport is also included. Use and disposal stages are not considered.	
8	Assumptions (e.g. allocation)	Rapeseed has an oil content of 40-42%. 1kg of oil is equal to 1kg of lubricant	S _{DATA} = 3
9	Data sources and quality	GREET and SimaPro-ecoinvent	
10	Impact assessment categories / methods	<ul style="list-style-type: none"> • Global warming • Acidification • Carcinogenics • Non carcinogenics • Respiratory effects • Eutrophication • Ozone depletion • Ecotoxicity • Photochemical smog 	S _{IMPACT} = 5
11	Conclusions	LCA results showed rapeseed lubricants as the major contributor in the acidification potential, carcinogenics, non-carcinogenics, respiratory effects, eutrophication potential and photochemical smog impact categories when compared to soybean and lubricant oils. Mineral lubricants dominated the global warming potential and ozone depletion potential categories. However, it should be noted that if using weighting had been performed in an improvement analysis these results could have been different. In addition, all LCAs have limitations that could alter the outcome as seen with the missing inventory that required additional calculations to	S _{OUTCOME} = 5

⁷² Cuevas, P. (2010). Comparative life cycle assessment of biolubricants and mineral based lubricants (Doctoral dissertation, University of Pittsburgh).

		obtain more accurate eutrophication potential results.	
TOTAL SCORE	S_{SCOPE} = 3 S_{DATA} = 3 S_{IMPACT} = 5 S_{OUTCOME} = 5		S_{TOTAL} = 16

2	Item	Observation	Scoring
1	Title	LCA of petroleum-base lubricants: state of art and inclusion of additives ⁷³	-
2	Authors	Andrea Raimondi, Giorgia Girotti, Gian Andrea Blengini, Debora Fino	-
3	Reference and year	2012, Volume 17, Issue 8, pp 987-996	-
4	Type of publication	LCA	
5	Scope	The aim of this paper is to integrate and expand previous LCAs of base oils and investigate on the contribution of lube additives to the environmental impacts of a fully formulated lubricant	
6	Functional unit	kilogram of product and per kilogram adjusted to the lifetime (kilometer-adjusted)	S _{SCOPE} = 3
7	System boundaries	Extraction, transportation and production until the exit of the refinery/factory in a from-cradle-to-gate perspective	
8	Assumptions (e.g. allocation)	The allocation criterion for outputs is mass. They select a representative additive for each category usually used in average engine lube oil.	
9	Data sources and quality	Boustead Model (2005), Ecoinvent (2007), European Reference Life Cycle Database-ELCD (2010), the IFEU/GEIR report issued by the lubricants industry and the Reference Document on Best Available Techniques for Mineral Oil and Gas Refineries-BREF. The data sources have very different bases for their data, which can generate heavy inconsistencies.	S _{DATA} = 3
10	Impact assessment categories / methods	<p>IMPACT 2002+:</p> <ul style="list-style-type: none"> • Human toxicity (carcinogenics and non-carcinogenics) • Respiratory inorganics • Ionizing radiation • Ozone layer depletion • Respiratory organics • Aquatic eco-toxicity • Terrestrial eco-toxicity • Aquatic acidification • Aquatic eutrophication • Terrestrial acidification/nitrification • Land occupation • Global warming • Non-renewable energy • Mineral extraction 	S _{IMPACT} = 5
11	Conclusions	<p>As base oil is concerned, this study made the point on data availability and provided a contribution in order to integrate and expand previous LCAs of mineral base oil and PAO⁷⁴. On the side of additives, the main conclusion is that in modern lubricants, the contribution of additives in terms of environmental impact can be remarkably high and, therefore, they should not be excluded.</p> <p>Modern synthetic lubricating base oils have higher impacts per kg in comparison to traditional mineral base oil. However, synthetic base oils offer a longer life time and require less oil changes, leading to a</p>	S _{OUTCOME} = 5

⁷³ Raimondi, A., Girotti, G., Blengini, G. A., & Fino, D. (2012). LCA of petroleum-based lubricants: state of art and inclusion of additives. *The International Journal of Life Cycle Assessment*, 17(8), 987-996.

⁷⁴ PAO = poly-alpha-olefins

		decrease of environmental impacts per distance covered (further research is need).	
TOTAL SCORE	S_{SCOPE} = 3 S_{DATA} = 3 S_{IMPACT} = 5 S_{OUTCOME} = 5		S_{TOTAL} = 16

3	Item	Observation	Scoring
1	Title	Life Cycle Analysis of Biolubricants for Aluminum Rolling ⁷⁵	-
2	Authors	Thomas L. Theis	-
3	Reference and year	2003-2006, EPA Grant Number: R831521	-
4	Type of publication	LCA (Monte Carlo Analysis (MCA) to determine system variability)	S _{SCOPE} = 3
5	Scope	This project examined issues associated with the substitution of petroleum-based lubricants with bio-based (i.e., plant-derived) lubricants for industrial applications. The purpose of this project was to conduct a comparative LCA for biolubricants and mineral oils, using MCA to incorporate data variability into the assessment.	
6	Functional unit	Area of aluminium rolled	
7	System boundaries	Soybean oil: soybean agriculture, extraction/processing and aluminum rolling. Mineral oil: Curde oil extraction, refining and aluminum rolling. Transportation between processes is also included.	
8	Assumptions (e.g. allocation)	Allocation is usually conducted on a mass, energy, or market basis. In this study, all allocation is conducted on a mass basis at the process level and is described in detail below. Although market-based allocation is also a reasonable alternative, the interdependence of corn-soybean agriculture complicates the allocation scheme. Allocation of emissions on an energy basis is rejected for this study since the ultimate function of the product is not related to energy purposes.	
9	Data sources and quality	REET	S _{DATA} = 3
10	Impact assessment categories / methods	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI). 12 impact categories: <ul style="list-style-type: none"> • Ozone depletion • Global warming • Acidification • Eutrophication • Photochemical smog • Ecotoxicity • Human health criteria air pollutants • Human health cancer • Human health noncancer • Fossil fuel • Land use • Water use 	S _{IMPACT} = 5
11	Conclusions	Comparative inventory emissions between soybean and mineral oils show that if they have similar use rates during performance, soybean oils have greater life cycle emissions of VOC, NO _x , SO _x , N ₂ O, NO ₃ ⁻ , and total P, and lower emissions of CO ₂ , CH ₄ , and PM ₁₀ as well as decreased fossil fuel consumption; however, experimental data obtained from an aluminium manufacturing facility indicate that significantly less soybean lubricant is required to achieve similar or superior performance. With improved performance and a lower use rate, a transition to soybean oil results in lower aggregate impacts of acidification, smog formation, and	S _{OUTCOME} = 5

⁷⁵ Theis, T., Bauer, D. (2006, October). Life cycle analysis of biolubricants for aluminium rolling. Technology for a Sustainable Environment, University of Illinois at Chicago.

		human health from criteria pollutants. Regardless of the quantity consumed, soybean-based lubricants exhibit significant climate change and fossil fuel use benefits; however, eutrophication impacts are much greater due to nonpoint nutrient emissions.	
TOTAL SCORE		S_{SCOPE} = 3 S_{DATA} = 3 S_{IMPACT} = 5 S_{OUTCOME} = 5	S_{TOTAL} = 16
4	Item	Observation	Scoring
1	Title	Life cycle assessment of a biobased chainsaw oil made on the farm in Wallonia ⁷⁶	-
2	Authors	Julie Roiz, Michel Paquot	-
3	Reference and year	2013, September 2013, Volume 18, Issue 8, pp 1485-1501 (The International Journal of Life Cycle Assessment)	-
4	Type of publication	LCA (ISO 14040, ISO 14044), attributional approach.	S _{SCOPE} = 3
5	Scope	The aim of this study is to quantify the environmental impacts of a biobased chainsaw oil made on the farm in Wallonia (a region of Belgium) and to compare it with a model mineral chainsaw oil.	
6	Functional unit	1 kg of base oil	
7	System boundaries	LCA cradle to grave. The biobased chainsaw oil system includes the agricultural stage which results in rape seeds, the crushing stage at the farm transforming the seeds in rapeseed oil and the end of life of the oil. The fossil chainsaw oil system includes the step of crude oil extraction, its transport to a refinery, the refining of crude oil into lubricant base oil and the end of life of the oil.	
8	Assumptions (e.g. allocation)	Both oils have the same technical characteristics. The use phase was not considered because is assumed to be identical.	
9	Data sources and quality	APPO	S _{DATA} = 5
10	Impact assessment categories / methods	The methods for life cycle impact assessment are IPCC, ReCiPe, CML and USEtox. 7 impact categories: <ul style="list-style-type: none"> • Global warming • Ozone depletion • Acidification • Photochemical oxidation • Aquatic eutrophication with marine eutrophication and freshwater eutrophication • Aquatic ecotoxicity (USEtox) • Abiotic depletion 	S _{IMPACT} = 3
11	Conclusions	The biobased chainsaw oil has a lower impact in four out of the seven impact categories (global warming, abiotic depletion, ozone depletion and photochemical oxidation) and a higher impact in three impact categories (acidification, aquatic eutrophication with marine eutrophication and aquatic ecotoxicity). By providing a detailed LCA on one biobased chainsaw oil, this study contributes to the development of LCA applied to biobased lubricants. This study outlines the importance of agricultural practices to the overall environmental impact of biobased lubricants.	S _{OUTCOME} = 5
TOTAL SCORE		S_{SCOPE} = 3 S_{DATA} = 5 S_{IMPACT} = 3 S_{OUTCOME} = 5	S_{TOTAL} = 16

5	Item	Observation	Scoring
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⁷⁶ Roiz, J., & Paquot, M. (2013). Life cycle assessment of a biobased chainsaw oil made on the farm in Wallonia. The International Journal of Life Cycle Assessment, 18(8), 1485-1501.

1	Title	The environmental impact of Palm Oil and Other vegetable Oils ⁷⁷	-
2	Authors	Erich E Dumelin	-
3	Reference and year	Society of Chemical Industry (SCI), 2009	-
4	Type of publication	LCA methodology according to the standard ISO 14040	S _{SCOPE} = 5
5	Scope	The aim of the paper is to compare the environmental impact of six different vegetable oils: palm, coconut, olive, soybean, rapeseed and sunflower oil.	
6	Functional unit	Hectare of crop production	
7	System boundaries	Fertilizer production, pesticide/herbicide production, oilseed agriculture (fertilizer use, pesticide use, water use, diesel oil consumption, oil seed yield), oil extraction (energy use and solvent use) and refining and transport (energy use, chemical use, effluent).	
8	Assumptions (e.g. allocation)	Economic value allocation	S _{DATA} = 3
9	Data sources and quality	However the variability in the agricultural practices, the data was collected in a specific location. The representative areas are: Malaysia (for palm fruit and coconut production), Germany (rapeseed), Brazil (soyabeans), France (sunflower) and Spain (olives).	
10	Impact assessment categories / methods	<ul style="list-style-type: none"> • Energy consumption • Acidification potential • Eutrophication potential • Global warming potential • Photochemical smog potential • Land use 	S _{IMPACT} = 3
11	Conclusions	The large impacts are produced during the agricultural stage. For this reason, the most effective way of improving environmental performance is to encourage farmers to use good, sustainable agricultural practices. Also the optimal growing conditions are important to reduce the environmental impact (climate and soil conditions).	S _{OUTCOME} = 5
TOTAL SCORE		S_{SCOPE}= 5 S_{DATA}= 3 S_{IMPACT}= 3 S_{OUTCOME}= 5	S_{TOTAL}= 16

6	Item	Observation	Scoring
1	Title	The contribution of Lube Additives to the LC Impacts of fully formulated Petroleum-Based Lubricants ⁷⁸	-
2	Authors	Girotti, G., Raimondi, A., Blengini, G., Fino, D.	-
3	Reference and year	2011	-
4	Type of publication	LCA methodology according to the standard ISO 14040	S _{SCOPE} = 3
5	Scope	Investigate and expand previous LCAs of lubricants and to investigate on the contribution of lube additives to the environmental impacts of fully formulated lubricants	
6	Functional unit	1 kg of final product	
7	System boundaries	From-cradle-to-gate. Extraction, transportation and production until the exit of the refinery/factory of both base oils and additives	
8	Assumptions	Mass allocation	

⁷⁷ Erich E. Dumelin (2009) The environmental impact of Palm Oil and Other vegetable Oils. Society of Chemical Industry (SCI)

⁷⁸ Girotti, G., Raimondi, A., Blengini, G., Fino, D. (2011). The Contribution of Lube Additives to the Life Cycle Impacts of Fully Formulated Petroleum-Based Lubricants. American Journal of Applied Sciences 8 (11): 1232-1240

	(e.g. allocation)		
9	Data sources and quality	Boustead Model 2005, Ecoinvent, European Reference Life Cycle Database-ELCD, Reference Document on Best Available Techniques for Mineral Oil and Gas Refineries-BREF,	S _{DATA} = 1
10	Impact assessment categories / methods	ReCiPe: <ul style="list-style-type: none"> • Climate change • Ozone depletion • Human toxicity • Photochemical oxidant formation • Particulate matter formation • Ionising radiation • Terrestrial acidification • Freshwater eutrophication • Marine eutrophication • Terrestrial ecotoxicity • Freshwater ecotoxicity • Marine ecotoxicity • Agricultural land occupation • Urban land occupation • Natural land transformation • Water depletion • Metal depletion • Fossil depletion 	S _{IMPACT} = 5
11	Conclusions	PAO shows the highest impacts in most of categories, with the exception of photochemical oxidant formation, freshwater eutrophication, freshwater and marine ecotoxicity, metal depletion and agricultural and urban land occupation, where the highest impacts are those of hydrocracked base oil. Synthetic oils offer a longer life time and require less oil changes, leading to a decrease of environmental impacts per distance covered. In modern lubricants the contribution of additives in terms of environmental impact can be remarkably high, they cannot be excluded.	S _{OUTCOME} = 5
TOTAL SCORE		S_{SCOPE}= 3 S_{DATA}= 1 S_{IMPACT}= 5 S_{OUTCOME}= 5	S_{TOTAL}= 14

7	Item	Observation	Scoring
1	Title	Life-Cycle Assessment of Mineral and Rapeseed Oil in Mobile Hydraulic Systems ⁷⁹	-
2	Authors	McManus MC, Hammond GP, Burrows CR	-
3	Reference and year	2002, Volume 7, Number 3-4, pp 163-167 (Journal of Industrial Ecology)	-
4	Type of publication	LCA	S _{SCOPE} = 3
5	Scope	The article examines the major segments of the life cycle of mineral and rapeseed oil used in mobile hydraulic systems, with case studies of a forestry harvester and a road sweeper.	
6	Functional unit	Use of the machinery over its lifetime. In the article was subdivided in some portions of the study to the production of 1 kg of oil or to the production of the machines.	
7	System boundaries	Production of mineral oil: the environmental impacts associated with oil exploration, development, and extraction have not been taken into account. The energy used to transporting crude oil is included. Production of rapeseed oil: seedbed preparation, sowing, fertilizing,	

⁷⁹ McManus, M. C., Hammond, G. P., & Burrows, C. R. (2003). Life- Cycle Assessment of Mineral and Rapeseed Oil in Mobile Hydraulic Systems. Journal of Industrial Ecology, 7(3- 4), 163-177.

		crop protection, rapeseed growth, harvesting, drying and storing, and crushing and refining.	
8	Assumptions (e.g. allocation)	The allocation of the production of rapeseed oil is made according to the dry weight	
9	Data sources and quality	BANES, IDEMAT	S _{DATA} = 1
10	Impact assessment categories / methods	<ul style="list-style-type: none"> • Greenhouse gases • Ozone-depleting gases • Acidification • Eutrophication • Heavy metals • Carcinogens • Winter smog • Summer smog • Pesticides • Energy • Solid waste 	S _{IMPACT} = 5
11	Conclusions	The article shows that it is not necessary better to operate systems using rapeseed oil in place of mineral oil when the whole life cycle is considered. Rapeseed fluids do not last as long when subjected to high pressure and temperature as mineral oils do. They also have a more destructive effect on some hydraulic components, which have to be replaced more frequently, causing more of an environmental burden.	S _{OUTCOME} = 3
TOTAL SCORE		S_{SCOPE} = 3 S_{DATA} = 1 S_{IMPACT} = 5 S_{OUTCOME} = 3	S_{TOTAL} = 12

8	Item	Observation	Scoring
1	Title	LCA of mineral oil-based and vegetable oil-based hydraulic fluids including comparison of biocatalytic and conventional production methods ⁸⁰	-
2	Authors	Ekman A, Börjesson P	-
3	Reference and year	2011, DOI: 10.1007/s11376-011-0263-0 (The International Journal of Life Cycle Assessment)	-
4	Type of publication	LCA	
5	Scope	The aim of this paper is to investigate the environmental impact of two types of hydraulic fluids, one based on mineral oil and one on vegetable oil. The difference in environmental impact of using chemical or biocatalytic production methods is also assessed.	S _{SCOPE} = 3
6	Functional unit	1 l of base fluid for hydraulic fluids	
7	System boundaries	Cradle-to-gate, including waste treatment	
8	Assumptions (e.g. allocation)	Mass allocation	
9	Data sources and quality	Boustead (2005), Eco-profiles of the European Plastic Industry	S _{DATA} = 1
10	Impact assessment categories / methods	<ul style="list-style-type: none"> • Primary energy consumption • Global warming potential • Eutrophication potential • Acidification potential • Photooxidant creation potential • Biodegradability 	S _{IMPACT} = 3
11	Conclusions	The contribution to GWP and primary energy consumption was higher	S _{OUTCOME} = 5

⁸⁰ Ekman, A., & Börjesson, P. (2011). Life cycle assessment of mineral oil-based and vegetable oil-based hydraulic fluids including comparison of biocatalytic and conventional production methods. The International Journal of Life Cycle Assessment, 16(4), 297-305.

		for the mineral oil based hydraulic fluid. The contribution to EP and AP were higher for the vegetable oil-based hydraulic fluid. The difference between the chemically catalysed method and the enzymatically catalysed method is negligible because the major environmental impact is due to the production of the raw materials.	
TOTAL SCORE	S_{SCOPE} = 3 S_{DATA} = 1 S_{IMPACT} = 3 S_{OUTCOME} = 5		S_{TOTAL} = 12

Complementary studies

9	Item	Observation	Scoring
1	Title	Comparative LCA of rapeseed oil and palm oil ⁸¹	-
2	Authors	Jannick H. Schmidt (2010)	-
3	Reference and year	2010, DOI: 10.1007/s11367-009-0142-0 (The International Journal of Life Cycle Assessment)	-
4	Type of publication	LCA	S _{SCOPE} = 3
5	Scope	The article compares rapeseed oil and palm oil as a local and global alternative for meeting the increasing demand for these products in the EU. Also identifies alternative ways of producing rapeseed oil and palm oil in order to reduce environmental impacts.	
6	Functional unit	1 t refined vegetable oil	
7	System boundaries	Crop production, milling and refinery, also transport is included	
8	Assumptions (e.g. allocation)	Different scenarios analysed	
9	Data sources and quality	-	S _{DATA} = 0
10	Impact assessment categories / methods	Ozone depletion Acidification Eutrophication Photochemical smog Land use Global warming Biodiversity	S _{IMPACT} = 3
11	Conclusions	Palm oil is environmentally preferable to rapeseed oil within ozone depletion, acidification, eutrophication, photochemical smog and land use, while the differences between global warming and biodiversity are less clear.	S _{OUTCOME} = 5
TOTAL SCORE	S_{SCOPE} = 3 S_{DATA} = 0 S_{IMPACT} = 3 S_{OUTCOME} = 5		S_{TOTAL} = 11

10	Item	Observation	Scoring
1	Title	Life-Cycle Assessment of Chainsaw Lubricants made from Rapeseed Oil or Mineral Oil ⁸²	-
2	Authors	P.S. Wightman, R.M. Eavis, K.C. Walker, S.E. Batchelor, S.P. Carruthers & E.J. Booth	-
3	Reference and year	1999, GCIRC -5-173 (The regional Institute)	-

⁸¹ Schmidt, J. H. (2010). Comparative life cycle assessment of rapeseed oil and palm oil. The International Journal of Life Cycle Assessment, 15(2), 183-197.

⁸² Wightman, S., Eavis, R. M., Walker, K. C., Batchelor, S. E., Carruthers, S. P., & Booth, E. J. (1999, September). Life-cycle assessment of chainsaw lubricants made from rapeseed oil or mineral oil. In 10th International Rapeseed Congress, Canberra.

4	Type of publication	LCA	
5	Scope	The environmental impacts of replacing mineral oil with rapeseed oil in chainsaw lubricants are described using comparative life-cycle assessment (LCA). This LCA was part of a study which, through combination of LCA and CBA (cost-benefit analysis), described the environmental and socio-economic impacts of replacing mineral oil with rapeseed oil in several products.	S _{SCOPE} = 3
6	Functional unit	The volume used in cutting 1000 m ³ of wood, assuming 80% harvester and 20% manual chainsaw use, in UK softwood plantations. For rapeseed chainsaw oil was 34 litres, and for mineral chainsaw oil was 56 litres	
7	System boundaries	Crop production / crushing stages/ mineral oil production/ distribution and packaging/ use operations	
8	Assumptions (e.g. allocation)	As a sensitivity analysis, an allocation based on 70:30 oil:meal was defined on a mass x economic value basis, using an economic value averaged from oil and meal prices in August 1996 and 1998.	
9	Data sources and quality	Audsley et al. (1997), Mortensen et al. (1997)	S _{DATA} = 1
10	Impact assessment categories / methods	GWP Nutrient Enrichment potential	S _{IMPACT} = 1
11	Conclusions	The use of rapeseed chainsaw bar oil provides a significant advantage over mineral oil-based chainsaw oil, in terms of Global Warming Potential (GWP), regardless of assumptions or allocation. However, allocation and the alternative land-use assumptions had a large influence on the other impacts studied, as demonstrated by the nutrient enrichment potential results. The most realistic scenario was 70% allocation, with oilseed rape replacing winter wheat (i.e. 70%OSR-WW). For this scenario, all the environmental impacts considered are lower for chainsaw lubricant made from rapeseed oil than from the comparable mineral oil product.	S _{OUTCOME} = 5
TOTAL SCORE		S_{SCOPE} = 3 S_{DATA} = 1 S_{IMPACT} = 1 S_{OUTCOME} = 5	S_{TOTAL} = 10

11	Item	Observation	Scoring
1	Title	A comparative life cycle assessment of the manufacture of base fluids for lubricants ⁸³	-
2	Authors	C. Våg, A. Marby, M. Kopp, L. Furberg, & T. Norrby	-
3	Reference and year	Volume 19, Issue 1, pages 39–57, April 2002 (Journal of Synthetic Lubrication)	-
4	Type of publication	LCA	S _{SCOPE} = 5
5	Scope	A comparative life cycle assessment (LCA) study of three types of base oils used in the manufacture of hydraulic fluids has been carried out.	
6	Functional unit	1m ³ of hydraulic fluid (consumption of lubricant during harvester operation during 1 year = 2000h).	
7	System boundaries	Cradle-to-gate perspective, considering that the hydraulic fluid is used in a total loss application. Additives and use of pesticides were not taken into account.	
8	Assumptions (e.g. allocation)	The technically useful lifetime of vegetable oil based hydraulic fluids are generally shorter than for the other fluid types.	

⁸³ Våg, C., Marby, A., Kopp, M., Furberg, L., & Norrby, T. (2002). A comparative life cycle assessment of the manufacture of base fluids for lubricants. Journal of Synthetic Lubrication, 19(1), 39-57.

		The variation in energy consumption and blending time for the three types of finished lubricants is of no significance to the outcome of the study.	
9	Data sources and quality	Statoil's supplier and other LCA studies	S _{DATA} = 1
10	Impact assessment categories / methods	Global Warming Potential and Acidification Potential	S _{IMPACT} = 1
11	Conclusions	Rapeseed oil based hydraulic fluid had the lowest environmental effect with regard to global warming and acidification potential. The emissions in kg CO ₂ eq. for the mineral base oil are near 3 500 kg, for the ester base oil the emissions represent 2 100 kg CO ₂ eq., and for the rapeseed base oil 1 400 kg CO ₂ eq. On the other hand, for the acidification potential the results are the following: 26 kg SO ₂ eq. for mineral base fluid, 16 kg SO ₂ eq. for synthetic and 11 kg SO ₂ eq. for vegetal base oil.	S _{OUTCOME} = 3
TOTAL SCORE		S_{SCOPE} = 5 S_{DATA} = 1 S_{IMPACT} = 1 S_{OUTCOME} = 3	S_{TOTAL} = 10

12	Item	Observation	Scoring
1	Title	The Influence of Agricultural Data Uncertainty in the LCA of biodegradable Hydraulic lubricants ⁸⁴	-
2	Authors	R. Ferret, G. Mendoza and M. Castilla	-
3	Reference and year	2004	-
4	Type of publication	LCA	S _{SCOPE} = 3
5	Scope	From a Life Cycle Assessment study of hydraulic lubricants from vegetable and mineral oil, it has been found that the agricultural step in the biodegradable hydraulic lubricant production has the main environmental impact. The aim of this study is to develop an uncertainty analysis of agricultural data used in the biodegradable hydraulic lubricant inventory from this LCA to determine the influence of data uncertainty in the environmental LCA result.	
6	Functional unit	20000 working hours, taking into account the life expectancy of a lubricant in a typical hydraulic system	
7	System boundaries	Cradle-to-grave. Two main parameters have been selected from agricultural step: fertilization rates and energy consumption.	
8	Assumptions (e.g. allocation)	Monte Carlo simulation	
9	Data sources and quality	-	S _{DATA} = 1
10	Impact assessment categories / methods	Global warming Acidification Eutrophication	S _{IMPACT} = 3
11	Conclusions	The Monte Carlo analysis allows knowing which environmental impact categories support the major uncertainty. The assumptions made in the LCA study for biodegradable lubricant inventory clearly influence the eutrophication potential impact category.	S _{OUTCOME} = 1

⁸⁴ Ferret, R., Mendoza, G., & Castilla, M. (2004, June). The influence of agricultural data uncertainty in the life cycle assessment of biodegradable hydraulic lubricants. In Complexity and integrated resources management—transactions of the 2nd biennial meeting of the international environmental modelling and software society (Vol. 1, pp. 301-307).

The strength of these papers lies in the comparison of different products in the same study, allowing the easy comparison between lubricants of different base products. Despite 12 papers have been considered, a total of 21 different lubricants are analysed (according the base fluid: mineral oils, synthetic oils and vegetable oils). Notwithstanding their potential relevance on impacts, the information about additives is limited; only 3 articles are related to the environmental impact of the additives in a lubricant product.^{73,76}

Most of the studies are developed in accordance with the ISO 14040 guidelines. Nevertheless, not all of them are complete LCA studies: 3 of them are cradle-to-grave LCA^{76,82,84}, and the rest do not represent the final stage of the lubricants: use and disposal stages.

4.2. LCA literature review results and supplementary evidence

The results revealed by the selected studies are presented separately for the different stages of the lifecycle of the lubricant under this chapter. Supplementary information on sustainability considerations in the different cycle stages has been included in order to cover most of the key aspects of the life cycle of lubricants.

2.1.1. Raw materials extraction, transport and processing of components

This section analyses the processes of extraction of raw materials and processing of the main components of lubricants, i.e. base fluids and additives and correspond to the first and second boxes in the LCA flowchart (see Figure 21). This stage of key importance since the nature and characteristics of substances will have consequences during all life of products. For instance, the use of bio-based raw materials will condition not only this stage but also the biodegradability of the final products, needed for instance in case of leakages or technically intended losses.

Base fluids comparison

Cuevas et al.⁷² performed a comparative life cycle assessment of rapeseed, soybean, and mineral based lubricants to determine the environmental impacts caused by these products. The assessment included an evaluation of the impacts to air and water generated during the extraction and production of these materials. The assessment resulted in rapeseed lubricants with the largest contribution in several impact categories including: acidification potential, photochemical smog, and eutrophication potential. Mineral lubricants dominated the global warming potential and ozone depletion potential categories.

Raimondi et al. 2012⁷³ compared mineral and synthetic base oils in a cradle-to-gate perspective. Higher impact has been detected for synthetic base oil in all the categories: the production of modern lubricants is linked to more complex and energy-consuming processes (Table 34). However, modern lubricating oils increase lifetime of engine oil, so adjusted impacts mineral base oil showed higher impacts per kilometre⁷³.

The contribution of the different phases (extraction, transport and refining) in the production process varies depending on the type of base fluid. For mineral base oil, the highest contribution is due to the extraction phase. On the other hand, the refining phase is the main contributor of the production of synthetic base oil. The transport phase

represents in all the categories the lowest impact (apart from the category mineral extraction of the mineral base oil production, which reaches 20% of the impact).

Table 34: Environmental impacts in the production of mineral, PAO (Poly-alpha-olefin) and hydrocracked base oils. FU: 1 kg of base oil. Source: Girotti et al. 2011⁷⁸.

Midpoint indicators	Unit	Mineral base oil	PAO base oil	Hydrocracked base oil
Climate change	kg CO ₂ eq.	1,02E+00	1,92E+00	1,02E+00
Ozone depletion	kg CFC-11 eq.	7,10E-07	7,60E-07	6,60E-07
Human toxicity	kg 1,4-DB eq.	1,20E-01	1,70E-01	1,30E-01
Photochemical oxidant formation	kg MNVOC	4,90E-03	6,80E-03	1,52E-02
Particulate matter formation	kg PM10 eq.	2,30E-03	3,20E-03	2,30E-03
Ionising radiation	Kg U235 eq.	1,60E-01	4,60E-01	2,70E-01
Terrestrial acidification	kg SO ₂ eq.	8,40E-03	1,13E-02	7,80E-03
Freshwater eutrophication	Kg P eq.	9,30E-06	1,20E-05	1,30E-05
Marine eutrophication	Kg N eq.	1,00E-03	1,50E-03	1,00E-03
Terrestrial ecotoxicity	kg 1,4-DB eq.	6,00E-04	6,00E-04	4,00E-04
Freshwater ecotoxicity	Kg 1,4-DB eq.	4,30E-03	5,30E-03	5,50E-03
Marine ecotoxicity	kg 1,4-DB eq.	1,70E-03	2,10E-03	2,60E-03
Agricultural land occupation	m ² a	3,30E-03	8,00E-03	1,73E-02
Urban land occupation	m ² a	9,10E-03	1,08E-02	1,16E-02
Natural land transformation	m ²	3,20E-03	3,40E-03	2,50E-03
Water depletion	m ³	7,00E-03	9,60E-03	8,30E-03
Metal depletion	kg Fe eq.	2,20E-02	2,90E-02	9,30E-02
Fossil depletion	kg oil eq.	1,46E+00	1,92E+00	1,83E+00

A comparison of three base fluids: mineral oil, synthetic oil, and vegetable oil, has been performed by Våg et al. 2002⁸³. The results showed that the rapeseed oil has the lowest environmental effect for global warming potential and acidification potential (Figure 22). Also the energy consumed during the processing of the oil has the lowest for rapeseed oil.

However, the LCA does not consider the hydraulic fluid lifetime for the different lubricants. Depending on the lifetime considered for the lubricants, the impact contribution could change: for example if the consumption rate of the vegetable oil is twice that of synthetic oil, the impact of vegetable oil could be higher than synthetic oil. Once more, the importance of considering all life cycle stages and an appropriate system boundary of the system is reflected.

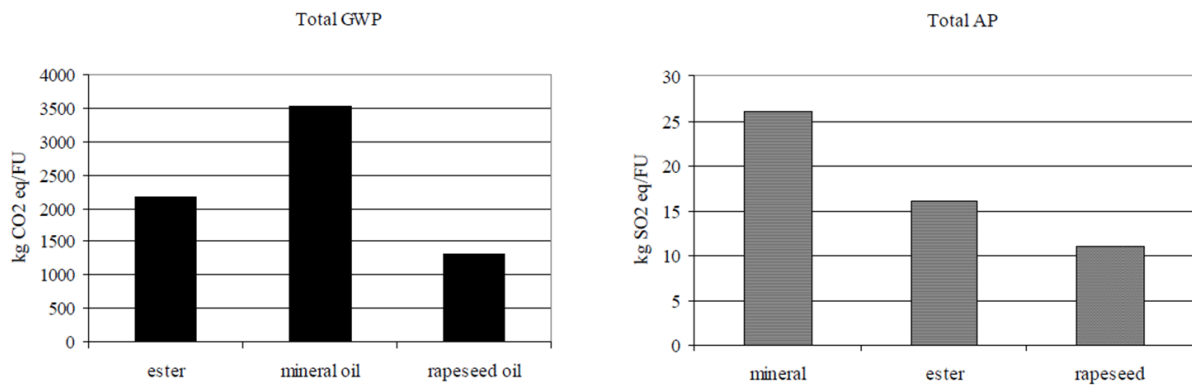


Figure 22: Contribution of Global warming potential (GWP) and Acidification potential (AP) for mineral base oil, synthetic base oil and vegetable base oil in a cradle-to-gate assessment. FU is 1m³ of hydraulic fluid. Source: Våg et al. 2002⁸³.

Theis 2006⁷⁵ compared two different base oils used for aluminium rolling. The life cycle assessment includes the impact of raw material, the extraction and processing and the aluminium rolling. The fossil energy consumed for vegetable base oil was 5,27 MJ/kg of oil, while for mineral base oil was 44,78 MJ/kg oil. On the other hand, the vegetable oil generated a negative impact for climate change category, due to the sequestration of carbon dioxide from the atmosphere. However, the eutrophication impact was higher for vegetable lubricants because the new tendencies in cultivation techniques.

Ekman & Börjesson 2011⁸⁰ investigated the environmental impact of one lubricant based on mineral oil and one based on vegetable oil. The results showed:

- The contribution to global warming is approximately four times higher for the mineral oil based lubricant than for the vegetable oil based.
- The contribution to acidification and eutrophication are higher for vegetable base oil lubricants due to the rapeseed cultivation.
- The photooxidant creation potential of mineral base oil lubricant is almost eight times higher than vegetable base oil.

Besides these impact results it was found that the consumption of primary energy for the production of mineral oil-based hydraulic fluids is more than twice for the vegetable. Also the biodegradability of vegetable base oil was found to be better.

Vegetable base oils

The increase in biobased products has led to many studies on the life cycle impacts of these products particularly during the agricultural phase and up to the production of oil for different uses such as cooking, fuel, and lubricant production among other applications. Minimal research on biobased lubricants has generated varying conclusions regarding the environmental effects of these products.

An environmental LCA of palm, rapeseed, soybean, coconut and sunflower oils has been analyzed⁷⁷. From a cradle to gate perspective, the sunflower oil tends to have high environmental impacts for the energy consumption, acidification, eutrophication and global warming; followed by rapeseed oil, coconut and palm oil. The high environmental impact of sunflower oil is because relative low yields per hectare compared to other crops and more fertilizers and pesticides per tonne of oil produced are used. On the other

hand, palm oil performs better due to the high yields per hectare that are obtained from land plantations.

The contribution to the total impact depends on the category analysed. Most of the contribution in global warming, eutrophication and acidification potential is due to the agriculture stage. Impact due to transport is mostly low, with the exception of photochemical smog potential where the contribution could be more than 60% (Figure 23).

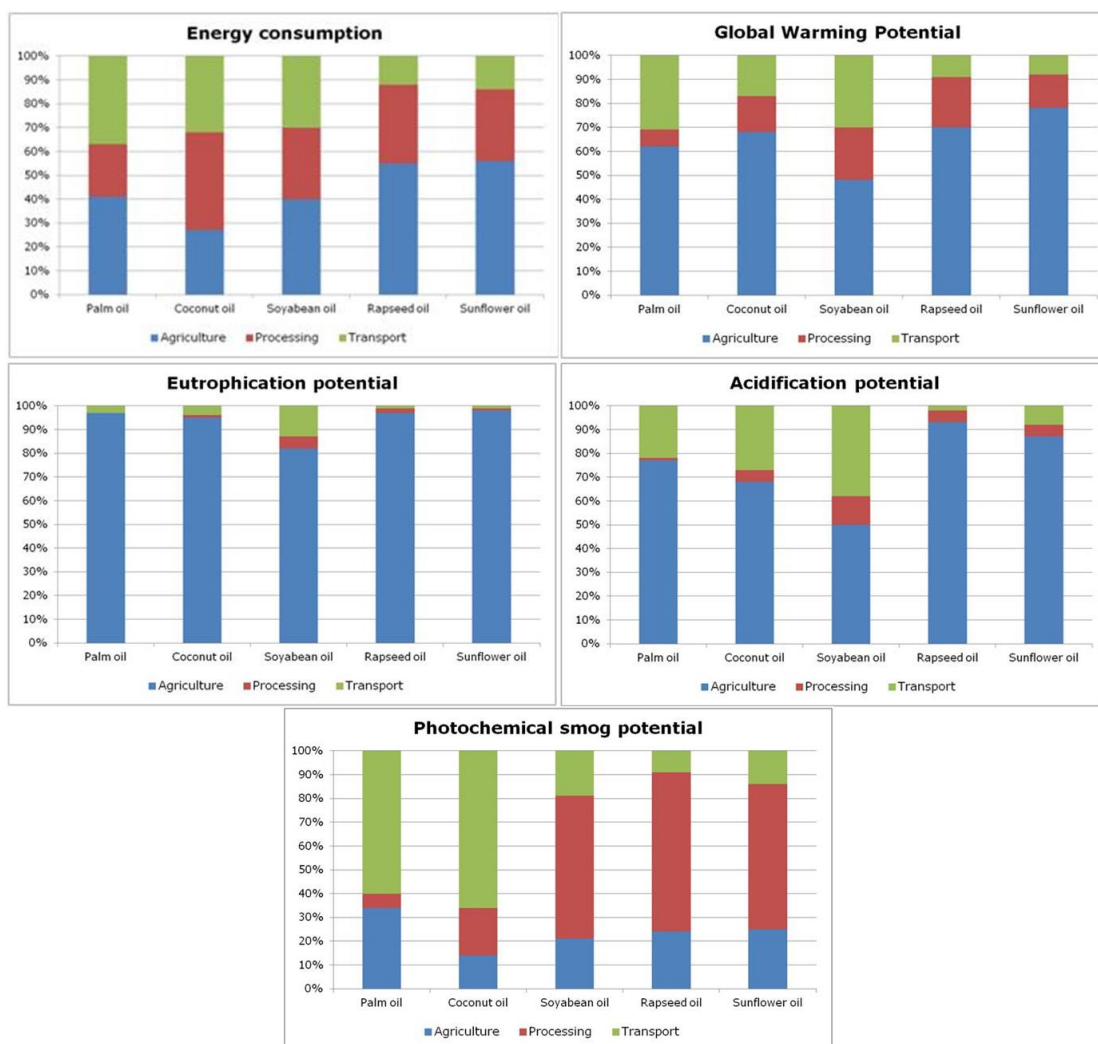


Figure 23: Process contribution to energy consumption, global warming potential, eutrophication potential, acidification potential and photochemical smog potential. Source: Dumelin, E 200977.

Cuevas 2010⁷² and Schmidt 2010⁸¹ have compared vegetable base oils. The cradle-to-gate analysis was made for soybean, rapeseed and palm base oil. Both articles concluded on the high impact of the rapeseed base oil.

The comparison between palm oil and rapeseed oil has shown lower impact in the ozone depletion category, acidification, eutrophication, land use and photochemical smog for palm oil. The contribution to the global warming depends on the changes in the cultivation area and the cultivation locally. Besides global warming, the impact associated with biodiversity and ecotoxicity depend on the different scenarios and is unclear the best crop option.

On the other hand, when the rapeseed base oil has been compared with soybean base oil, the categories with a higher contribution for rapeseed base oils have been acidification potential, carcinogenics, respiratory effects, eutrophication and photochemical smog. In the case of global warming, the impact in both oils presented negative values due to the assumption that CO₂ is sequestered during the farming stage. Soybean oil has negative impact in the ecotoxicity category because the method assumed that cadmium, chromium, copper, nickel and zinc emissions are absorbed by the soil.

Indeed, the impact associated with the production of vegetable base oil is strongly linked with the decisions of crop producers, who decide the type and the amount of fertilizers and pesticides applied to the crop. Using good and sustainable agricultural practices, environmental impacts of vegetable oils could be reduced. Moreover, the contribution of the optimal growing conditions; climate and soil conditions, will also affect the crop productivity.

To delve deeper into this issue, the major vegetable oils used for industrial purposes in Europe has been analysed with the software Simapro 8.0, and data from Agri-footprint database, version 1.0 (May 2014). The methodology used for the analysis has been ILCD 2011 Midpoint⁸⁵. They are presented in Table 35.

Table 35: Environmental impacts of the production of 1 kg of: sunflower oil and rapeseed oil. Source: Agri-footprint database.

Impact category	Unit	Sunflower oil	Rapeseed oil
Climate change	kg CO ₂ eq	3,41E+00	1,60E+00
Ozone depletion	kg CFC ⁻¹¹ eq	9,60E-09	8,00E-09
Human toxicity, cancer effects	CTUh	1,96E-07	6,30E-08
Particulate matter	kg PM2.5 eq	1,81E-03	1,17E-03
Ionizing radiation HH	kBq U235 eq	1,15E-02	9,89E-03
Ionizing radiation E (interim)	CTUe	1,14E-07	9,77E-08
Photochemical ozone formation	kg NMVOC eq	8,57E-03	2,97E-03
Acidification	molc H ⁺ eq	6,73E-02	5,03E-02
Terrestrial eutrophication	molc N eq	2,75E-01	2,24E-01
Freshwater eutrophication	kg P eq	3,13E-04	1,03E-05
Marine eutrophication	kg N eq	3,73E-02	3,13E-02
Freshwater ecotoxicity	CTUe	1,64E+01	7,74E+00
Land use	kg C deficit	1,36E+02	3,61E+01
Water resource depletion	m ³ water eq	5,01E-02	2,03E-03
Mineral, fossil & ren resource depletion	kg Sb eq	6,25E-05	1,57E-05

The system boundaries of the oils studied cover:

⁸⁵ European Commission, Joint Research Centre, Institute for Environment and Sustainability. Characterisation factors of the ILCD Recommended Life Cycle Impact Assessment methods. Database and Supporting Information. First edition. February 2012. EUR 25167. Luxembourg. Publications Office of the European Union; 2012.

- The production process, including also fertilizer use, diesel use for field management practices, field emissions to the air and water, direct land use change, water use and emissions due to pesticide use,
- Milling and processing to refined oil,
- Transport is not included.

The main impact categories are analysed and compared to identify the contribution of the different crops to each category. In the following figure the relative impact on climate change, ozone depletion, photochemical ozone formation, acidification, freshwater eutrophication, marine eutrophication, freshwater ecotoxicity and resource depletion are presented. The highest relative impact in all impact categories can be assigned to the sunflower oil.

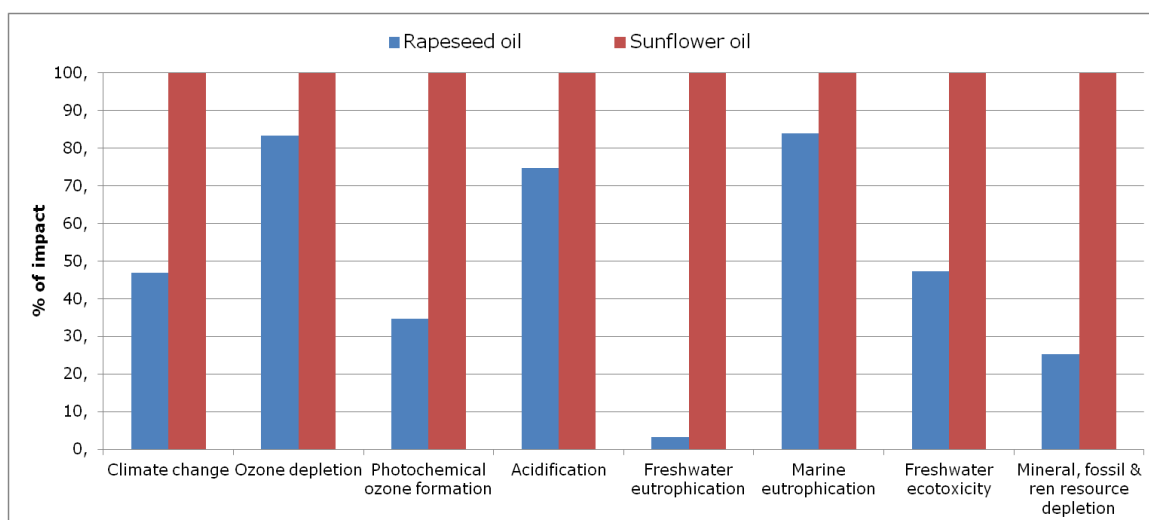


Figure 24: Relative environmental impacts of the production of 1 kg of: sunflower oil, rapeseed oil.

Additives

Typically, additives represent approximately 7% of a lubricant. Additives can provide different characteristics to base oils, such as: antioxidant, corrosion inhibitor, rust inhibitor, anti-wear, anti-foam, extreme pressure, friction modifiers, and viscosity index improver.⁷²

The articles related with the environmental impact of the additives^{74,78} have been analysed in depth.^{73,78} Both articles have the same authors and the conclusions are the same. However, as previously mentioned, both articles are considered as relevant papers for this review due to some differences in content.

Girotti et al. 2011⁷⁸ evaluates the relative additive impacts in a lubricant product formulated as: 80% base fluid, 20% additives (includes dispersant, detergent, viscosity modifier, antioxidant, and antiwear). The results show that the contribution of additives in terms of environmental impact cannot be considered negligible, due to they can be up to 80% of the total impacts, while they represents only 20% in mass.

The impact categories that represent more than the 20% of the total impact along the life cycle are: climate change, human toxicity, photochemical oxidant formation, particulate matter formation, ionising radiation, freshwater eutrophication, marine eutrophication, marine ecotoxicity, agricultural land occupation, urban land occupation, water depletion, metal depletion, and fossil depletion. For agricultural land occupation

and metal depletion, the impact generated by the amount of additives is greater than the impact generated by the base fluid.

Roiz & Paquot 2012⁷⁶ refers to the previous article to perform a sensitivity analysis. The results show the following: additives represented 5.5% in mass, and in the biobased chainsaw oil the impact could be up to 57% to the total impact for some impact category; and in the mineral chainsaw oil, the impact could be up to 55% to the total impact for some categories. The most affected categories by additives are: freshwater eutrophication, abiotic depletion, photochemical oxidation, and ecotoxicity potential.

To sum it up, the relative impact of the additives is higher than the relative impact for the base. Moreover, the percentage of additives in lubricant composition is increasing and consequently the environmental impact of the lubricant will enlarge.

The lubricating additives industry is continuously evolving in order to improve properties and performance of commercial lubricants, reduce fuel consumption and increase lifetime of engines. Additives are analyzed further from the hazardous substances perspective in Section 4.6.1.2.

Supplementary evidence on base fluids

Oil based lubricants

- **Vegetable oils** used in lubricants are mainly derived from rapeseed, sunflower, palm and coconut⁶⁹.

In Europe, rapeseed and sunflower oils are the major vegetable oils used for industrial purposes, including lubricant production, while soybean and corn are mostly used in the United States. Europe utilizes rapeseed and sunflower oils due to their availability, thermal oxidation stability, and superior flowing properties compared to other vegetable oils. Biobased lubricants can be used in many applications and are classified in several categories or uses including: hydraulic fluids, greases, motor oils, transmission and gear oils, chain and cable lubricants, metalworking fluids, degreaser, corrosion inhibitor, food grade oils, 2-cycle engine oils, penetrating oils, and compressor oils.⁷²

The main advantages of vegetable oils are that they are readily available, have a lower price than synthetic esters, are 100 % renewable, and are readily biodegradable. The technological drawbacks are their sensitivity to high temperatures and poorer low-temperature performance and oxidative stability.

➤ **Sustainable origin of vegetable oils**

A wide range of types of vegetable oils are used as lubricants and additives for industrial lubricant applications⁸⁶:

Type of oil	Application
Canola oil	Hydraulic oils, tractor transmission fluids,

⁸⁶ Shashidhara YM, Jayaram SR (2010) Vegetable oil as a potential cutting fluid—an evolution. Tribol Int 43:1073–1081

	metalworking fluids, food grade lubes, penetrating oils, chain bar lubes
Castor oil	Gear lubricants, greases
Coconut oil	Gas engine oils
Olive oil	Automotive lubricants
Palm oil	Rolling lubricant, -steel industry, grease
Rapeseed oil	Chain saw bar lubricants, Biodegradable greases
Soybean oil	Lubricants, biodiesel fuel, metal casting/working, hydraulic oil
Jojoba oil	Grease, lubricant applications
Crambe oil	Grease, intermediate chemicals, surfactants
Sunflower oil	Grease,
Tallow oil	Steam cylinder oils, ,lubricants,

Despite the potential environmental advantages of using these vegetable oils in comparison with mineral or synthetic oils, some impacts from vegetable oils used should be considered, especially those related to the agriculture stage. Since one of the environmental impacts source of vegetable oils is the agriculture operations, oils coming from plantations with good sustainability harvesting practices are desired. For this reason it should be guaranteed that vegetable ingredients come from sustainable managed source according to the principle of sustainability for economic, social and environmental aspects in order to guarantee that these vegetable raw materials have the minimum environmental impact during the agriculture stage.

Palm and soybean oils are the oils more controversial, because of the deforestation association with their plantations in Southeast Asia (Palm) and Amazon rainforest (Soy). Some certifications exist for these oils. For instance, for Palm oil exist the Roundtable on Sustainable Palm Oil (RSPO) certification, which is the main scheme of initiatives that aims to promote the growth and use of sustainable vegetable oils based on economic, social and ecological criteria. Similar initiatives regarding other renewable products, e.g. soy beans (Round Table on Responsible Soy (RTRS)) and sugar cane, are currently being developed. Some producer countries have developed their own certificates for palm oil such as Malaysia Sustainable Palm Oil (MSPO) certification and the mandatory Indonesian Sustainable Palm Oil (ISPO) certification. All official certifications should prove compliance with the ISO Guide 65/66. General criteria:

- Economic criterion: continuous efficiency improvements; documentation on the improvement of production conditions and continuous increases in yield which lead to work and employment
- Ecological criterion: rainforest or other areas of high conservation value may not be destroyed to make way for new plantations
- Social criterion: working conditions must be consistent with industry standards and minimum wages must be paid. The RSPO also addresses health and safety at work.

In the European Union, under the Renewable Energy Directive (RED)⁸⁷, only those vegetable oils that have been verifiably certified as sustainable can receive state support for energy use and may be counted towards national renewable energy targets. The established standards are related to requirements concerning changes in the use of land, Greenhouse Gas Effect calculations and traceability, and they determine if these raw materials may be considered as sustainable or not. To meet this regulation, they have created the RTRS Annex for Biofuels. This Annex includes all the requirements of the directive and, although certification is only optional, it assures that producers will export soy to any of the member states of the European Union in the form of raw material for biofuel production.⁸⁸

- **Mineral oils**

Mineral base oil is produced from crude oil through several processes of distillation and refinery.⁷³ Impacts are related to the phase of extraction and to the transport from on-shore and off-shore sites to the refinery (main transportation systems: oil pipeline and transoceanic tanker). The first steps of processing are the basic distillations (atmospheric and vacuum) and further specific refining stages to purify the base oil. Accordingly, 112 kg of base oil are produced from 1 t of crude oil.

- **Synthetic oils** include among others polyalphaolefins (PAO), synthetic esters and polyalkylene glycols (PAGs). PAOs are petrochemical derived synthetic oils that most resemble mineral oils. The environmental impact of synthetic oils can be higher in the production phase, since greenhouse emissions of PAO are almost twice higher than those of mineral base oil, due to higher quantities of refinery gas burned for heat consumption and, in general, to a more energy consuming production process⁸⁹. However the characteristics of these lubricants allow a longer life of the lubricant and require less oil changes, leading to a decrease of environmental impacts per distance covered. Moreover, while they appear chemically similar to mineral oils refined from crude oil, PAOs do not contain the impurities or waxes inherent in conventional mineral oils.
- **Re-refined oil** is used oil that undergoes an extensive re-refining process to remove contaminants to produce fresh base oil by means of heating and simple chemical or mechanical operations. In cases where primarily the composition and source of a used oil is known and reliable the resulting oil can be blended with additives and returned to original application, as lubrication. GEIR (*Groupement Européen de l'Industrie de la Régénération*) considers that with modern re-refining technologies regenerated used oils can be re-refined over and over limitless number of times with no quality loss of its derivative product. Such

⁸⁷ Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

⁸⁸ <http://www.responsiblesoy.org/la-rtrs-presenta-anexo-sobre-biocombustibles-para-el-cumplimiento-de-los-requisitos-de-la-directiva-eu-red/?lang=en>

⁸⁹ Madanhire, I., & Mbohwa, C. (2016). Lubricant Additive Impacts on Human Health and the Environment. In *Mitigating Environmental Impact of Petroleum Lubricants* (pp. 17-34). Springer International Publishing

appropriately regenerated used oils will produce very high quality base oils reducing the impact on the water and soil. Waste oil regeneration contributes to CO₂ emissions reduction associated with extracting and processing crude oil and is key process for closing the loop of the lubricant lifecycle which is in line with the circular economy strategy. With modern re-refining technologies, CO₂ emissions (kg of CO₂ per ton of base oil) can be reduced by more than 50% as compared to the conventional production of base oil.⁹⁰ Re-refined oil is further analyzed in the end-of life phase (see chapter 2.1.4).

Water based lubricants

For some applications such as hydraulic fluids, metalworking fluids or mould release, water based lubricants are commonly used. These lubricants are diluted in water before its application in situ since they are sold in concentrated format.

Environmental impact may occur mainly during the disposal of waste fluids. Sometimes these water based lubricants are removed through waters at their end-of-life, causing pollution to water if they are not treated correctly. The risks that short and long term impacts on entire living occur could be very high. Metalworking fluids and its additives are analysed further in detail in Sections 4.8.1 and 4.6.1.2 respectively.

Supplementary evidence on transport processes

This section analyses the transport process impact because it has not been addressed on the life cycle assessment review due to the lack of data. To provide information about this issue, transport contribution has been analysed with Simapro 8.0.

The process *Lubricating oil* of the database Ecoinvent 3 has been assessed. The system boundary includes from the reception of diesel at the factory gate to the production of 1kg of lubricating oil. The dataset includes the input material, energy uses, infrastructure and emissions. The transport until the factory and the transport from the factory to the user are also included.

The main impact categories have been selected to show the relative contribution of transport in all the process with the methodology of ILCD 2011 Midpoint.⁹¹ The contribution varies depending on the impact category evaluated. However the highest contribution never exceeds 5%: the percentage goes from 4,2% in marine eutrophication to 0,3% in ozone depletion (Table 36).

Table 36: Relative impact of transport on the production of 1 kg of lubricating oil

Impact Category	Lubricant	Transport
Climate change (%)	98,3	1,7
Ozone depletion (%)	99,7	0,3
Human toxicity, cancer effects (%)	97,7	2,3
Human toxicity, non-cancer effects (%)	98,7	1,3

⁹⁰ GEIR Fishing Vessel registered in Norway: position (GEIR: Groupement Européen de l'Industrie de la Régénération)

Photochemical ozone formation (%)	99,1	0,9
Acidification (%)	97,5	2,5
Freshwater eutrophication (%)	99	1
Marine eutrophication (%)	95,8	4,2
Freshwater ecotoxicity (%)	98,5	1,5
Mineral, fossil & ren resource depletion (%)	99,1	0,9

The relative impact of transport in average does not achieve 2% (Figure 25), for this reason it might be of low relevance to include the transport processes in the revised criteria set.

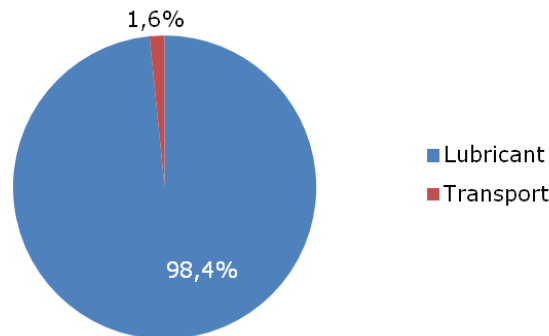
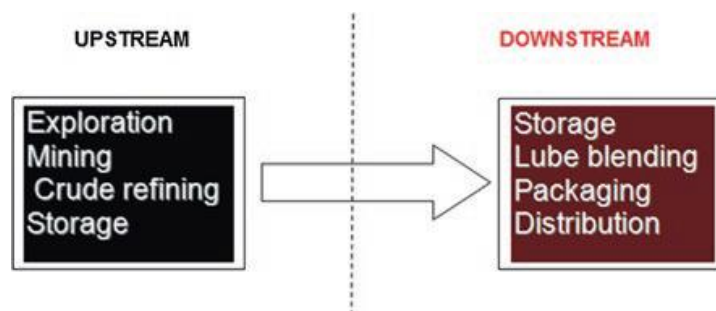


Figure 25: Relative impact of transport in the production of 1 kg of lubricating oil.

2.1.2. Manufacturing of lubricant, packaging and distribution

The productive process of a lubricant product can be divided into upstream processes (contemplated in raw materials section (section 2.1.1)) and downstream processes (including manufacturing or blending) and followed by packaging and distribution. This chapter assesses the downstream processes, packaging and distribution and correspond to the third and fourth boxes in the LCA flowchart (see Figure 21).



Whereas some refineries also produce the final lubricant products, most non crude producing countries are involved only with the downstream operation of physically mixing the raw materials in a lube blending plant.⁸⁹

After processing the raw materials; including base fluid (refining for mineral oil, chemical processing for synthetic oil and agriculture and extraction/processing for vegetable oil) and additives, the manufacturing process consist on blending process. The major steps involved in the lubricant blending process are⁸⁹:

- 1) Reception and storage of base oils, additive and packaging materials

- 2) Physical mixing as per formulations sheet and agitation blending of base and additives. The oil is mixed with the additive to give the desired physical properties (previously explained). Production usually takes place in 1000-30000 litres batches.
- 3) Testing of the lubricant quality
- 4) Filling of packaging containers with oil
- 5) Warehouse storage and distribution of finished lubricants

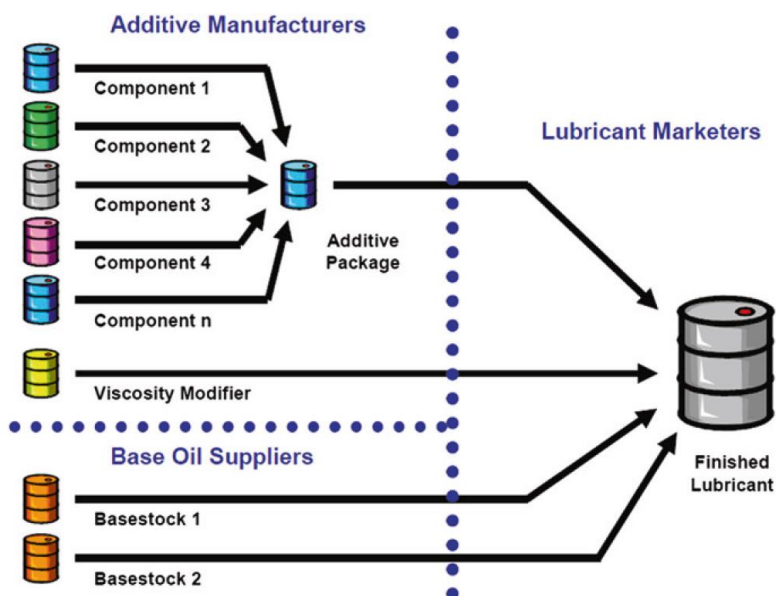


Figure 26: Lubricant manufacturing. Source: Madanhire & Mbohwa, 2016. 89

The impact assessed during manufacturing in a life cycle includes energy, water and resource consumption during the production of the lubricant. Considering a mineral oil as a raw material, the production of the lubricant covered from the entrance of raw material to the factory up to the output of the final product: mineral-base lubricating oil.

Using the software Ecoinvent 8.0., an example of lubricant production has been analysed. The process (Table 37) represents the production of 1kg of liquid lubricating oil, including raw materials, energy consumption and emissions generated during the process. The infrastructure also is included with a default value. The data used is an average of European processes for raw materials and electricity mix used.

The main impact categories have been evaluated with the methodology of ILCD 2011 Midpoint⁹¹ to distinguish between the impact generated due to the raw material or the lubricant manufacturing. In the following table it can be seen that manufacturing stage have lower impacts than raw materials extraction and processing, although it can have relevant values in some categories like freshwater eutrophication or freshwater ecotoxicity.

⁹¹ European Commission, Joint Research Centre, Institute for Environment and Sustainability. Characterisation factors of the ILCD Recommended Life Cycle Impact Assessment methods. Database and Supporting Information. First edition. February 2012. EUR 25167. Luxembourg. Publications Office of the European Union; 2012.

Table 37: Relative impact of manufacturing stage in the production of 1 kg of lubricating oil

Impact category	Raw Material	Manufacturing
Climate change (%)	74,1	25,9
Ozone depletion (%)	91,9	8,1
Photochemical ozone formation (%)	97,0	3,0
Acidification (%)	83,6	16,4
Freshwater eutrophication (%)	28,9	71,1
Marine eutrophication (%)	83,1	16,9
Freshwater ecotoxicity (%)	45,7	54,3
Mineral, fossil & ren resource depletion (%)	90,1	9,9

On the other hand, the relative impact of the manufacturing stage in life cycle of lubricating oil has been analysed by Ekman & Börjesson⁸⁰: in a cradle-to-gate perspective the paper describes the impact of the extraction of crude oil, the refining, the lubricant production, and the waste treatment on the impact categories of global warming, acidification potential, and eutrophication potential. The lubricant production represents the following percentages approximately in relation to the entire life cycle analysed:

- Global warming potential: 30%
- Acidification potential: 75%
- Eutrophication potential: 80%
- Photooxidation creation potential: 50%

However, the impact considered does not include the additives impacts, which, as mentioned above, could contribute to 20% on average of the lubricating oil product.

Supplementary evidence on packaging

Lubricants are packed in many different ways (materials, designs). Packaging of lubricant products can vary from low capacity packaging for particular uses, to big packaging units (typically from a 250 ml bottles to big capacity pails or tanks). The four main industrial lubricant packages are pails (20 litres), drums (200 litres), totes (1600 litres) and bulk tanks.

The lack of data makes it difficult to obtain a satisfactory understanding of the relative impact of the packaging in relation with the rest of life cycle stages. Nevertheless, it seems there is a strong relation between the materials and substances used for packaging as well as the packaging design with the potential impacts during use and end of life.

Some materials and substances used in the packaging could be considered relevant due to its potential environmental impact and its inherent toxicity. In addition, the packages are designed to preserve product quality, allow the user easier handling and provide comprehensive information for the consumer. Some environmental problems related to packaging come from spills during storage, handling, use and packaging waste. It should be considered that approximately 50% of all traditional lubricants are released into the environment during use, spills, and disposal. Packaging should be designed to guarantee a good storage and handling of lubricants, which ensures the high quality preserved,

which is essential in extending the life of machinery through use of a clean and healthy fluid.

At the end-of-life of the packaging, waste packaging shall be managed as a hazardous waste since they are classified as hazardous by the European Waste Catalogue: *150110 Packaging containing residues of or contaminated by dangerous substances* (since lubricants are considered hazardous substances). For this reason proper collection and treatment is needed in order to guarantee the potential recovery, reuse or recycling of this packaging.

Against the background, some strategies to reduce the environmental impact of a packaging are the followings:

- Packaging raw materials: use of no-toxic or less contaminant substances as raw material, and the use of recycled materials.
- Good protection during storage and handling of the lubricant, with spill protection mechanisms.
- Dispensing: the diversified selection of dispensing closures offer great opportunities for convenience and function, the optimization of the packaging could reduce the losses of lubricant in the environment during use.
- Packaging end of life: the possibility of recovery or recycling the packaging at its end-of-life.

It is therefore recommended that the packaging of lubricant is designed to limit losses during dispensing. The packaging should be designed in a way that as little oil as possible is able to remain inside. In addition it might be important to include information on handling and disposal information requirements for waste oil in the case of lubricants designed to be sold to private end consumers.

2.1.3. Use phase

Use phase is not included in most of the articles studied. Authors^{75,76} exclude the use phase in studies focused in comparisons of different type of lubricants because they consider that the impact generated is identical since the same functionality is compared.

Wightman et al. 1999⁸² and Ferret et.al. 2004⁸⁴ include in their analysis the use stage of the lubricants. Ferret et al. 2004 assumed a lifetime of 20000 working hours, taking into account the life expectancy of a lubricant in a typical hydraulic system.

Wightman et al. 1999 concludes that all the environmental impact categories considered are lower for chainsaw lubricant made from rapeseed oil than from the comparable mineral oil product. The use stage of mineral oil had included the emissions of CO₂ of the degradation of oil; in contrast for vegetable oil had been assumed that the CO₂ emissions from degradation are assimilated in subsequent crops.

Mc Manus et al. 2003⁷⁹ quantify the use throughout the machines' life on their life cycle assessment. The use of rapeseed and mineral oil in mobile hydraulic systems are compared, considering that rapeseed oil have to be replaced twice as often as mineral and that the components in a hydraulic system are replaced once for a system running on mineral oil and twice for a system running on rapeseed oil. The results determine that when the whole life cycle is considered, the environmental impact of the system running on rapeseed fluid is greater than that of those running on mineral oil.

In fact, the lubricant functionality depends on the user and it is necessary to define the final use of the lubricant to analyse the entire life cycle. However, the use stage gives important information: lifetime. Depending on lubricant lifetime the impact could change due to the decrease of the lubricant consumption (if analyses in longer scale). Raimondi et al. 2012⁷³ reflected this idea comparing the impact with two functional units: per 1 kg of product and per km adjusted. The synthetic lubricants have higher impact per kg in comparison to mineral base oil lubricants. However, synthetic lubricants offer a longer life time and requires less oil changes, leading to a decrease of environmental impacts per km adjusted (Figure 27). These variations on results indicate the importance of including functionality and use on LCA studies.

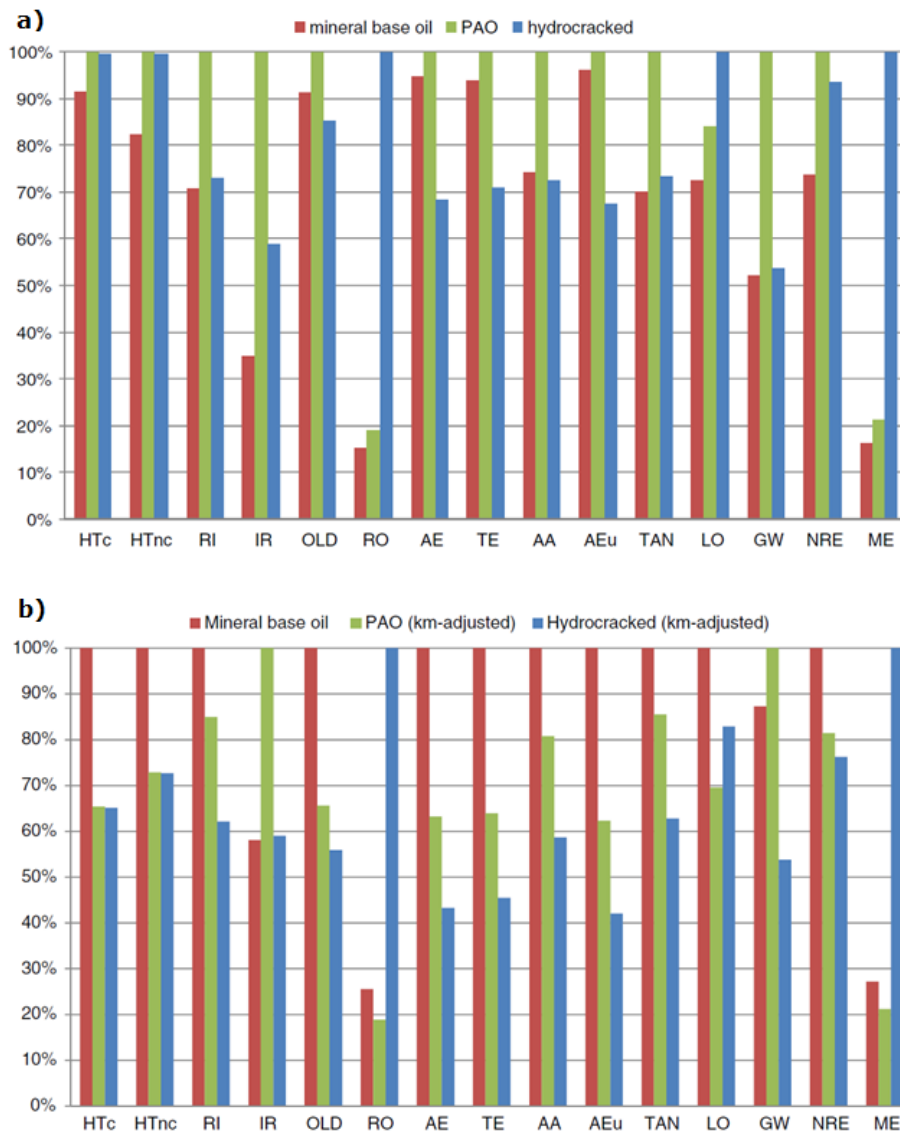


Figure 27: Comparison of from-cradle-to-gate environmental impacts related to mineral base oil, PAO base oil and base oil hydrocracked. a) Data per 1 kg of base oil, b) Data per 1 kg adjusted to the lubricant lifetime. Source: Raimondi et al. 2012⁷³.

Supplementary evidence on use phase

Lubricants are designed for specific uses and applications to ensure they meet system specifications and operating conditions. Formulation of lubricants will depend on their purpose and designed application.

During use, lubricant properties can contribute to minimize the environmental impacts of several processes and equipment; since they may be used in order to optimize energy efficiency and minimize wear in the machinery which they lubricate and which have maximized service lifetimes in order to reduce the amount of lubricant required⁸⁹. For this reason the performance of these products is of high importance in terms of sustainability.

The use or application of a lubricant product will highly condition its potential environmental impact, considering the probability of release to the environment (application way and loss during use and management of used oil) and the consequences in terms of toxicity and impact on human health and the different environmental systems.

Approximately 50% of all traditional lubricants are released into the environment during use, spills, and disposal⁷². One of the characteristics that will condition the environmental impact of a lubricant once it reaches the environment is the biodegradability. Due to their poor degradability mineral oils remain in the eco-system for a long time and even in case of high dilutions there will have a fatal eco-toxicological effect. In contrast with traditional lubricants, biolubricants can be biodegradable and may have a low toxicity as long as the additives utilized also possess these characteristics. Although biolubricants have numerous benefits, some disadvantages have been observed, particularly during the use phase including: temperature limitations, bad odour, metal discoloration, viscosity limitations, and poor thermal and oxidative stability. The best opportunity for biolubricant usage is in situations where the lubricant can be unintentionally exposed to humans, food or the environment, since the use of high toxicity products in these scenarios has the potential to cause severe damage. Therefore, further considerations should be made for lubricants that will be used in total loss applications, food industry, or systems with leakage. However, additives must also have biodegradable and low toxicity characteristics for the biolubricants to be used in these applications⁷². At present the use of pure native plant oils is limited to total loss applications and those with very low thermal stress.

In addition to reducing environmental impacts, biolubricants can result in a cleaner work environment, less skin problems for workers, better safety due to flashpoint properties, constant viscosity, less oil mist and vapor emissions, and a competitive tool life.⁹²

During use of lubricants⁸⁹ in say engines, gearboxes, hydraulic systems, turbines or air compressors, the oil is contaminated with wear debris; the lubricating base oil deteriorates and is degraded to acids; the additives have decomposed into other chemical species; and process fluids such as degreasers and solvents have mixed into the used oil. It was also noted that used oil contains wear metals such as iron, tin and copper as well as lead from leaded petrol used by motorists. Zinc arises from the additive packages in lubricating oils. Many organic molecules arise from the breakdown of additives and base oils. The most potentially harmful molecule is the polycyclic aromatic hydrocarbon (PAH) such as benz(a)pyrene and chrysene. Petrol engines generate the most PAH molecules per 1000 km, with diesel engines below that and two-stroke engines generating the least amount of PAHs.

⁹² IENICA (2004). Biolubricants- Market Data Sheet. UK, Central Science Laboratory:1-11.

Any release of used oil to the environment, by accident or otherwise, threatens ground soil and surface waters with oil contamination there by endangering drinking water supply and aquatic organisms. Used oil can damage the environment in several different ways such as:

- Spilled oil tends to accumulate in the environment, causing soil and water pollution. Oil decomposes very slowly. It reduces the oxygen supply to the microorganisms that break the oil down into non-hazardous compounds.
- Toxic gases and harmful metallic dust particles are produced by the ordinary combustion of used oil. The high concentration of metal ions, lead, zinc, chromium and copper in used oil can be toxic to ecological systems and to human health if they are emitted from the exhaust stack of uncontrolled burners and furnaces.
- Some of the additives used in lubricants can contaminate the environment e.g., zinc dialkyl dithiophosphates, molybdenum disulphide, and other organometallic compounds.
- Certain compounds in used oil —e.g., poly-aromatic hydrocarbons (PAHs) — can be very dangerous to human health. Some are carcinogenic and mutagenic. The PAH content of engine oil increases with operating time, because the PAH formed during combustion in petrol engines is accumulated in the oil.
- Lubricating oil is transformed by the high temperatures and stress of an engine's operation; resulting in oxidation, nitration, cracking of polymers and decomposition of organ-metallic compounds.
- Other contaminants also accumulate in oil during use-fuel, antifreeze/coolant, water, wear metals, metal oxides and combustion products.

Oil in equipment should not be changed unless it has reached the end of its useful life. This is typically not the case, because the oil is often changed based on an arbitrary time criteria or because of contaminants such as water or dirt. These contaminants can normally be removed with the proper equipment. A longer oil lifecycle not only contributes to less liquid waste, but there are other benefits as well: cost savings because labour efforts can be used more effectively elsewhere, and fewer shutdowns for oil changes. These added costs can sum up to at least five times the price of the oil alone. In addition, not having to drain the old oil, move it for disposal and bring in new oil also means fewer chances of spills. Spillage can often occur when a pail is knocked over or a drain valve breaks off. Equipment users in the construction, earthmoving, forestry and farming industries are increasingly seeking "green" solutions because environmental contamination may be a significant issue. Although only a small portion of lubricants used in these applications may pose an actual threat to the environment, this can add up to several million metric tons worldwide.

The lubricant families have been detailed in this section, focusing on the way of application, the potential release to the environment and the potential impacts on environment and humans, both during use and during disposal of waste oils (since these two stages are closely related, especially in those cases where the waste oil is not collected and recovered) at the end of life.

TOTAL LOSS

Lubricant loss: TOTAL

Use/application

This family included the following applications, (According to ISO):

- Rough applications, axles, railway, etc.
- Lightly loaded parts (rolling bearings, gears), plain bearings in hydrodynamic regime
- Open gears, wire ropes, mechanical chains
- Chains of chain saws

Potential release to Sensitive areas of environment (YES/NO)

This category of lubricants are totally lost during use; the oil is not recovered and ends-up into the different compartments of the environment since they are virtually released to the environment, very often in high sensitive areas as example:

- Chain-saw: Virtually all of the chain saw lubricant ends up in the environment during use, normally in forest ecosystems.
- Rail-way: At present a large amount of rail and rail-curve lubricants are used throughout the world. After operation these lubricants fall on the railroad tracks and pollute the environment, since if these lubricants do not decompose in natural conditions they can damage the ecosystems associated.
- Open gears (in maritime ecosystems): they are in direct contact with maritime water, potentially polluting the aquatic ecosystem.

Key environmental problem to be targeted

Use:

Emissions to air, soil and water is unavoidable, being especially problematic when these lubricants are used in sensitive areas (forest, natural ground soil and groundwater, maritime ecosystem, etc.).

Disposal:

Any release of used oil to the environment can pollute ground soil and surface and ground waters, endangering drinking water supply and aquatic organisms. These oils are not recovered after use, so used oil is release to the environment.

METAL WORKING FLUIDS

Lubricant loss: ACCIDENTAL

Use/application

Metalworking fluids (MWFs) are used to reduce heat and friction and to remove metal particles in industrial machining operations. There are numerous formulations, ranging from straight oils (such as petroleum oils) to water-based fluids, which include soluble oils and semisynthetic/synthetic fluids. MWFs may be complex mixtures of oils, emulsifiers, anti-weld agents, corrosion inhibitors, extreme pressure additives, buffers (alkaline reserve), biocides, and other additives. In use, the fluid complexity is compounded by contamination with substances from the manufacturing process (such as tramp oils, hydraulic fluids, and particulate matter from machining operations). Furthermore, water-based metalworking fluids support microbial growth, which introduces biological contaminants (such as bacterial and fungal cells or cell components and their related biological byproducts such as endotoxins, exotoxins, and mycotoxins).⁹³

⁹³ <https://www.cdc.gov/niosh/topics/metalworking/>

Potential release to Sensitive areas of environment (YES/NO)

Disposal:

Environmental impact occurs mainly during disposal of waste fluids.

Human health worker exposure:

Although this industrial lubricant is used indoors, main problematic issue is related to worker exposure. Some 1,2 million workers in machine finishing, machine tooling, and other metalworking and metal-forming operations are potentially exposed. Workers can be exposed to the fluids by breathing aerosols generated in the machining process, or through skin contact when they handle parts, tools, and equipment covered with the fluids. The National Institute for Occupational Safety and Health (NIOSH) defines MWF aerosol as the mist and all contaminants in the mist generated during grinding and machining operations involving products from metal and metal substitutes. Occupational exposures to metalworking fluids may cause a variety of health effects. Respiratory conditions include hypersensitivity pneumonitis (HP), chronic bronchitis, impaired lung function, and asthma.⁹³

Key environmental problem to be targeted

Disposal:

The importance of reducing the impacts of MWFs has become central to improving the sustainability of metals manufacturing. The disposal of used oils is challenging and costly. The large volumes of aqueous waste carry toxic metals from manufacturing (e.g., cobalt and lead) into the environment, along with a host of chemicals such as corrosion inhibitors, defoaming agents, surfactants, chlorinated fatty acids and chelating agents that pose environmental risks. MWF treatment and release to the environment can also lead to significant oxygen depletion and nutrient loading in surface waters further posing environmental risks.⁹⁴

MOULD RELEASE

Lubricant loss: TOTAL (concrete mould release), **ACCIDENTAL** (Industrial mould release)

Use/application

Mould release agents can coat moulds with paintbrushes (generally for smaller projects) or spray hoses (for more automated projects).

Water based mould release agents are growing in importance in the market.

Apart from industrial mould release, a specific category is **mould concrete release agents**, that can be especial environmental impact since is easily released to the environment. Mould concrete release agents are used for lubrication during the process of detaching the moulded concrete from the mould (formwork) and prevent adhesion of freshly placed concrete to the forming surface.

Normally petroleum-based mould release lubricants are used in the workplaces involving pre-cast and construction-related concreting operations.

Potential release to Sensitive areas of environment (YES/NO)

⁹⁴ Steven J. Skerlos, Kim F. Hayes, Andres F. Clarens, Fu Zhao. Current Advances in Sustainable Metalworking Fluids Research

<p>YES</p> <p>Concrete mould release:</p> <p>The lubricant can be introduced to the environment instead of being applied to the concrete forms, due for instance to over-application of form release agents in the precast industry. Some of this overspray ends up on the floor, ultimately washes off and contaminates the outside ground. These lubricants can be left on place instead of being recovered, ending up directly to the environment.</p>	<p>NO</p> <p>Industrial mould release:</p> <p>They do not have potential release to sensitive areas since they are use basically in industrial operations.</p>
<p>A second area of concern regarding the environment is Volatile Organic Compounds (VOCs) in form release agents.</p>	
<p>Key environmental problem to be targeted</p> <p>Concrete mould release: Loss to the environment during use</p> <p>Industrial mould release: Main environmental impacts can be caused by uncorrect waste management.</p>	
<p>ENGINE OILS</p>	
<p>Lubricant loss: TOTAL (2-T), ACCIDENTAL (4-T)</p>	
<p>Use/application</p> <p>Engine oils are used to power cars, motorcycles, lawnmowers, engine generators and other machineries.</p> <p>Regarding the 2-stroke engine oils:</p> <p>the two-stroke engine are commonly used in high-power and handheld applications; they are normally found in small, portable, or specialized machine applications such as outboard motors, high-performance, small-capacity motorcycles, mopeds, underbones, scooters, snowmobiles, karts, ultralights, model airplanes and model vehicles, lawnmowers, chainsaws, weed-wackers and dirt bikes or instance, they are usually used in simple engine such as pleasure boats. The number of pleasure boats in the North Sea area has been estimated to be in the region of 2 million. Of these, it is estimated that 1 million crafts have outboard two-stroke engines. Approximately 20,000 tonnes (40 million pounds) of hydrocarbons are emitted from this number of two-stroke outboards into water and air every year. At the same time more than 1,000 tonnes (2 million pounds) of unburned engine oil is emitted with the exhaust gases into the water.⁹⁵</p>	
<p>Potential release to Sensitive areas of environment (YES/NO)</p>	
<p>2-T: YES</p> <p>Two stroke engine oils are emitted in form of burned and unburned emissions to the air and water, usually in sensitive airs. For instance for boats applications, 20-30% of the fuel and the added oil that these two-stroke use are emitted unburned directly into the</p>	<p>4-T: NO</p> <p>During normal use 4-T are not release to the environment (only due to accidental spills). The environmental impacts occur mainly during disposal of waste oils.</p>

⁹⁵ <http://www.kimointernational.org/WebData/Files/RESL102D.pdf>

water.

Key environmental problem to be targeted

2-T:

Differently from 4-stroke engines, in 2-stroke engines there is no dedicated lubrication system, the lubricant is mixed with fuel. Lubricating oil is less combustible than gasoline; some of the oil that is mixed with gasoline will survive to be emitted in the exhaust. It is estimated that particulate emissions from a single 2-stroke motorcycle is comparable to those from a diesel truck or bus. PM, particularly the finer ones, are associated with respiratory problems.

4-T:

4-stroke engine oil is exposed to heat and oxygen during engine combustion, which changes its chemical makeup. **Used motor** oil contains numerous toxic substances, including polycyclic aromatic hydrocarbons, which are known to cause cancer. In addition, tiny pieces of metal from engine wear and tear, such as lead, zinc and arsenic, make their way into lubricants, further contributing to the polluting potential of used motor oil. During use, investigations have shown a clear effect of lubricant oil on emissions, which depends on lube oil characteristics, especially sulphur content, metal content, volatility and density.⁹⁶

Lubricant-related particulate emissions account for up to 35 % of total particulate emissions of engines. Regarding the contribution of lubricant properties to diesel exhaust emissions, it is tested that NOx and PM emissions are lower with synthetic oil than with mineral oils. Test results showed that mineral oils produce by 8 % higher NOx emission than the synthetic oil, whereas the specific particulate emissions of synthetic oil were 19–24 % smaller than those of the mineral oils. This is possibly a consequence of the different additives and aromatic contents of the oils.⁸⁹

(Disposal) One of the main environmental concerns for 4-stroke engine waste oil is the uncontrolled waste disposal by particular users.

Temporary protection against corrosion

Lubricant loss: TOTAL

Use/application

Protective lubricant that can be easily removed from the metal surface after treatment. The different uses and applications include the following⁹⁷:

- Steel and coated steel strip
- Steel profiles, sections and tubes
- Aluminium or other alloy strip and sections
- Machined parts and components either as finished items or for later assembly
- Tools and machine tools in manufacture, storage and supply
- Fasteners such as screws, rivets, bolts, etc.
- Machinery parts, either finished or for later assembly
- Automotive components and sub-components

⁹⁶ Investigations have shown a clear effect of lubricant oil on emissions, which depends on lube oil characteristics, especially sulfur content, metal content, volatility and density.

⁹⁷ Guide to Temporary Corrosion Protectives. 2003, National Corrosion Service, NPL.

- Electrical parts and assemblies
- Construction and off-highway equipment
- Metal tanks, valves, and lines
- Agricultural parts and machinery
- Vehicles or machinery protected in shipment
- Assemblies of equipment, moth-balled for long or short periods

Removal of temporary protectives is normally achieved using the same techniques employed for precleaning although the standard of cleanliness required will be dictated by any further process the part may undergo. **In many cases** the protective system may be left in place.

Potential release to Sensitive areas of environment (YES/NO)

Protection when exposed to a variety of differing corrosive atmospheres, indoors, outdoors either under cover or fully exposed, in a marine environment, under effects of direct sunlight, perhaps in a radiation flux, in the presence of specific chemical corrosives in an industrial environment, etc.

Key environmental problem to be targeted

The area or environment in which a Temporary Corrosion Protective is used may dictate or require special considerations in terms of toxicity, emissions to atmosphere, potential for pollution of earth or water, or for contact with food.

GEARS

Lubricant loss: ACCIDENTAL, PARTIAL

Use/application

Gear lubricants are used in transmissions, transfer cases, and differentials in automobiles, trucks, and other machinery.

Potential release to Sensitive areas of environment (YES/NO)

Potential release is relevant for open gears (e.g. boats). These types of applications are covered in the *category A Total loss*.

For the rest of gear applications, release to the environment is accidental or partial, since they are used in industrial gears normally indoors and a control use and waste disposal is possible (Disposal).

Key environmental problem to be targeted

Partial and accidental losses during use or at end-of-life to sensitive environment compartments (e.g. ground soil or water through wastewater).

HYDRAULIC SYSTEMS

Lubricant loss: ACCIDENTAL, PARTIAL

Use/application

Hydraulic fluids are a very large class of materials that are used in machines and equipment to transfer pressure from one point to another. They are used in many ways including all fluids for car automatic transmissions, brakes, and power steering. Hydraulic fluids are also used in many

machines like tractors and other farm equipment, forklift trucks, bulldozers, and other construction equipment, and airplanes. In industry, hydraulic fluids are used in machines that push, lift, pull, turn, and hold things.⁹⁸

Potential release to Sensitive areas of environment (YES/NO)

Hydraulic fluids can enter the environment from spills, leaks in machines that use them, or from storage areas and waste sites.⁹⁸

Hydraulic fluids are of increasing importance for applications in environmentally sensitive areas where a potential loss could be encountered, such as excavators, earthmoving equipment and tractors, in agricultural, mining and forestry applications and in fresh water (groundwater) sensitive areas.⁸⁹

Key environmental problem to be targeted

European studies have identified hydraulic fluid leakage as one of the primary groundwater contamination, **due to accidental** contact with the environment.

If spilled on soil, some of the ingredients in hydraulic fluids will stay on top and others will sink into the groundwater. In water, some hydraulic fluids' ingredients will transfer to the bottom and can stay there for more than a year. Certain chemicals in hydraulic fluids may break down in air, soil, or water.⁹⁸

GREASES

Lubricant loss: TOTAL, ACCIDENTAL, PARTIAL

Use/application

Greases application are extensive, they are used when it is not practical or convenient to use oil lubricant. Semisolid lubricants are applied to mechanisms that can only be lubricated

Infrequently and where lubricating oil would not stay in position. Greases are useful in applications where simplified maintenance is required, the requirement of cleanliness is better, and the protection against contaminants is needed. Grease acts as a sealant to prevent lubricant leakage and also to prevent entrance of corrosive contaminants and foreign materials. The cost of contain the grease is lower, the fluid lubricant characteristics requires an expensive system of circulating equipment and retention devices.

Potential release to Sensitive areas of environment (YES/NO)

Despite they are more consistent and the spill probability is lower, greases are often applied in open systems due to their characteristics. So the environmental impact on sensitive areas could be important: marine greases or greases for the central greasing system of the locomotive wheel trains.

Key environmental problem to be targeted

Losses during use or at end-of-life to sensitive environment compartments could take place due to

⁹⁸ Keeping The Lid On Hydraulic Fluids. Jun 27, 2005 Edited by Alan L. Hitchcox, editor | Hydraulics & Pneumatics

the **diversity of application of greases.**

TURBINES (stern tube oils)

Lubricant loss: TOTAL (stern tube oils)/ ACCIDENTAL (industrial turbines)

Use/application

Stern tubes: The significance of lubricant discharges (not accidental spills) to the aquatic ecosystem is substantial. The majority of ocean going ships operate with oil-lubricated stern tubes and use lubricating oils in a large number of applications in on-deck and underwater (submerged) machinery.

Industrial turbines: Industrial processes

Potential release to Sensitive areas of environment (YES/NO)

Stern tube oil: YES

Oil leakage from stern tubes, once considered a part of normal "operational consumption" of oil, has become an issue of concern and is now considered as oil pollution. Stern tube leakage is a significant source of lubricant oil inputs to the aquatic environment.

Industrial turbines: NO

They do not have potential release to sensitive areas since they are use basically in industrial operations.

Key environmental problem to be targeted

Stern tubes: A 2001 study commissioned by the European Commission DG Joint Research Centre revealed that routine unauthorized operational discharges of oil from ships in the Mediterranean Sea created more pollution than accidental spills (Pavlakis et al., 2001). Stern tube leakage was identified as a major source of these discharges.⁹⁹

Industrial turbines: Main environmental impacts can be caused by uncorrect waste management.

Compressors, Pneumatic tools, Heat transfer fluids, Heat treatment (Process oils), Slideways and Spindle bearings, bearings, and associated clutches

Lubricant loss: ACCIDENTAL, PARTIAL

Use/application

These process oils are used in different industrial processes. Their use is indoor and within confined compartments, so relevant loses to the environment or exposure to workers are not foreseen.

Potential release to Sensitive areas of environment (YES/NO)

These oils are used under confined equipment and under controlled conditions, so that release to

⁹⁹ Environmentally Acceptable Lubricants. EPA800-R-11-002 November 2011

environment is of low probability.

Key environmental problem to be targeted

(Disposal) A correct control of waste is a critical issue to assure minimal environmental impact.

Table 38: Summary of use application of lubricant families and environmental considerations

Group of lubricant	Lubricant loss	Market share	Use/application	Potential release to sensitive areas of environment	Key environmental problem to be targeted
Mould release	Total (concrete mould release)	5% (IND MWF)	Spraying OUTDOOR application (environment and worker exposure)	Emission to air, waste release to water system, soil emissions	Contamination of water, groundwater and groundsoil with polluted oil
	Accidental (industrial mould release)		Spraying INDOOR application (worker exposure)	Waste release to water system	(Disposal) Contamination of water with polluted oil
Metalworking	Accidental		Painting /Spraying INDOOR application (worker exposure)	(Disposal) Waste release to water system	(Disposal) Contamination of water with polluted oil
Internal combustion engine oils	Total (two stroke)	40%	Mixing with fuel in 2-stroke engines	Total release to environment. Release of burnt and unburnt emissions to air, soil and water.	Pollution to aquatic system, air emissions
	Accidental (four stroke)		Internal combustion engines vehicles	(Disposal) Losses due to spills, improper waste or disposal	(Disposal) Pollution to groundwater and soil
Hydraulic systems	Accidental/Partial	9%	Transfer pressure in machines and equipments	Losses due to spills, improper waste or disposal	Pollution to groundwater
Gears	Accidental/Partial	10%	Transmissions, transfer cases, and differentials in automobiles, truck and other machinery	NO	-
Greases	Total/Accidental/Partial	3%	Used extensively as a substitute of lubricant oil in a wide range of applications	Direct emissions to the environment (When it is applied outdoors), partial or accidental release, potentially in sensitive areas depending on the application	Potential for pollution of soil and water
Turbines	Total (STERN TUBE OILS)	4% (IND Engine oils)	Stern tube oils are used underwater and are in direct contact with maritime waters	Direct emission to maritime ecosystem under normal pertaion conditions	Pollution of maritime ecosystem and aquatic organisms
	Accidental/Partial (INDUSTRIAL)		Indoor use in confined systems	NO	-
Total loss systems	Total	17% (Industrial others, Industrial general)	Rough applications, lightly loaded parts, open gears, wire ropes, mechanical chains, chains of chain saw, etc	(During use) Oil not recovered: the lubricant ends-up into the environment	Contamination of air, soil and water
Spindle bearings, bearings, and	Accidental/Partial		Normally indoor use in confined and industrial systems	NO Only partial losses or losses due to spills, improper waste or disposal	-

Group of lubricant	Lubricant loss	Market share	Use/application	Potential release to sensitive areas of environment	Key environmental problem to be targeted
associated clutches					
Temporary protection against corrosion	Total		Protective lubricant that can be easily removed from the metal surface after treatment.	When it is applied outdoors e.g. marine or other sensitive environments	Toxicity through emissions to atmosphere, potential for pollution of earth or water, or for contact with food.
Slideways	Partial		These lubricants are used to lubricate slideways and sometimes the accompanying pneumatic equipment in industrial machinery. Slideways are guiding surfaces on the bed of a machine along which a table or a carriage moves.	NO	-
Compressors	Accidental	12% (IND process oils)	Indoor use in confined systems	NO	-
Pneumatic tools	Accidental/Partial		Indoor use in confined systems	NO	-
Heat transfer fluids	Accidental		Indoor use in confined systems	NO	-
Heat treatment	Accidental		Indoor use in confined systems	NO	-

2.1.4. End-of-life

The disposal stage of the lubricants is only represented in Roiz & Paquot 2012⁷⁶, Wightman et al. 1998⁸², and Ferret et al. 2004⁸⁴. However, the conclusions about the impact generated during the end of life are not too wide. The impact at the end of life for the biobased lubricants is negligible in all the categories; for the mineral lubricants the only category affected in the end of life phase is Global Warming Potential: the end of life contributes in 80% of the total impact. See Figure 28.

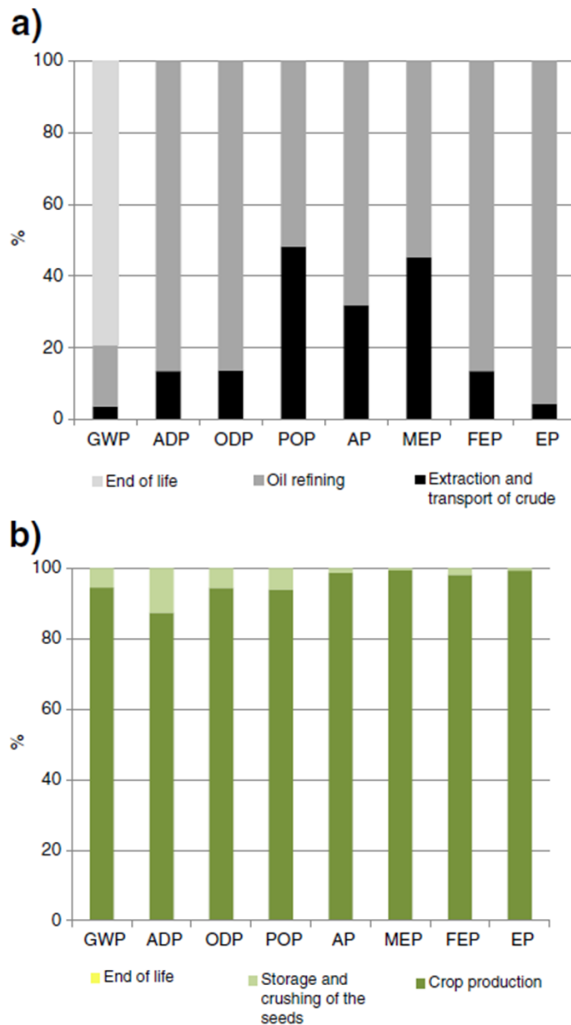


Figure 28: Contribution of the life cycle stage to the overall environmental impact of the mineral (a) and the biobased (b) chainsaw oils. Source: Roiz & Paquot, 2012⁷⁶.

Nevertheless, some recent reports state the relevance of end-of-life stage on the global environmental impacts of lubricants, since it is the stage where used lubricants can enter to the environment causing pollution in the different compartments.

Supplementary evidence on end-of-life

Waste oil generation and legislation framework

Used lubricating oils represent the largest amount of liquid, non-aqueous hazardous waste in the world¹⁰⁰. The EU consumed in 2006 roughly 5.8 million tonnes of oils per year. Through their use they lose their properties or become contaminated and at some point they cease to be fit for use. These used oils are then replaced by fresh lubricating oils generating waste oils. Following a period of use that is typically less than 6 months, the remaining lubricant is recovered along with various combustion, friction and heat-related contaminants. This oil, often mixed with other contaminants such as water, solvents, antifreeze, brake fluid, paint and fuels enters the waste management market.¹⁰¹

The 50% of purchased oils will become waste oils potentially recoverable (the rest is lost during use; through leakages, exhaust emissions, etc.). That represents approximately 3 million tonnes of waste oil to manage every year in the EU.¹⁰⁰

Waste oil management is governed by the Waste Framework Directive 2008/98/EC, especially by Article 21, which stipulates that Member States shall take the necessary measures to ensure that:

- a) Waste oils are collected separately, where technically feasible;
- b) Waste oils are treated in accordance with Articles 4 (waste hierarchy) and 13 (protection of the environment and human health);
- c) Where technically feasible and economically viable, waste oils of different characteristics should not be mixed and waste oils should not be mixed with other kinds of waste or substances, if such mixing impedes their treatment.

The European Commission adopted an ambitious Circular Economy Package, which includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy which will boost global competitiveness, foster sustainable economic growth and generate new jobs.

The proposed actions in the package will contribute to "closing the loop" of product lifecycles through greater recycling and re-use, and bring benefits for both the environment and the economy.¹⁰²

In addition, the Waste Framework Directive 2008/98/EC establishes priority for re-refining of used oil for recovery of base oil as long as there are no technical, economic or organisational obstacles. The priority given to re-refining was based on the goal of resource preservation and is in line with the circular economy principles.

Collection of waste lubricants

Severe contamination can result from waste oils being left on the ground or released to aquatic ecosystems. Thus, it is crucial to collect as much as possible this very valuable resource, in order to avoid the contamination of the environment and to be able to profit from the very high recovery potential of this waste stream.¹⁰⁰

Life cycle assessment emphasizes used oil disposal as the critical phase of the lube to be paid greater attention to reduce environmental impact. Uncontrolled disposal

¹⁰⁰ http://ec.europa.eu/environment/waste/oil_index.htm

¹⁰¹ David Fitzsimons. Improving Markets for Waste Oils. A report for OECD. Republished 2010

¹⁰² http://ec.europa.eu/environment/circular-economy/index_en.htm

of lubricant has adverse effect on the soils, aquatic life and renders water unfit for drinking.

Engine oil represents more than 70% of the collectable waste oil and industrial oils comprise the balance of 30%⁸⁹. Appropriate collection and disposal arrangements for WO from industrial or automotive origin (garages...) are generally well established in Europe. However, WO from 'Do-It-Yourself' (DIY) engine oil changes by particular users is less likely to be collected and so presents the greatest risk of improper disposal.¹⁰³ At present, used motor oil is the largest source of oil pollution in waterways. The main WO collection points are gas stations, vehicles reparation workshops, industries, harbours and airports.¹⁰⁴ Industrial and commercial automotive market represents the 39,6% and the 32,7% respectively, however the industrial and professional use is covered by the safety data sheet. The safety data sheet includes information about the hazards of the substance and/or mixture and instructions for disposal (waste life cycle stage). Exposure scenarios are annexed to the Safety Data Sheet (SDS)¹⁰⁵ providing information to the users about the risk management measures that have to be implemented or recommended by the manufacturers for safe use of the substance and/or mixture. It includes operational conditions (e.g. duration and frequency of use, amount used, process temperature, pH...) and the necessary risk management measures (e.g. local exhaust ventilation or a certain type of glove, waste water and gas treatment) taken by the downstream user to control risk. In this sense, appropriate collection and disposal arrangements for waste oils from industrial and commercial automotive origin (industries, garages...) are generally well established in Europe and handling them to authorized collectors that will ensure their adequate recovery. Unlike professional or industrial use, consumer use is also covered by the safety data sheet however, if the substance or mixture is sold to the general public, an SDS does not need to be provided¹⁰⁶. Therefore, communicating information concerning hazards and appropriate protective measures are not addressed to the consumers due to there are no provisions in REACH under which an SDS has to be supplied to a member of the general public ("consumer").

In some countries economic instruments such as different types of tax reliefs on lubricants (e.g. in Finland, Spain or Greece) exist to support collection and management of waste oils, however, as taxation is national competence of EU Member States, it will depend on the Member State if they would be willing to pursue such measure or not. Extended producer responsibility (EPR) schemes are already well-functioning for the waste oil industry. Usually, the EPR schemes are managed by means of a consortium which supports the collection, transportation and management of waste oils. Depending on the EPR scheme and national legislation in place, obligations by the consortium to send waste oil for re-refining rather than energy recovery (burning) also exist. Examples of well-functioning EPR

¹⁰³ European commission. Dg environment. A2- sustainable resources-consumption and waste. Critical review of existing studies and life cycle analysis on the regeneration and incineration of wo. (December 2001).

¹⁰⁴ Innovative Collection System & Life Cycle Assessment for Waste Lube Oils ICOL Layman's Report Project LIFE 02/ENV/GR/360

¹⁰⁵ Only when the hazardous substance is registered under REACH in quantity greater than 10 tonnes/year.

¹⁰⁶ Unless it is requested by a downstream user or distributor.

schemes are implemented in Italy, Spain, Greece (Law 4042/2012 and Presidential Decree 82/2004, Official Gazette 64A/2.5.2004) and Denmark.¹⁰⁷

Treatment technologies for waste oil lubricants

Different treatment processes exist currently in Europe. The most significant ones are listed below.¹⁰³

Table 39: Treatment processes in Europe. Source: Integrated Pollution Prevention and Control. Reference Document on Best Available Techniques for the Waste Treatment Industries¹⁰⁸

Waste oil (WO)	Type of treatment	Resulting Products
Clean WO	RE-USE	<ul style="list-style-type: none"> • Hydraulic or cutting oil <ul style="list-style-type: none"> ▪ electricity companies ▪ shipping industry ▪ major engineering companies • Mould oil or base oil for the production chain saw oil
Engine WO + clean WO	REGENERATION or RE-REFINING	<ul style="list-style-type: none"> • Lubricant base oil
All types of WO Including synthetic oils	THERMAL CRACKING	<ul style="list-style-type: none"> • Distillate gas oil products <ul style="list-style-type: none"> ▪ gas oil (also called heating oil , diesel oil, furnace oil ...) ▪ de-metallised fuel oil ▪ marine gasoil (MGO) ▪ re-refined light base oil
WO Mixed wastes	GASIFICATION	<ul style="list-style-type: none"> • Synthetic gas <ul style="list-style-type: none"> ▪ hydrogen ▪ methanol
All types of WO, especially heavy polluted ones	SEVERE RE- PROCESSING	<ul style="list-style-type: none"> • De-metallised fuel oil (or heavy distillate) <ul style="list-style-type: none"> ▪ marine diesel oil (M D O) ▪ fuel for heating plants...
	MILD RE-PRO CESSING and burning	<ul style="list-style-type: none"> • Replacement fuel oil (RFO) <ul style="list-style-type: none"> ▪ road stone plants, cement kilns, large marine engines, pulverised power stations.
	DIRECT BURNING (waste incinerators, cement kilns, greenhouses, workshops)	-

Waste lubricating oils can be re-refined indefinitely. Currently, about 13% (Figure 29) of all base oils consumed in the EU come from re-refined waste oils. The other 87% are virgin base oils produced from crude oil refining, mostly imported and produced by major global companies.¹⁰⁷ Despite the introduction of the waste hierarchy some years ago, its inadequate implementation across the Member States along with competition for energetic recovery (burning) of waste oils continue to be issues that prevent further re-refining of waste oils across Europe. In some Member States, best-practice examples can be identified with national re-refining rates of up to 98% for collectable waste oils. Best practice examples include Greece, Italy, Spain and Portugal.

¹⁰⁷ GEIR (Groupement Européen de l'Industrie de la Régénération) Waste Framework Directive revision: European waste oil re-refining industry position (June 2016) (http://www.geir-rerefining.org/documents/GEIRpositionpaperWFD_2016_FINAL.pdf)

¹⁰⁸ Integrated Pollution Prevention and Control. BAT for the Waste Treatments Industries (August, 2006)

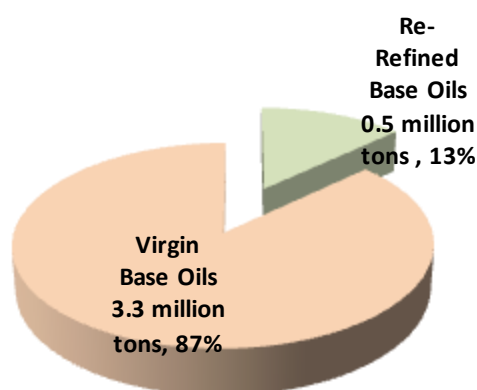


Figure 29: Re-refining quota Base Oil

Source: GEIR, Dec.2015

The ability to recycle waste oils is very closely linked to the oil's composition, level, type of contamination and of course economic aspects. Of these, only very few are primarily re-refiners, which recover lube oil for reuse. The others recycle waste oil by producing fuel for burning/ energy recovery. About 35 % of the collected oil is re-refined into base oil; the remaining 65 % is burnt replacing coal (10 %), or used as heavy fuel oil (45 %) and unknown other products (10 %). It is also suspected that a substantial amount of used oil is lost or illegally burnt or dumped in the environment.⁹⁰

A questionnaire from GEIR from 2006 gives an idea of the quantities of oil waste collected and the waste treatment applied in different EU countries¹⁰⁹.

Table 40: Lubricant consumption in different EU countries. Also represents the collectable waste oil and the total collected waste oil.

EU Member state	Lubricant consumption	Collectable waste oil	Collected waste oil	Efficiency waste oil collection (% collected / collectable)
Austria	79000	-	39596	-
Belgium	142000	-	60000	-
Bulgaria	55000	-	17000	-
Cyprus	-	-	4300	-
Czech Republic	110689	33207	32867	98%
Denmark	67500	-	20000	-
Estonia	19000	5700	5400	95%
Finland	79000	23700	22500	95%
France	765000	336600	224759	67%
Germany	1174000	-	525000	-

¹⁰⁹ <http://www.geir-rerefining.org/documents/WO-questionnaire-EU27-final-022208.pdf>

EU Member state	Lubricant consumption	Collectable waste oil	Collected waste oil	Efficiency waste oil collection (% collected / collectable)
Greece	100000	42000	36000	86%
Hungary	109000	54500	27823	51%
Ireland	38000	-	20000	-
Italy	542000	265580	216300	81%
Latvia	37400	11220	11000	98%
Lithuania	49000	14700	14000	95%
Luxembourg	10000	-	5364	-
Malta	4000	-	1200	-
Netherlands	252000	-	50000	-
Poland	351000	171990	76500	44%
Romania	130000	-	27663	-
Portugal	89000	40050	28700	72%
Slovenia	20000	-	3967	-
Slovakia	50000	-	15000	-
Spain	545000	218000	160000	73%
Sweden	148000	44400	45000	100%
United Kingdom	800000	400000	350000	87%

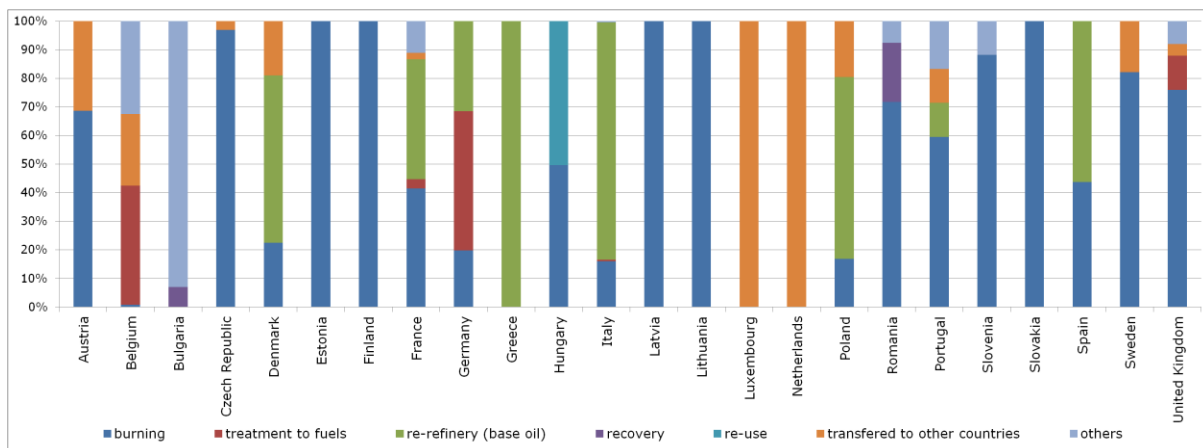


Figure 30: Waste treatment in different EU countries.

The data of used oil collection and utilization are treated in order to describe in percentage the waste oil treatment in different EU countries (Figure 30). The main treatment used in the EU countries was the burning to obtain energy. Following for the re-refinery of oil in countries like Denmark, Greece, Italy and Poland. Luxemburg and Netherlands transferred all the waste oil to other countries.

In recent years, developments of a regulatory nature and within the lubricants industry and the re-refining industry have given rise to changes to several important environmental and economic aspects affecting the re-refining industry. Key developments supporting this view include¹¹⁰:

- New regeneration technologies with improved performance have been developed and implemented;

- Regulatory requirements concerning motor vehicle emissions have enhanced the quality of lubricants;
- In today's markets, the amounts of synthetic and semi-synthetic compounds used have increased significantly and keep on increasing. These more sophisticated and stable oils require far more energy to manufacture and allow re-refiners to manufacture high quality base oils more easily because the inherent quality of collected used oils is substantially improving.

Benefits from re-refining

Environmental benefits from re-refining vs. virgin base oil processing

The environmental benefits of used oil regeneration compared to refining virgin base oil are established by a number of Life Cycle Assessment studies published in Europe to date.¹¹⁰ Results of comparative LCA between re-refined oil and virgin base oil show that re-refining base oil to base oil causes far less environmental impact than processing base oil from crude oil across the board. Re-refining therefore clearly leads to a decrease in environmental burdens. This LCA was made considering advanced technical standards on re-refining technologies.¹¹⁰

Another LCA study¹¹¹ made also clear that regeneration is by far better than virgin oil production for most impact categories studied.

Environmental benefits of re-refining vs. burning

A LCA review from 2008¹⁰³ stated, according to the existing LCAs regarding the comparison among different treatments, the following conclusions:

- Compared to thermal cracking, regeneration would have environmental advantages and drawbacks depending on the impact considered.
- Regeneration would be preferable to gasification for all impacts except solid waste and water input.
- A modern regeneration technology would become preferable to refinery recycling for some impact categories or equivalent for the others.

Some earlier LCA studies gave rise to an indifferent assessment of re-refining when comparing it with combustion options in certain large-scale facilities, such as cement kilns.¹¹⁰

The comparative Life Cycle Assessment¹¹¹ between regeneration and combustion incineration of WO was realised by taking into account alternative life cycles, i.e. from virgin lube oil production (as the alternative system to regeneration) to heavy fuel oil combustion in cement kilns. The different studied scenarios made clear that regeneration is by far better than virgin oil production and the uncontrolled final disposal (dumping, illegal burning or discharge) of the WO. The combustion in cement kilns is also a merit solution but it must be strictly controlled, in order to avoid the undesired heavy metal and carcinogens diffusion in the environment.

¹¹⁰ Ecological and energetic assessment of re-refining used oils to base oils: Substitution of primarily produced base oils including semi-synthetic and synthetic compounds. commissioned by GEIR - Groupement Européen de l'Industrie de la Régénération. February 2005

¹¹¹ Innovative Collection System & Life Cycle Assessment for Waste Lube Oils ICOL Layman's Report Project LIFE 02/ENV/GR/360

Considering uncontrolled or improper burning of used oils, it should be stressed that their thermal degradation can lead to the formation of dioxins and furans. Moreover, emissions released by the practices of oil burning include carbon monoxide (CO), sulphur oxides (SO_x), nitrogen oxides (NO_x), particulate matter (PM), metals, hydrogen chloride, global warming gases (carbon dioxide, CO₂ and CH₄), and other organic compounds, all harmful or toxic to the environment.

Part of total inevitable losses (attributed to evaporative loss (VOC), worn or improperly maintained equipment parts resulting in unintentional leaks and spills), undergoes natural degradation, while a practically unidentifiable portion ends up in plants, animals and humans causing acute or cumulative and chronic health problems. In summary, heavy metals, carcinogens emissions and other airborne pollutants resulting from the incineration are the main reasons that make regeneration the most environmental friendly solution.

Another LCA¹¹⁰ raised the query that LCA results of comparing re-refining with incineration is strongly influenced by the question of which primary fuels are substituted by waste oil combustion. Waste oil can be used to fuel a broad range of facilities. Most LCA studies of used oil recovery have considered the use in cement kilns, although it is only one (approximately 16%) of several options practised in the European Union. The European cement industry's main fuel sources are coal and petroleum coke. With respect to other combustion facilities besides cement works, mainly fuel oil is replaced. Results from this LCA study showed that for the majority of impact categories regeneration is shown to be more beneficial than direct burning. This can be categorically stated where the fuel to be replaced is fuel oil or gas. Where coal and petroleum coke are substituted, combustion is more beneficial in relation to global warming.

A recent study found that re-refining used oils saves about 8 % of the energy content of the used oil compared to combusting the oil for heating purposes; stating that to achieve maximum energy conservation and environmental benefit, it is preferable to re-refine used oils into regenerated base oils that can be blended into finished lube oil products compared to combustion for heating value recovery. Re-refining oils can lead to additional environmental benefits because the toxic heavy metals (e.g., zinc, lead, cadmium, and chromium) are extracted from the used oil. These metal compounds are solidified and stabilized into asphalt flux, thereby posing minimal environmental risk. If used oils are combusted, however, metals in the flue gases can be released into the atmosphere unless they are captured by air pollution abatement equipment⁸⁹.

As conclusion, it can be stated that a proper collection and posterior re-refining is the option to minimize the used lubricants entry into the environment. This translates into cost and environmental savings, with respect to buying a batch of a new lubricant as well as in disposal costs, and the potential damage to the environment, if the disposal method is inappropriate⁸⁹.

4.3. Environmental assessment conclusions

A robust quantification of the overall environmental impact of lubricants would entail a detailed Life Cycle Assessment (LCA), with a scope covering manufacturing, use and fate at end of life, and with system boundaries encompassing petroleum, petrochemical, oleochemical and engineering industry activities. This would be a

complex process, due to the very broad scope required, and also to some particular issues which are characteristic of the industry and the applications. One complication is that lubricants are typically manufactured as co-products in integrated product networks, based on petroleum refining, oleochemical refining or chemical processing.

In spite of the limitations, the environmental assessment allowed to find the main areas of environmental concern from a life cycle perspective of the lubricant product group. This section summarises the main conclusions that can be extracted from the results revealed by LCA literature review and the supplementary environmental evidence.

In general, considering a cradle-to-grave approach, studies indicate that the release to the environment during use and disposal stages can be critical from an environmental point of view. Nevertheless most LCAs studied only cover cradle-to-gate scope and for this reason a quantification of the relevance of these last stages are not feasible.

The most affected impact categories due to vegetable base fluid lubricant are the eutrophication potential, aquatic ecotoxicity and acidification potential^{72,75,76,80}. This high value is a consequence of the agricultural techniques used during the crop production: the pesticides with high content of nitrogen are a clear example. For this reason, having better agricultural practices could be determinant for the success of vegetable base fluid lubricants. However, data quality for the agricultural production is one of the main sources of uncertainty, especially regarding the establishment of valid data sets describing crop production in a consistent way, which includes the choice of representative regions as well as adequate scenarios⁸⁴.

The most affected category when talking about mineral lubricants is global warming potential, abiotic depletion, ozone layer depletion and photooxidant creation potential^{72,75,76,80,83}.

Human toxicity presents more controversy: McManus et al. 2003⁷⁹ obtained higher impact for rapeseed oil, Theis et al. 2004⁷⁵ also considered higher impact for vegetable base fluid (in this case for soybean oil). However, Cuevas 2010⁷² assessment showed that rapeseed contributed 5,91E-03 kg of benzene eq/kg lubricant in the carcinogenic category, while soybean and mineral lubricants contributed 9,84E-04 kg of benzene eq/kg lubricant and 2,54E-03 kg of benzene eq/kg lubricant, respectively. Human toxicity has been the less analysed category, even so human impact has been analysed broadly in the section 3 of this Task 3, technical analysis.

Bellow a summary of the main impact according the life cycle stages are detailed:

1. Raw material extraction, transport and processing of components

The raw materials can be of high importance, since the extraction and processing (especially due to energy consumption) of these materials can have relevant impacts. Moreover the composition of lubricants will condition the potential impact to the environment during and after their use, since formulation is related to inherent biodegradability and toxicity of the product.

Comparing **different base fluids**:

- In general **vegetable oil** brings advantages due its renewable origin and higher biodegradability. The highest impacts for vegetable oils are due to agriculture stage, so impacts highly depend on the crop operations. LCA comparative studies indicate lower energy consumption during processing and lower impacts for the global warming potential than mineral and synthetic oils.
- Regarding **synthetic oils**, the refining/synthesis phase is the main contributor of impacts. In the production stage they have higher impacts than mineral oil due to more complex processing and higher energy consumption. However they have a longer life and lower impact during use.
- For **mineral base oil**, the highest contribution is due to the extraction phase.
- **Re-refined oils** bring environmental advantages. With modern re-refining technologies, CO₂ emissions can be reduced by more than 50% as compared to the conventional production of base oil.
- The environmental impact of **water base fluid** could occur mainly during the disposal of waste fluids.

In relation to **additives** (being between 7-20% of formulation by weight), despite not being covered in most of LCA studies, they can have relevant contribution to life cycle impacts of lubricants for some impact categories where impact from additives can be up to 50% of the total impacts (in particular for carcinogens and mineral extraction).

With regard the **transport**, the relative impacts seem to be of low relevance.

2. Manufacturing of lubricant, packaging and distribution

Manufacturing comprises the blending of substances and it is a less complex process and with lower environmental impact than the processing of raw materials (where energy consumption is more relevant), although it can have relevant impacts in some categories.

The **packaging** of lubricants can have a broad range of types, due to the different applications and typologies of lubricants. Packaging is less covered in LCA studies, and the relevance of the potential impacts is not known however there are sustainability measures such as using environmentally friendly materials, design for a correct use/application/resistance to spillage and correct disposal that might be of easy implementation while bringing environmental benefits.

3. Use phase

The **use** stage of a lubricant product will highly condition its potential environmental impact, considering the probability of release to the environment (application and loss during use and management of used oil) and the consequences in terms of toxicity and impact on human health and the different environmental systems (especially for losses in sensitive areas). This impact is

highly important since approximately 50% of all traditional lubricants are released into the environment during use, spills, or disposal. Any release of used oil to the environment, by accident or otherwise, threatens ground soil and surface waters with oil contamination there by endangering drinking water supply and aquatic organisms.

4. End-of-life

LCA studies emphasize used oil disposal as the critical phase of the lube to be paid greater attention to reduce environmental impact. Uncontrolled disposal of lubricant has adverse effect on the soils, aquatic life and drinking water. The 50% of used oils will become waste oils potentially recoverable (the rest is lost during use; through leakages, exhaust emissions, etc.). Waste oils (WO) are hazardous waste as they display some hazardous properties. In addition to additives, waste oil is also likely to contain metals from engine wear; unburned fuel; PAH (polyaromatic hydrocarbons) from polymerisation and incomplete combustion of fuel; particulates and water. Proper collection and posterior re-refining is the best option from an environmental point of view; it has lower impacts than disposal (burning) and also it has associated environmental savings with respect to using new lubricant as raw material.

3 Analysis of hazardous substances used in lubricant sector

4.4. Introduction to REACH and CLP Regulations

The Regulation (EC) 1907/2006, mainly known as REACH, concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals, entered into force on 1st June 2007. REACH does not allow placing on the market substances on their own, in mixtures and in certain cases in articles in quantities equal or superior to 1 tonne per year if they have not been registered by every legal entity that manufactures or imports outside the European Union. REACH will be gradually implemented in the European Economic Area¹¹² through a phased approach with a timeline that extends until June 2018.

The Regulation (EC) 1272/2009 on classification, labelling and packaging of substances and mixtures (CLP), entered into force on 20th January 2009 and is based on the United Nations' Globally Harmonised System (GHS). The CLP Regulation ensures that the hazards of chemicals are properly communicated to workers and consumers in the European Union through classification and labelling of chemicals by standard statements and pictograms on labels and safety data sheets. Before placing chemicals on the market, the industry must establish the potential risks to human health and the environment of substances and mixtures, classifying them in line with the identified hazards.

Like REACH, the requirements in CLP were gradually implemented. The date from which substances classification and labelling must be consistent with CLP was December 2010 and for mixtures June 2015. Then CLP Regulation replaced the Council Directive 67/548/EEC¹¹³ as well as Directive 1999/45/EEC¹¹⁴.

The aim of REACH and CLP is to ensure a high level of protection of human health and the environment from the risks that can be posed by chemicals, as well as promote alternative methods for the assessment of the hazards of substances and ensure the free movement of registered substances along the European Economic Area (EEA) while enhancing the competitiveness of the EU chemicals industry.

Moreover, REACH and CLP place greater responsibility on industry to manage the risks that chemicals may pose to the health and the environment, as well as to provide sufficient information on the safety of the products that would be communicated through the supply chain. Manufacturers and importers will be required to identify and manage risks linked to the substances they manufacture and/or import in quantities of 1 tonne or more per year. To ensure that they actually meet these obligations, a registration process should require them to

¹¹² REACH applies in all 27 Member States of the European Union, as well as Iceland, Liechtenstein and Norway.

¹¹³ Directive 67/548/EEC of 27 June 1967 on the approximation of the laws, regulations and administrative provisions related to the classification, labeling and packaging of dangerous substances

¹¹⁴ Directive 1999/45/EEC of the European Parliament and of the Council 31 May 1999 concerning the approximation of the laws, regulations and administrative provisions of the Member States relating to the classification, packaging and labeling of dangerous mixtures.

submit a dossier jointly containing this information to ECHA ¹¹⁵. In addition, communication of technical advice to support risk management should be encouraged throughout the supply chain to other professionals such as downstream users or distributors to meet their responsibility in relation to the management of risks arising from the identified uses of substances. They have to demonstrate to ECHA how the substance can be safely used and they must communicate the risk management measures to the users.

Obligations under REACH are determined by the company's role: manufacturer, importer, downstream user or distributor. Mainly, manufacturers of lubricants are defined, according to REACH, as:

- **Downstream users:** Formulators are downstream users who produce mixtures and usually supply them down the supply chain or directly to consumers. They mix together substances and/or mixtures, with no chemical reaction taking place during the process.

European manufacturers of lubricants develop highly specialised, proprietary additives that typically enter the market within complex chemical formulations targeting specific automotive, industrial and heavy duty lubricating oil applications.

Downstream users have a key role to play in advancing the safe use of chemicals by implementing safe use at their own site and communicating relevant information both to their suppliers and their customers.

In the case of substances of very high concern (SVHC), the authorisation process will ensure the good functioning of the internal market while assuring that their risks are properly controlled and these substances are progressively replaced by suitable alternative substances or technologies where these are economically and technically viable. To this end, all manufacturers and importers shall apply for authorisation of substances included in Annex XIV and it should be granted by the Commission only if the risks arising from their use are adequately controlled or the use can be justified for socio-economic reasons and no suitable alternatives are available. In the case that the risks cannot be managed, authorities can restrict partially or totally the use of these substances of concern. The companies that do not undertake this procedure will not be able to manufacture, sell or use their products and would consequently be forced to stop their activity.

Certain substances of concern may be subject to controls under the Authorisation process of REACH. The following criteria will be used to identify substances of very high concern:

- Substances that stay in the environment for a long time, build up in the tissue of animals and cause some form of harmful effect (persistent, bioaccumulative and toxic – PBT), or those that stay in the environment for a very long time and build up in the tissue of animals very readily (very persistent, very bioaccumulative – vPvB).

¹¹⁵ ECHA: European Chemicals Agency based in Helsinki.

- Those substances which can cause cancer, genetic mutations or cause reproductive problems (these substances will have at least one of the following CLP Hazard statements H350, H350i, H340, H360F, H360D, H360FD, H360Df, H360Fd; risk phrases R45, R49, R46, R60, R61).
- Substances that cause similarly serious effects to those above e.g. those having endocrine disrupting properties (i.e. chemicals which mimic hormones and disrupt the function of hormones that occur naturally in people and animals), or those for which there is scientific evidence of probable serious effects to human health or the environment giving rise to an equivalent level of concern to those of other substances listed above.

Currently¹¹⁶, there are 169 substances on the candidate list¹¹⁷ of substances of very high concern for authorisation. ECHA prioritises the substances from the Candidate List to determine which ones should be included in the Authorisation List (Annex XIV of REACH) and therefore, subject to authorisation. This prioritisation is primarily based on intrinsic properties, volumes and dispersive uses of substances on the EU market.

Nowadays, there are a total of 31 substances subjected to authorization¹¹⁸ included in Annex XIV, being the last updated on 11th January 2016.

4.5. Considerations on EU Ecolabel hazardous criterion

The hazardous substance criterion in each Ecolabel product group reflects the requirements set in **Article 6(6) and 6(7)** of the **Ecolabel Regulation (EC) No 66/2010**¹¹⁹.

According to the Article 6(6), the EU Ecolabel may not be awarded to goods containing substances or mixtures meeting the criteria for classification as toxic, hazardous to the environment, carcinogenic, mutagenic or toxic for reproduction (CMR), in accordance with CLP Regulation (EC) No 1272/2008, nor to goods containing substances referred to in Article 57 of REACH Regulation.

The Article 57 of REACH regulation establishes the criteria for Substances of Very High Concern (SVHC), that is substances classified as Category 1A and 1B carcinogenic, mutagenic and reproductive (CMR); substances that are persistent, bioaccumulative and toxic (PBT) or very persistent and very bioaccumulative (vPvB); substances which give rise to an equivalent level of concern, such as substances having endocrine disrupting properties.

Criteria for Substances of Very High Concern (SVHC) (REACH Article 57)

(a) substances meeting the criteria for classification in the hazard class carcinogenicity category 1A or 1B in accordance with section 3.6 of Annex I to

¹¹⁶ Last updated 20th June 2016

¹¹⁷ Candidate list of substances of very high concern, available online at: <http://echa.europa.eu/web/guest/candidate-list-table>

¹¹⁸ Authorisation list of substances of very high concern, available online at: <http://echa.europa.eu/web/guest/candidate-list-table>

¹¹⁹ Regulation (EC) N 66/2010 of the European Parliament and the council of 25 November 2009 on the EU Ecolabel. For more details see: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:027:0001:0019:EN:PDF>

Regulation (EC) No 1272/2008;

(b) substances meeting the criteria for classification in the hazard class germ cell mutagenicity category 1A or 1B in accordance with section 3.5 of Annex I to Regulation (EC) No 1272/2008;

(c) substances meeting the criteria for classification in the hazard class reproductive toxicity category 1A or 1B, adverse effects on sexual function and fertility or on development in accordance with section 3.7 of Annex I to Regulation(EC) No 1272/2008;

(d) substances which are persistent, bioaccumulative and toxic in accordance with the criteria set out in Annex XIII of this Regulation;

(e) substances which are very persistent and very bioaccumulative in accordance with the criteria set out in Annex XIII of this Regulation;

(f) substances — such as those having endocrine disrupting properties or those having persistent, bioaccumulative and toxic properties or very persistent and very bioaccumulative properties, which do not fulfil the criteria of points (d) or (e) — for which there is scientific evidence of probable serious effects to human health or the environment which give rise to an equivalent level of concern to those of other substances listed in points (a) to (e) and which are identified on a case-by-case basis in accordance with the procedure set out in Article 59.

The article **6(7)** does, however, recognise that under certain circumstances there may be a technical or environmental justification to allow using a substance restricted by Article 6(6). In this situation **derogations** may be given. However no derogations from the exclusion from the Article 6(6) shall be given for substances identified as SVHC and included in the Candidate List according to Article 59 of the REACH Regulation and which are present in the final product at concentrations higher than 0.1%.

Regarding the interpretation and implementation of Articles 6(6) and 6(7), the **EU Ecolabel Chemicals Horizontal Task Force** has issued a document¹²⁰ with a proposed approach. The document proposes grouping of the hazards statements¹²¹ and substances addressed by REACH article 57, as specified in the table below (as per Regulation (EC) No. 1272/2008):

- **Group 1: Hazards subject to complete restriction**

Substances present in mixtures, in an article or in any homogenous part of a complex article that meet the criteria of Article 57 of REACH regulation or that are identified according to the procedure described in Article 59 (1) of

¹²⁰ Findings of the EU Ecolabel Chemicals Horizontal Task Force - Proposed approach to hazardous substance criteria development. 24th February 2014. Available online at: http://ec.europa.eu/environment/ecolabel/documents/Chemicals%20HTF_Approach%20paper.pdf

¹²¹ According to Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006.

that Regulation. This shall include the hazards listed below, as well as, endocrine disruptors, neurotoxins and sensitisers of equivalent concern.

- **Group 2: Priority hazards for restriction to which stricter conditions shall apply**

Substances that, in combination with these hazards, are also very persistent, persistent, very bioaccumulative or bioaccumulative, as defined according to Annex XIII of the REACH Regulation, shall be treated as Group 1 substances.

- **Group 3: Hazards to which greater flexibility may be applied**

Flexibility may be applied only if the fate of the product is not in the aquatic environment (e.g. in paints and soaps where there is the potential for wide dispersive release into the aquatic environment).

Table 41. List of hazard statements

Carcinogenic, mutagenic or toxic for reproduction	
GROUP 1: Category 1A and 1B	GROUP 2: Category 2
H340 May cause genetic defects	H341 Suspected of causing genetic defects
H350 May cause cancer	H351 Suspected of causing cancer
H350i May cause cancer by inhalation	
H360F May damage fertility	H361f Suspected of damaging fertility
H360D May damage the unborn child	H361d Suspected of damaging the unborn child
H360FD May damage fertility. May damage the unborn child	H361fd Suspected of damaging fertility. Suspected of damaging the unborn child
H360Fd May damage fertility. Suspected of damaging the unborn child	H362 May cause harm to breast fed children
H360Df May damage the unborn child. Suspected of damaging fertility	
Acute toxicity	
GROUP 2: Category 1 and 2	GROUP 3: Category 3
H300 Fatal if swallowed	H301 Toxic if swallowed
H310 Fatal in contact with skin	H311 Toxic in contact with skin
H330 Fatal if inhaled	H331 Toxic if inhaled
H304 May be fatal if swallowed and enters airways	EUH070 Toxic by eye contact
Specific target organ toxicity (STOT)	
GROUP 2: Category 1	GROUP 3: Category 2
H370 Causes damage to organs	H371 May cause damage to organs
H372 Causes damage to organs through	H373 May cause damage to organs through

prolonged or repeated exposure	prolonged or repeated exposure
Respiratory and skin sensitisation (where applicable)	
GROUP 2: Category 1/1A	Category 1B
H317: May cause allergic skin reaction	H317 May cause allergic skin reaction
H334: May cause allergy or asthma symptoms or breathing difficulties if inhaled	H334 May cause allergy or asthma symptoms or breathing difficulties if inhaled
Hazardous to the aquatic environment	
GROUP 2: Category 1 and 2	GROUP 3: Category 3 and 4*
H400 Very toxic to aquatic life	H412 Harmful to aquatic life with long-lasting effects
H410 Very toxic to aquatic life with long-lasting effects	H413 May cause long-lasting effects to aquatic life
H411 Toxic to aquatic life with long-lasting effects	
GROUP 2: Hazardous to the ozone layer	
H420 Harms public health and the environment by destroying ozone in the upper atmosphere	

The **EU Ecolabel Chemicals Horizontal Task Force** document outlines the guiding principles and a six interrelated tasks to hazardous substance criteria development according to the Figure 31 below:

- **Task 1: Product definition and bill of components, materials and substances.** The aim is to build-up a profile of the material and chemical composition of representative product(s) and their associated articles, including parts, devices and consumables, and/or ingredients.
- **Task 2: Screening for restricted substances and hazard classifications.** The aim is to identify substances and hazards from the SVHC Candidate List, REACH Annex XIV, Article 57 substance screening and Member State intentions that are relevant to the product functions as well as related component materials, devices and mixtures. To identify points in the life cycle of the product where hazard classifications associated with substances that may be in the final product are the most relevant.
- **Task 3: Product hazard substitution and green chemistry & engineering initiatives.** The aim is to develop a picture of the practical substitution potential for hazards incorporated within the product, as well as the chemical management systems used for production processes and supply chains for products that represent indicatively the best on the market in terms of environmental performance as defined in the EU Ecolabel Regulation.

This should be used to inform the ambition level for the criteria and the need for derogations. It shall also ensure that substitutions do not result in an inferior product. Where substitutes exist but have a low market share then

the selectivity of the criteria set and the fitness for use of the product shall be important considerations.

- **Task 4: Screening and investigation of derogation requests.** The aim is to investigate derogation requests that may relate to specific materials, substances or groups of substances. This process shall be based on the best available scientific knowledge on the potential hazard, product function and the potential for substitution including, if available, market information.
- **Task 5: Specification of the criteria and derogation conditions.** The aim is to tailor and specify the criterion and any associated derogation conditions according to the findings from tasks 1-5-
- **Task 6: Specification of verification requirements.** The aim is to tailor and specify the assessment and verification requirements according to the burden of proof and reputational risk identified for the product.

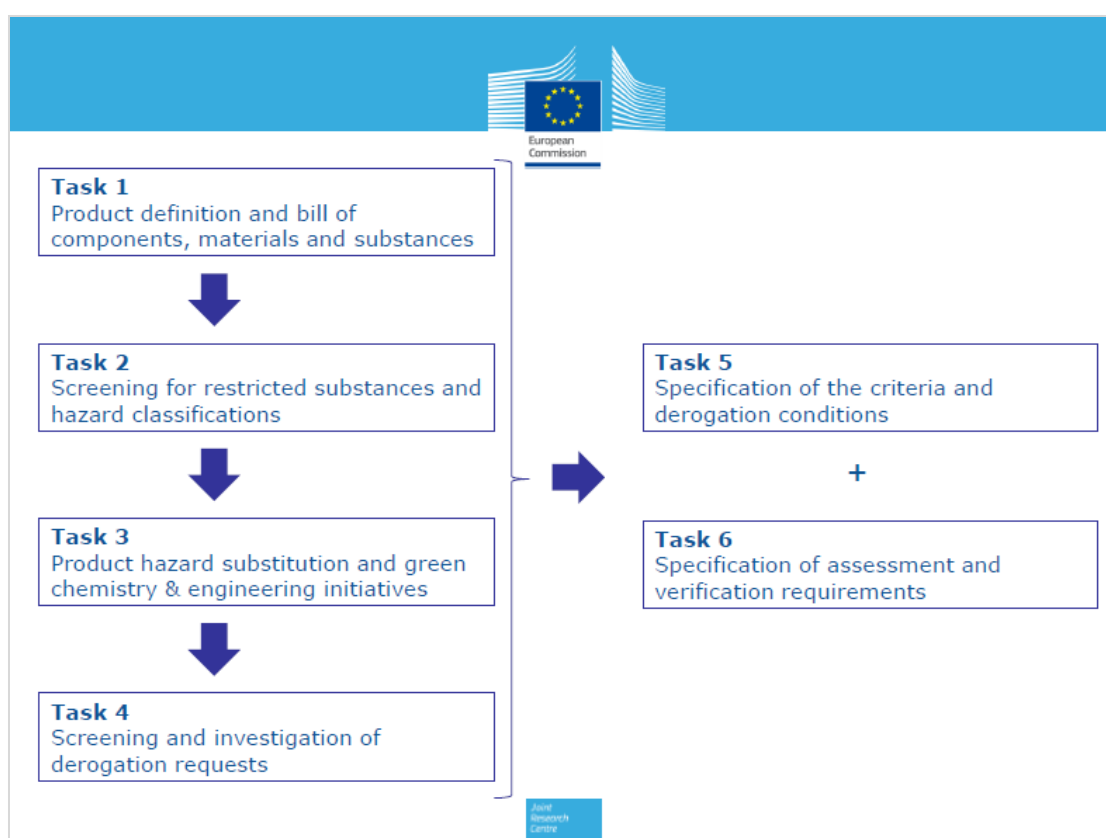


Figure 31. Proposed six steps in hazardous substance criteria development

Existing EU Ecolabel criteria on Hazardous substances

The EU Ecolabel decision for **lubricants (2011/381/EU)** reflects the **requirements of the Article 6(6) of the Ecolabel Regulation (EC) No 66/2010 in Criterion 1(a)**. This criterion needs to be fulfilled complied with by all ingredients (substances or mixtures) the concentration of which exceeds 0,010% weight by weight in the final product. This includes also each ingredient of any mixture used in the formulation exceeding 0,010% by weight of the final product.

Requirements set in Article 6(7) of the Ecolabel Regulation are addressed in the **Criterion 1(b)** of the above-mentioned Commission's decision. However the thresholds applied are different:

- **According to the Article 6(7) of the Ecolabel Regulation:** no derogations from the exclusion in Article 6(6) shall be given for substances identified as SVHC and included in the Candidate List according to Article 59 of the REACH Regulation and which are present in the final product at concentrations higher than **0.1% (w/w)**.
- **According to the EU Ecolabel for Lubricants (2011/381/EU):** no derogations from the exclusion in Article 6(6) shall be given for substances identified as SVHC and included in the list foreseen in Article 59 of the REACH Regulation, when present in mixtures, in concentrations higher than **0.01% (w/w)**.

Derogations from criterion 1(a) are listed in Table 1 of the Commission's decision. There is no derogation for specific substances but a general derogation to the lowest classification limit in Regulation (EC) No 1272/2008 or Directive 1999/45/EC (that would trigger the classification of the final product) applies to the lubricant. In summary, this means that criterion 1(a) only applies to the candidate lubricant (mixture) irrespective of the classifications of its components (i.e., substances included within the candidate lubricant), except for SVHC substances (Cat 1A/Cat 1B CMRs). Therefore, as long as the final lubricant (mixture) is not assigned to any of the restricted hazard statement/risk phrases set out in Criterion 1(a), it would be eligible for the EU Ecolabel. According to the current criteria, substances with health or environmental hazards statements are allowed but only under the limit concentration for which the final product (lubricant) would be classified. Thus in practice Criterion 1(a) applies to the final product and not to the components.

In addition **criterion 2** of the existing EU Ecolabel addresses specific substances and priority lists in the lubricants product group, which are not allowed in quantities exceeding 0,010% (w/w) of the final product. The EU Directive on the aquatic policy and the OSPAR treaty contains a list of priority substances which emission to the water compartments should be limited. The criterion explicitly refers to the OSPAR list. In addition there are restrictions on organic halogens and nitrite compounds. Most criteria of national ecolabels exclude organic halogen compounds for reasons related to the incineration of used lubricants, due to the formation of dioxins and furans. Nitrite compounds are excluded in most criteria of national ecolabels since they form nitrosamines that are carcinogenic.

4.6. Methodology approach for hazardous substance criteria revision

According to the Regulation (EC) No 66/2010, the EU Ecolabel promotes products with reduced impacts during their entire life cycle. Article 6 highlights the importance of taking a whole life cycle perspective to the evaluation of the most significant environmental impacts, including:

- Impacts on climate change, nature and biodiversity
- Energy and resource consumption
- Generation of waste
- Emissions to all environmental media, pollution through physical effects

- The use and release of hazardous substances

Thus, the EU Ecolabel covers both aspects related to environmental impacts conventionally evaluated through the LCA methodology and other “non-LCA” aspects related to health and hazards inherent to the products.

Some impact assessment categories conventionally included in LCA studies are directly (e.g. human toxicity) or indirectly (e.g. ozone depletion) related also to health issues. However, the LCA methodology typically characterises environmental burdens attributed to inputs and outputs from the product system and it does not analyse the hazards associated to a product, as done for instance in risk assessment. In this sense, REACH and LCA have been integrated, according to the figure below, with the objective to identify all relevant environmental and human health impacts that will be dealt with in the process of the hazardous substance criteria revision.



Figure 32: Elements of the approach based on LCA and REACH used in the revision of the criteria on hazardous substances

Conducting LCAs allows characterizing the environmental performance of lubricants over its entire life cycle. This involves the production of the product, the development of the product, the manufacturing process and the end-of-life options, taking into account eco-design actions. On the other hand, the analysis of hazardous substances used in the lubricant sector according to REACH regulation has been carried out. The REACH analysis specifically takes into account the identification of hazardous substances in particular with regard to substances of very high concern (Annex XIV of REACH Regulation¹²²) and the candidate list for

¹²² Authorization list of Substances of Very High Concern included in Annex XIV of REACH regulation. More information available online at: <http://echa.europa.eu/es/addressing-chemicals-of-concern/authorisation/recommendation-for-inclusion-in-the-authorisation-list/authorisation-list>

authorisation¹²³. According to this, focus on substances of very high concern (Annex XIV of REACH Regulation) and the candidate list for authorisation as referred in REACH Regulation was given. In this sense, a methodology approach on how to analyse and screen the hazards associated to the products, which are typically not fully assessed in LCA, has also been proposed:

- **Phase 1: Identification of substances and mixtures used in the lubricant sector**

Analysis of the most common chemical substances present in the products and their function has been carried out. Many of these substances only circulate in commerce as integral parts of more complex and highly competitive chemical mixtures. Then, these formulations are supplied to downstream users who prepare and market the finished lubricants. What distinguishes one formulation from another are the performance claims made in the market.

The additive preparations, when combined in the proper proportion, perform distinctive and quantifiable functions in bulk finished lubricants.

- **Phase 2: Obtaining information on composition**

Information of the characteristics of different products existing on the market has been gathered in order to do a preliminary analysis of the most common substances used. Initially, for this analysis, information from literature was collected.

However, details of the intrinsic chemical identities and proportions of these mixed substances are almost always confidential. Typically the technology is protected via formal patents or other Intellectual Property Rights to prevent competitors from copying, and this manufacturing paradigm is extremely unlikely to change in the future due to the very proprietary nature of the lubricants sector in general.

- **Phase 3: Assessing the hazards inherent to the lubricants**

Main hazardous substances used in the lubricant sector have been analysed in section 4.6.1. This analysis has been based on the information provided by the list of harmonized classification according to Annex VI of CLP regulation and ECHA. It is important to remember that less dangerous chemicals are not necessarily harmless. Therefore, risk management measures are still needed in many cases.

Some other sources of information such as literature and/or databases have been taken into account, e.g. the ECHA database on registered substances and the ECHA classification and labelling inventory.

4.6.1. Hazardous substances in the lubricant sector

According to the Task 1, scope and definition, there is no single and simple way to define lubricants, however the definition of a lubricant based on the composition: base fluids and additives, is relevant when carrying out the analysis of hazardous substances.

Lubricating oils, including such oils whose primary purpose is other than lubrication (e.g. electric insulation), and lubricating greases contain a base fluid component

¹²³ Candidate List of substances of very high concern for Authorisation. More information available online at: <https://echa.europa.eu/candidate-list-table>

and additives, used to tailor the lubricants for different applications. Lubricating greases also contain a further compound, a thickener, typically a metallic (calcium, aluminum) soap.

Additives are essential in lubricants for reinforcing the performance of base oils and for suppressing their deficiencies. The principal function classes of additives are:

- Antioxidants
- Anti-wear (AE)
- Extreme pressure (EP)
- Corrosion inhibitor/Rust inhibitor
- Detergents
- Dispersants
- Metal deactivator
- Friction modifiers
- Anti-foaming agent
- Viscosity modifiers
- Demulsifying/emulsifying
- Pour point depressants
- Thickening agents for greases
- Biocides

Typically lubricants are formulated end products consisting of a range between 80-93% base oils and 7-20% additives. For example, according to the European Waste Oil Re-refining Industry Association (GEIR)¹²⁴, lubricants contain 88% of base oil and 12% additives.

Therefore, a useful categorization of lubricants is on the basis of the chemical family to which the base oils belong including mineral and synthetic oils, as well as, vegetable oils.

Most commonly base oils and additives used in lubricants are explained in detail in sections below.

Lubricant persistence in the environment largely depends upon the base fluid, however if very toxic additives are used they may negatively affect the persistence.

It is worth notice that it was not possible to obtain a satisfactory assessment of the hazards of the substances used in the lubricant sector due to the lack of information regarding the composition of the lubricants.

4.6.1.1. Base fluids

Mineral oils

Mineral base lubricants are dominant, exceeding the major percentage of the entire lubricants market. They consist predominantly of hydrocarbons (extremely complex mixtures of C₂₀–C₅₀) containing a range of linear alkanes (waxes), branched alkanes (paraffinics), alicyclic (naphthenic), olefinic and aromatic species. They also contain some sulphur and nitrogen compounds with traces of a number of metals.

¹²⁴ Waste Framework Directive revision: European waste oil re-refining industry position, 16 June 2016. More information available on line at: http://www.geir-rerefining.org/documents/GEIRpositionpaperWFD_2016_FINAL.pdf

Generally, the conventional mineral base lubricants reach a 90% biodegradation only after a period of one year and their complete degradation sometimes takes much longer.

Waste oils (Used oils)

The term "used oils" designates the waste product resulting from applications of lubricating oil, whose original characteristics have changed during the use to the extent rendering it unsuitable for further use in the applications it was originally intended for. The process of collecting used lubricants and their treatment and re-refining has significantly increased in recent years, fostering the use of **recycled oils** as a valuable resource in lubricants industry. However, in terms of chemical composition, along with original substances from base oil component and additives, used oil also contains products of oxidation and degradation of the base oil and additives, as well as contaminants induced during the application (e.g. motor oils are often contaminated with traces of fuel, products or fuel combustion and coolant). Major pollutants usually present in used oils are various organic acids, polymer resins, metal wear particles (lead, chromium, nickel, cadmium, aluminum, etc.), polycyclic aromatic hydrocarbons (PAH), mercaptans, various halogenated compounds, soot, sand, dust and microbes. In addition to this, but less frequently, used oil can also contain extremely harmful polychlorinated biphenyls (PCB), polychlorinated terphenyls (PCT) or polybrominated biphenyls (PBB) – all often commonly designated as PCB compounds. PCB is one of persistent organic pollutants (POP) that act as endocrine disrupter by blocking hormone messages.

In terms of hazardous properties, used oils are considered:

- Irritant, carcinogenic
- One of potentially most hazardous categories of pollutants with far more severe impact on environment compared to that of new lubricating oils¹²⁵

Regardless of the fact that the content of harmful substances or pollutants in some used oils may be insignificant, according to the European List of Waste (Commission Decision 2000/532/EC and its subsequent amendments Commission Decision 2014/955/EU) all "oil wastes" except edible oils are classified as hazardous waste (they are classified as 13 – Waste oil and liquid fuels in the European Catalogue of wastes) due to the intrinsic properties of base oils, e.g. their flammability.

Synthetic oils

Synthetic oils include among others polyalphaolefins (PAO), synthetic esters and polyalkylene glycols (PAGs). PAOs are petrochemical derived synthetic oils that most resemble mineral oils and constitute the most widely used synthetic motor oil in the U.S and Europe. Synthetic esters can be either from petrochemical or oleochemical origin. Five different categories of synthetic esters can be distinguished: monoesters, di-esters, phthalate esters, polyol esters and complex esters. Polyalkylene glycols (PAGs) are polymers from petrochemical origin

¹²⁵ Background analysis for development and establishment of a Lubricating Oil Management system. Final project report, by Bosna-S Consulting Sarajevo, June 2006

commonly made from ethylene oxide and propylene oxides. Most synthetic base oil range originates from Europe and Asia because of the technology involved.¹²⁶

Synthetic base oils featuring biodegradability include some synthetic esters and polyethylene glycols. According to CLP regulation, substances are considered rapidly degradable in the environment if one of the following criteria holds true:

- a) If, in 28-day ready biodegradation studies, at least the following levels of degradation are achieved:
 - i. Tests based on dissolved organic carbon: 70 %;
 - ii. Tests based on oxygen depletion or carbon dioxide generation: 60 % of theoretical maximum.
- b) If, in those cases where only BOD and COD data are available, when the ratio of BOD 5 /COD is $\geq 0,5$; or
- c) If other convincing scientific evidence is available to demonstrate that the substance can be degraded (biotically and/or abiotically) in the aquatic environment to a level > 70 % within a 28-day period.

However, it should be kept in mind that the speed of biological degradation of a substance does not necessarily reflect its harmfulness to flora or fauna. Thus a substance may despite a fast degradation cause significant environmental impact, though within a shorter period of time.

Vegetable oils

Vegetable oils are biodegradable and do not have toxic properties, while their sources are renewable. However, besides numerous good properties, vegetable oils have poor low temperature properties (pour point), oxidation and hydrolytic stability relative to conventional oil. Even though these deficiencies can be compensated by the use of additives, or even by genetic modifications, they do not limit the application of vegetable oils to formulations of lubricants for mainly agricultural machinery, food industry equipment, nautical two-stroke engines, chainsaws used in forestry, and some hydraulic systems. Consequently, it can be expected that environmental impacts to water, soil or living organisms will be minimized.

4.6.1.2. Additives

The additive preparations, when combined in the proper proportion, perform distinctive and quantifiable functions in bulk finished lubricants such as friction, reduction, protection of metal surfaces, heat transfer, engine seal protection, separation and suspension of contaminants.

An overview of the principal function classes of additives and examples of the typical compounds is presented in Table 42.

Table 42: Main additives, application, typical compounds and functions.¹²⁷

¹²⁶ I. Madanhire and C. Mbohwa, *Mitigating Environmental Impact of Petroleum Lubricants*, DOI 10.1007/978-3-319-31358-0_2. Springer International Publishing Switzerland 2016

¹²⁷ Machinery Lubrication: What you should know about lubricant toxicity, Michael C. Brown. <http://www.machinerylubrication.com/Read/30448/know-lubricant-toxicity>

Additive type	Purpose	Typical compounds	Functions
Anti-wear and EP Agents	Reduce friction and wear, and prevent scoring and seizure	Zinc dithiophosphates, organic phosphates, acid phosphates, organic sulphur and chlorine compounds, sulphurized fats, sulphides and disulphides	Chemical reaction with metal surface to form a film with lower shear strength than the metal, thereby preventing metal-to-metal contact
Corrosion and Rust Inhibitors	Prevent corrosion and rusting of metal parts in contact with the lubricant	Zinc dithiophosphates, metal phenolates, basic metal sulfonates, fatty acids and amines	Preferential adsorption of polar constituent on metal surface to provide protective film or neutralize corrosive acids
Detergents	Keep surfaces free of deposits	Metallo-organic compounds of sodium, calcium and magnesium-phenolates, phosphonates and sulfonates	Chemical reaction with sludge and varnish precursors to neutralize them and keep them soluble
Dispersants	Keep insoluble contaminants dispersed in the lubricant	Alkylsuccinimides, alkylsuccinic esters and Mannich reaction products	Contaminants are bonded by a polar attraction to dispersant molecules, prevented from agglomerating and kept in suspension due to the solubility of the dispersant
Friction modifiers	Alter the coefficient of friction	Organic fatty acids and amides, lard oil, high-molecular-weight organic phosphorus and phosphoric acid esters	Preferential adsorption of surface-active materials
Pour point dispersants	Enable lubricant to flow at low temperatures	Alkylated naphthalene and phenolic polymers, polymethacrylates, maleate/fumarate copolymer esters	Modify wax crystal formation to reduce interlocking
Seal swell agents	Swell elastomeric seals	Organic phosphates and aromatic hydrocarbons	Chemical reaction with elastomer to cause slight swell
Viscosity modifiers	Reduce the rate of viscosity change with temperature	Polymers and copolymers of olefins, methacrylates, dienes or alkylated styrenes	Polymers expand with increasing temperature to counteract oil thinning
Anti-foamants	Prevent lubricant from forming a persistent foam	Silicone polymers, organic copolymers	Reduce surface tension to speed collapse of foam
Antioxidants	Retard oxidative decomposition	Zinc dithiophosphates, hindered phenols, aromatic amines, sulphurized phenols	Decompose peroxides and terminate free-radical reactions
Metal deactivators	Reduce catalytic effect of metals on oxidation rate	Organic complexes containing nitrogen or sulphur, amines, sulphides and phosphites	Form inactive film on metal surfaces by complexing with metallic ions

For each of performance functions, there is a multitude of formulating approaches, with different additive components or different intrinsic proportions of components designed to assure the necessary performance claims associated with the finished lubricants. Often the additive components are supplied to the lubricant formulators in the so-called **additive packages**, which composition is not fully known. Thus there is a lack of information regarding the detailed composition of the additives and of the final product for each of the lubricant families.

The later mentioned makes difficult to identify the exact name of the substances that compose an additive. The name of the substance (together with its CAS number) is required information to identify the intrinsic hazards of the substances through their classification according to the CLP Regulation. It is important to note that not all compounds belonging to a chemical family have the same hazards,

some could be potentially harmful to human health and/or to the environment, while others not.

As it can be seen in Table 42, some chemical compound can serve the purpose of different performance functions. One of the most popular multifunctional additives used is Zinc dithiophosphate (ZDDP). It acts as anti-oxidant, anti-wear agent and corrosion inhibitor. Table 43 shows the CLP classification of ZDDP and of other examples for anti-wear/extreme pressure agents and antioxidants. For the reasons mentioned above it was not possible to extend this information to the remaining classes of additives. Nevertheless and according to Madanhire (2016)¹²⁸ the hazards to human health of the additives most used are normally related to:

- Acute oral toxicity
- Acute dermal toxicity
- Eye irritation
- Skin irritation
- Skin sensitization.

Table 43: Examples of substances used as AW/EP and AO additives and corresponding CLP classification.

Additive type	Substance name	CAS	Classification	
			Hazard code (H statement)	Class and Category
Anti-wear (AW) and Extreme-Pressure (EP) Agents	Zinc dithiophosphate (ZDDP)	68649-42-3	Skin Irrit. 2 (H315) Eye Dam. 1 (H318) Aquatic Chronic 2 (H411)	
	Tris (nonylphenyl) phosphite (TNPP)	26523-78-4	Skin Sens. 1 (H317)* Aquatic Acute 1 (H400)* Aquatic Chronic 1 (H410)*	
	Triphenyl phosphorothionate (TPPT)	597-82-0	Repr.2 (H361) Aquatic Chronic 4 (H413)	
Antioxidants (AO)	Poly(1,2-dihydro-2,2,4-trimethylquinoline)	26780-96-1	Aquatic Chronic 3 (H412)	
	alkylated diphenylamine	68921-45-9	Aquatic Chronic 2 (H411)	
	Propyl gallate (Propyl 3,4,5-trihydroxybenzoate)	121-79-9	Acute Tox. 4 (H302)* Skin Sens. 1 (H317)*	
	2,6-di-tert-butylphenol	128-39-2	Skin Irrit. 2 (H315) Aquatic Chronic 1 (H410)	

(* Harmonised Classification)

Neither mineral nor synthetic base oils can satisfy today's lubricant performance requirements without using additives. Against this background, it was not possible

¹²⁸ Ignatio Madanhire, Mitigating Environmental Impact of Petroleum Lubricants. 2016

to obtain a satisfactory assessment of the hazards of the substances used as additives in the lubricant sector. Regarding the drivers in additives and lubricant formulation, they will continue to undergo changes mainly motivated by regulations, and also due to an increasing concern to use environmentally friendly lubricants especially in ecologically sensitive areas.

Additives for lubricating greases

A lubricating grease consists of a lubricating oil, additives, and a thickener. Owing to their semisolid consistency, lubricating greases hold some advantages over lubricating oils. A grease is more easily sealed into a bearing than an oil; a grease does not require a circulating system; and in wet or dusty environments, a grease can act as a seal against contaminants. For these reasons, greases are often the preferred lubricant for ball and roller bearings.

The main ingredient that differentiates a grease from an oil is the grease **thickener**. Their concentration in the lubricant may be 3-25%. Most grease thickeners are soaps composed of the reaction product of a fatty acid derivative and a metallic hydroxide (typically lithium, aluminum, calcium). Other salts may be combined with the soap thickeners to impart higher grease dropping points (temperature at which the grease liquefies). Such greases are called complex greases. A smaller proportion of lubricating greases are manufactured with non soap thickeners such as organoclays or polyurea compounds.

Some of the more common thickeners are as follows:

- Simple or complex metal soaps:
 - Lithium simple or complex soaps
 - Calcium simple or complex soaps
 - Aluminum simple or complex soaps
 - Sodium simple or complex soaps
- Thickener with no soap base:
 - Organoclays
 - Polyurea
 - Terephthalic and phosphoric acid salts
- Inorganic thickeners:
 - Molybdenum disulphide
 - Graphite

Because interaction of grease additives and grease thickener must be considered for the development of optimum grease formulations, it follows that the importance of various grease additives may change as the popularity of the various grease thickeners changes. Although the versatility of lithium soap and lithium complex greases causes them to be the most widely used grease types, polyurea greases are growing in popularity as they tend to give significantly longer bearing lives in certain sealed bearing applications.

Biocides

Although all organic-based functional fluids (lubricants) are usually subject to potential microbiological deterioration, only those products that are water-based are usually candidates for biocides use. Therefore, biocides are typically used in metalworking fluids, hydraulic fluids and mould release.

Water-based fluids are sensitive to attack by bacteria and fungi. The bacteria can degrade the emulsions and change the properties of the products. The appropriate biocide is essential to control the presence of micro-organisms and the formation of biofilms in order to maintain the performance and lifetime of the fluid. However, while biocides are added to reduce the amount of microbial growth, the biocide products themselves may have hazardous properties.

Biocides will be revised extensively due to their sensitizing potential and the possible enlargement of the scope based on human health issues concern.

Chemicals used to extend the life and usefulness of water-based lubricants are extremely important to lubricant users due to lubricant-preserving chemicals have made possible a wide variety of otherwise unsuitable applications.

The Biocidal Products Regulation (BPR, Regulation (EU) 528/2012)¹²⁹ concerns the placing on the market and use of biocidal products which are used to protect humans, animals, materials or articles against harmful organisms like pests or bacteria, by the action of the active substances contained in the biocidal product. This regulation on the use and placing on the market of biocidal products will repeal and replace the current directive on biocides (Directive 98/8/EC). It has entered into force on 1 January 2013 and will be applicable from 1 September 2013, with a transitional period for certain provisions. According to this, all biocidal products require an authorisation before they can be placed on the market, and the active substances contained in that biocidal product must be previously approved by product type.

Various agents of biocides can be used for the protection and preservation of water-based lubricants. Biocidal products of Product type 6 (Preservative for products during storage) are used for the preservation of manufactured products, other than foodstuffs or feeding stuffs, in cans, tanks or other closed containers by control of microbial deterioration to ensure their shelf life. Product type 6 (PT6) relates to the use of in-can preservatives and relevant applications include lubricants (professional use). In-can preservatives may be used to prevent biodeterioration of aqueous fluids, which may cause:

- pH-reduction
- Loss of viscosity
- Evolution of gas
- Coagulation
- Sfoul smell (biological degradation)
- Colour changes
- Breaking of emulsion
- Colonies on surface

The application of in-can preservatives in lubricants concerns the application in cooling-lubricants used in metalworking. However, there is a potential overlap with product type 13 (Working or cutting fluid preservatives), defined as products to

¹²⁹ More information available online at: <http://echa.europa.eu/regulations/biocidal-products-regulation>

control microbial deterioration in fluids used for working or cutting metal, glass or other materials.

Lubricants preservatives are covered under Product type 6, defined as preservatives for products during storage and Product type 13, working or cutting fluid preservatives. The European Commission includes approved active substances in a list of approved active substances (formerly Annex I of Directive 98/8/EC¹³⁰). The European Commission keeps the list updated and electronically available to the public. A list of active substances currently notified for use as PT6 in-can preservatives according to the BPR can be found on the ECHA webpage¹³¹. For PT6, approximately 9 substances have been notified.

Currently¹³², the list of approved substances to be used for product type 6 and 13 are:

¹³⁰ More information available online at:

http://ec.europa.eu/environment/biocides/2012/approved_substances.htm

¹³¹ More information available online at:

<https://www.echa.europa.eu/web/guest/information-on-chemicals/biocidal-active-substances>

¹³² Last updated: 27th July 2016

Table 44: List of approved substances to be used for product type 6: Preservatives for products during storage

PRODUCT TYPE 6: PRESERVATIVES FOR PRODUCTS DURING STORAGE								
Active substance	EC number	CAS number	Legal Act	Date of Approval	Expire Date	Classification ¹³³		Specific Conc. Limits, M-factors ¹³⁴
						Hazard Class and category code(s)	Hazard Statement	
2-bromo-2-(bromomethyl)pentanedinitrile (DBDCB)	252-681-0	35691-65-7	Reg (EU)2016/1086	01/01/2018	01/01/2028	Acute Tox. 4 (oral) ; Acute Tox. 2 (inhalation) ; Skin sens. 1 ; Eye Dam. 1 ; Aquatic Chronic 2 ;	H302: Harmful if swallowed H330: Fatal if inhaled H302: Harmful if swallowed H330: Fatal if inhaled H317: May cause an allergic skin reaction H318: Causes serious eye damage H411: Toxic to aquatic organisms with long lasting effects	-
3-iodo-2-propynylbutylcarbamate (IPBC)	259-627-5	55406-53-6	Regulation (EU) 1037/2013	01/07/2015	01/07/2025	Acute Tox 3 Eye Dam. 1 Acute Tox 4 Skin Sens. 1 STOT SE3 Aquatic Acute 1 Aquatic Chronic 1*	H331: Toxic if inhaled H318: Causes serious eye damage H302: Harmful if swallowed H317: May cause an allergic skin reaction H335: May cause respiratory irritation H400: Very toxic to aquatic life H410: Very toxic to aquatic life with long-lasting effects*	M-factor 10 (acute), 1* (chronic)
Biphenyl-2-ol	201-993-5	90-43-7	(EU) 2016/105	01/07/2017	01/07/2027	Eye Irrit.2 Skin Irrit.2 STOT SE3	H319: Causes serious eye irritation H315: Causes skin	-

¹³³ Harmonised classification

¹³⁴ Multiplying factors (M-factors) for substances classified as hazardous to the aquatic environment, acute category 1 or chronic category 1, should be assigned to a substance by a manufacturer, importer or downstream user.

PRODUCT TYPE 6: PRESERVATIVES FOR PRODUCTS DURING STORAGE								
Active substance	EC number	CAS number	Legal Act	Date of Approval	Expire Date	Classification ¹³³		Specific Conc. Limits, M-factors ¹³⁴
						Hazard Class and category code(s)	Hazard Statement	
						Aquatic Acute 1	irritation H335: May cause respiratory irritation H400: Very toxic to aquatic life	
Glutaral (Glutaraldehyde) ¹³⁵	203-856-5	111-30-8	(EU)2015/1759	01/10/2016	01/10/2026	Acute Tox. 3 * Acute Tox. 3 * Skin Corr. 1B Resp. Sens. 1 Skin Sens. 1 Aquatic Acute 1	H331: Toxic if inhaled H301: Toxic if swallowed H314: Causes severe skin burns and eye damage H334: May cause allergy or asthma symptoms or breathing difficulties if inhaled H317: May cause an allergic skin reaction H400: Very toxic to aquatic life	C ≥ 10 % Skin Corr. 1B; H314 0,5 % ≤ C < 10 % Skin Irrit. 2; H315 2 % ≤ C < 10 % Eye Dam. ; H318 0,5 % ≤ C < 2 % Eye Irrit. 2; H319 C ≥ 0,5 % STOT SE; H335 C ≥ 0,5 % Skin Sens. 1; H317
Hydrogen peroxide	231-765-0	7722-84-1	(EU)2015/1730	01/02/2017	01/02/2027	Ox. Liq. 1 Acute Tox. 4 Acute Tox. 4 Skin Corr. 1A	H271 May cause fire or explosion; strong oxidiser. H332 Harmful if inhaled. H302 Harmful if swallowed. H314 Causes severe skin burns and eye damage.	Ox. Liq.1; H271: C ≥ 70 % Ox. Liq. 2; H272: 50 % ≤ C < 70 % Skin Corr. 1A; H314: C ≥ 70 % Skin Corr. 1B; H314: 50 % ≤ C < 70 % Skin Irrit. 2; H315: 35 % ≤ C < 50 % Eye Dam. 1; H318: 8 % ≤ C < 50 % Eye Irrit. 2; H319: 5 % ≤ C < 8 % STOT SE3; H335: C ≥ 35

¹³⁵ Note: Annex VI of Regulation 1272/2008 lists glutaraldehyde as the pure (100%) substance

PRODUCT TYPE 6: PRESERVATIVES FOR PRODUCTS DURING STORAGE								
Active substance	EC number	CAS number	Legal Act	Date of Approval	Expire Date	Classification ¹³³		Specific Conc. Limits, M-factors ¹³⁴
						Hazard Class and category code(s)	Hazard Statement	
								%
Mixture of 5-chloro-2-methyl-2H-isothiazol-3-one (EINECS 247-500-7) and 2-methyl-2H-isothiazol-3-one (EINECS 220-239-6) (Mixture of CMIT/MIT) ¹³⁶		55965-84-9	(EU)2016/131	01/07/2017	01/07/2027	Acute Tox. 3 Acute Tox. 3 Acute Tox. 3 Skin Corr. 1B Skin Sens. 1 Aquatic Acute 1 Aquatic chronic	H331: Toxic if inhaled H311: Toxic in contact with skin H301: Toxic if swallowed H314: Causes severe skin burns and eye damage H317: May cause an allergic skin reaction H400: Very toxic to aquatic life H410 Very toxic to aquatic life with long lasting effects.	Skin Corr. 1B; H314: Causes severe skin burns and eye damage C ≥ 0.6% Eye Irrit. 2; H319: Causes serious eye irritation Skin Irrit. 2; H315: Causes skin irritation 0.06% ≤ C < 0.6% Skin Sens.1/H317: May cause an allergic skin reaction C ≥ 0.0015%
N,N'-methylenebismorpholine (MBM) ¹³⁷	227-062-3	5625-90-1	Reg. (EU) 2015/1981	01/04/2017	01/04/2022	Skin Corr. 1 Skin Sens. 1 Carc. 1B Muta 2	H314: Causes severe skin burns and eye damage H317: May cause an allergic skin Reaction H350: May cause cancer H341: Suspected of causing genetic defects	-
N-(trichloromethylthio)phthalimide (Folpet)	205-088-6	133-07-3	(EU)2015/1757	01/01/2016	01/01/2026	Acute Tox. 4 Eye Irrit. 2 Skin Sens 1 Carc. 2	H332: Harmful if inhaled H319: Causes serious eye irritation H317: May cause an	M factor 10.

¹³⁶ Active substance (C(M)IT/MIT 100%)

¹³⁷ For the active substance there is no harmonised classification available in Annex VI of Reg. (EU) No 1272/2008. For the hydrolysis products Morpholine and Formaldehyde there are harmonised classifications available in Annex VI of Reg. (EU) No 1272/2008 and in the 6. ATP to Reg. (EU) No 1272/2008, respectively. Classification is to be decided by RAC (**Committee for Risk Assessment**) and COM. This proposal has been submitted by RMS (Rapporteur Member State).

PRODUCT TYPE 6: PRESERVATIVES FOR PRODUCTS DURING STORAGE								
Active substance	EC number	CAS number	Legal Act	Date of Approval	Expire Date	Classification ¹³³		Specific Conc. Limits, M-factors ¹³⁴
						Hazard Class and category code(s)	Hazard Statement	
						Aquatic Acute 1	allergic skin reaction H351: Suspected of causing cancer H400: Very toxic to aquatic life.	
Peracetic acid	201-186-8	79-21-0	Regulation (EU) 2016/672	01/10/2017	01/10/2027	Flam. Liq. 3 Org. Perox. D Acute Tox. 4 Acute Tox. 4 Acute Tox. 4 Skin Corr. 1A Aquatic Acute 1	H226 Flammable liquid and vapour. H242 Heating may cause a fire. H332 Harmful if inhaled. H312 Harmful in contact with skin. H302 Harmful if swallowed. H314 Causes severe skin burns and eye damage. H400 Very toxic to aquatic life.	STOT SE3; H335: C ≥ 1 %

Source: European Commission website

Table 45: List of approved substances to be used for product type 13: Working or cutting fluid preservatives

PRODUCT TYPE 13: Working or cutting fluid preservatives								
Active substance	EC number	CAS number	Legal Act	Date of Approval	Expire Date	Classification ¹³⁸		Specific Conc. Limits, M-factors
						Hazard Class and category code(s)	Hazard Statement	
2-methyl-2H-isothiazol-3-one (MIT)	220-239-6	2682-20-4	(EU)2015/1726	01/10/2016	01/10/2026	Acute Tox. 3 (oral); Acute Tox. 3 (dermal); Acute Tox. 2 (inhalation); Skin corr. I B; Skin sens. IA; STOT Single 3; Aquatic Acute 1; Aquatic Chronic 1	H301; Toxic if swallowed. H311; Toxic in contact with skin. H330; Fatal if inhaled. H314; Causes severe skin burns and eye damage. H317; May cause an allergic skin reaction. H335; May cause respiratory irritation. H410; Very toxic to aquatic organisms with long lasting effects.	SCL ≥ 0.06 % M=10 (Aquatic acute 1) M=1 (Aquatic chronic 1)
3-iodo-2-propynylbutylcarbamate (IPBC)	259-627-5	55406-53-6	(EU)2015/1728	01/12/2016	01/12/2026	Acute Tox 3 Eye Dam. 1 Acute Tox 4 Skin Sens. 1 STOT RE 1 Aquatic Acute 1 Aquatic Chronic 1	H331: Toxic if inhaled H318: Causes serious eye damage H302: Harmful if swallowed H317: May cause an allergic skin reaction H372 (larynx): Causes damage to organs through prolonged or repeated exposure H400: Very toxic to aquatic life H410: Very toxic to aquatic life with long-lasting effects	M-factor 10 for acute and 1 for chronic
Biphenyl-2-ol	201-993-5	90-43-7	(EU)2016/105	01/07/2017	01/07/2027	Eye Irrit.2 Skin Irrit.2 STOT SE 3 Aquatic Acute 1	H319: Causes serious eye irritation H315: Causes skin irritation H335: May cause	

¹³⁸ Harmonised classification

PRODUCT TYPE 13: Working or cutting fluid preservatives								
Active substance	EC number	CAS number	Legal Act	Date of Approval	Expire Date	Classification ¹³⁸		Specific Conc. Limits, M-factors
						Hazard Class and category code(s)	Hazard Statement	
							respiratory irritation H400: Very toxic to aquatic life	
Mixture of 5-chloro-2-methyl-2H-isothiazol-3-one (EINECS 247-500-7) and 2-methyl-2H-isothiazol-3-one (EINECS 220-239-6) (Mixture of CMIT/MIT)		55965-84-9	(EU)2016/131	01/07/2017	01/07/2027	Acute Tox. 3 Acute Tox. 3 Acute Tox. 3 Skin Corr. 1B Skin Sens. 1 Aquatic Acute 1 Aquatic chronic	H331: Toxic if inhaled H311: Toxic in contact with skin H301: Toxic if swallowed H314: Causes severe skin burns and eye damage H317: May cause an allergic skin reaction H400: Very toxic to aquatic life H410 Very toxic to aquatic life with long lasting effects.	Skin Corr. 1B; H314 C ≥ 0.6% Eye Irrit. 2; H319 Skin Irrit. 2; H315 0.06% ≤ C < 0.6% Skin Sens.1/H317 C ≥ 0.0015%
N,N'-methylenebismorpholine (MBM)	227-062-3	5625-90-1	Reg (EU) 2015/1981	01/04/2017	01/04/2022	Skin Corr. 1 Skin Sens. 1 Carc. 1B Muta 2	H314: Causes severe skin burns and eye damage H317: May cause an allergic skin Reaction H350: May cause cancer H341: Suspected of causing genetic defects	-

Source: European Commission website

Common biocidal active substances for PT6 and PT13

Only biocidal products containing biocidal active substances approved by European Commission and authorized for use in lubricants are allowed for use.

Chloromethylisothiazolinone (CMIT) and methylisothiazolinone (MIT) are widely used in lubricants due to their effectiveness within such wide pH range. The dosage of CMIT+MIT added to the products is usually very low.

Mixture of CMIT + MIT¹³⁹ (3:1) has already harmonized classification and labeling in Annex VI of CLP regulation with the following H-statements: Acute Tox.3 H331, Acute Tox.3 H311, Acute Tox.3 H301, Skin Corr. 1B H314, Skin sens.1 H317, Aquatic Acute 1 H400, Aquatic Chronic 1 H410, which would exclude its use from the ecolabelled products above certain concentration.

CMIT+ MIT are usually used and sold as a mixture of CMIT/MIT in ratio (3:1) because of their wider effectiveness in combating bacteria, fungi and yeasts and also their cheaper price. The pH of the product to be preserved is one of the main factors that limit the use of preservatives. Depending on the stabilization and other compounds present in the formulation, the CMIT/MIT can be almost with no pH restrictions comparing with other preservatives. If only CMIT separately is used, the CMIT component begins to degrade quickly. CMIT degradation also occurs in systems containing small amounts of reducing agents such as sulphites, sulphides or sulphur containing amino acids. That's one of the reason why CMIT/MIT is almost always used in a mixture.

According to the CLP classification, if the concentration of CMIT/MIT (3:1) is \geq 0,0015% (15 ppm), the final mixture must be classified as Skin Sens 1; H317. This explains why the mixtures of CMIT/MIT are found in a concentration below 15ppm as then a classification is avoided.

Nanomaterials

In accordance with the report "Nanomaterials in consumer products, availability on the European market and adequacy of the regulatory framework"¹⁴⁰ some materials intentionally manufactured for use as nanoforms are used in lubricant products.

Definition of nanomaterials

In general the term 'nanomaterial' usually refers to 'materials with external dimensions, or an internal structure, measured in nanometres that exhibit additional or different properties and behaviour compared with coarser materials with the same chemical composition'¹⁴¹.

¹³⁹ Reaction mass of: 5-chloro-2-methyl-4-isothiazolin-3-one [EC no. 247-500-7] and 2-methyl-2H-isothiazol-3-one [EC no. 220-239-6] (3:1).

¹⁴⁰ Nanomaterials in consumer products, Availability on the European market and adequacy of the regulatory framework RIVM/SIR Advisory 11014 (IP/A/ENVI/IC/2006-193), available online at: http://static.sdu.dk/mediafiles//Files/Om_SDU/Fakulteterne/Teknik/NANO/4%20nanomaterials%20in%20consumer%20products_2006.pdf.

¹⁴¹ Loevestam, G. et al., Considerations on a Definition of Nanomaterial for Regulatory Purposes, European Commission, JointResearch Centre, EUR 24403 EN (2010).

The European Commission adopted a definition of a nanomaterial¹⁴² in 2011 (Recommendation on the definition of a nanomaterial (2011/696/EU)). According to the Recommendation a “Nanomaterial” means:

A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100 nm.

In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the number size distribution threshold of 50 % may be replaced by a threshold between 1 and 50 %.

By derogation from the above, fullerenes, graphene flakes and single wall carbon nanotubes with one or more external dimensions below 1 nm should be considered as nanomaterials.

However, its provision includes a requirement for review “*in the light of experience and of scientific and technological developments. The review should particularly focus on whether the number size distribution threshold of 50% should be increased or decreased*”. The Commission is expected to conclude the review in 2016, following the consultation of its draft findings with the stakeholders towards the end of 2015.

Nanomaterials are not intrinsically hazardous per se but there may be a need to take into account specific considerations in their risk assessment. Therefore one purpose of the definition is to provide clear and unambiguous criteria to identify materials for which such considerations apply. **It is only the results of the risk assessment that will determine whether the nanomaterial is hazardous and whether or not further action is justified.**

In general, Hansen et al. (2007)¹⁴³ proposed a general framework for categories of all nanomaterials to aid hazard identification of these materials based on the location of the nanomaterials in the system/material. Nanomaterials can be grouped in three categories:

- a) Materials that are nanostructured in the bulk of the product
 - One-phase materials (solid product),
 - Multi-phase materials (solid packaging with a liquid product inside).
- b) Materials that have nanostructure on the product surface
 - One-phase materials structured on the nanoscale at the surface,
 - Nanoscale thick unpatterned films on a substrate of different material,

¹⁴² Commission Recommendation of 18 October 2011 On The Definition of Nanomaterial (2011/696/EU), available online at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:275:0038:0040:EN:PDF>.

¹⁴³Wijnhoven, S.W.P. et al, Development of an inventory for consumer products containing nanomaterials, final report 070307/2010/580587/SER/D3.

- Patterned films of nanoscale thickness or a surface having nanoscale dimensions.
- c) As particles
- Surface-bound nanomaterials,
 - Nanoparticles suspended in liquids,
 - Nanoparticles suspended in solids,
 - Free airborne particles.

On the basis of available information, lubricants can be assigned to the third category: nanoparticles suspended in liquids.

It is important to mention that the nanomaterials, when used in a product, could be differentiated based on their physical state as embedded to substrate ones and free nanomaterials. This difference is important when exposure to consumers is considered. The consumers are exposed to nano in case of free nanomaterials whereas they are not or less exposed in case of embedded nano-ingredients¹⁴⁴.

The location of the nanomaterial is related with the following exposure categories:

- a) **Expected to cause exposure:** when consumers are in direct contact with the products (**relevant e.g. for “nanoparticles in liquids”** and “airborne particles”).
- b) **May cause exposure:** Although the nanoparticles in the product are not considered to be released intentionally, they may be released from the product because of wear and tear, e.g. “surface bound nanoparticles”.
- c) **No expected exposure to the consumer:** Negligible exposure is expected when nanoparticles are encapsulated in the product.

However, even embedded forms may become free, for example by manipulations or erosion. Therefore, it is critically important to take into account a life cycle perspective. One prominent example may be carbon nanotubes, which are mainly embedded in composites and, therefore, exposure during manufacturing and potentially during subsequent manipulation such as recycling may be the principal concern.

Legislative framework

REACH is the legislation applicable to the manufacturer and/or importer, placing on the market and using substances on their own, in preparations or in articles. Currently, nanomaterials are covered by the definition of a “substance” under REACH, although there is no explicit reference to nanomaterials and the same REACH provisions apply to all chemical substances. However, some adjustments are still needed in REACH legislation to assess and control the risks of nanomaterials.

¹⁴⁴ Poland, C.A. et al., Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study, *Nature Nanotechnology* 3, 423 (2008).

REACH places responsibility on industry to manage the risks that chemicals may pose to human health and environment, as well as to provide safety information that should be passed down the supply chain.

Until recently ECHA¹⁴⁵ has not given any specific guidance concerning nanomaterials. In 2009 the Commission launched a REACH Implementation Project on Nanomaterials (RIPoN) to provide advice on key aspects of REACH with regard to nanomaterials concerning Information Requirements (RIPoN 2) and Chemical Safety Assessment (RIPoN 3)¹⁴⁶. Based on the results, on 30 April 2012 ECHA published three new annexes updating Chapters R. 7a, R. 7b, R. 7c (these three guidances are currently being updated – May 2016¹⁴⁷), R8 and R10 of the Guidance on Information Requirements and Chemical Safety Assessment. Moreover, more guidances are currently being updated such as Guidance for identification and naming of substances under REACH and CLP and Appendix on recommendations for nanomaterials applicable to the Guidance on Registration (currently being updated on May 2016) in order to update the guidance for registration of substances in nanoform. These new guidances are mainly recommendations for registering nanomaterials and the adequacy of test methods. As a result, manufactured nanomaterials are expected to undergo similar tests like other chemicals. Therefore, assuming that they are not classified with the restricted risk phrases, they will then fulfil the requirements of the EU Ecolabel criterion on the use of hazardous substances (the criterion which is based on article 6.6 and 6.7 of Ecolabel Regulation 66/2012) and would be allowed.

Apart from the previously mentioned issues, works are being conducted with regard to the evaluation of the legislative framework for controlling and appropriate disposal of nanomaterials at the end of life phase. A recent study of MILIEU and Amec¹⁴⁸ examined the legislative framework for controlling nanomaterial release. It was noted that limitations in both exposure and hazard data for specific nanomaterials cause difficulties in assessment of the potential risks which nanomaterials can cause. The precautionary principle for the control of nanomaterials was emphasized by the authors. Another study¹⁴⁹ suggests that more data collection and research should be done in the area of waste disposal for nanotechnology to ensure that appropriate means of control are in place.

¹⁴⁵ ECHA, European Chemical Agency: <http://echa.europa.eu/>.

¹⁴⁶ Specific Advice on Fulfilling Information Requirements for Nanomaterials under REACH (RIP-On 2) – Final Project Report, Hankin S.M., Peters S.A.K., Poland C.A., Foss Hansen S., Holmqvist J., Ross B.L., Varet J. and Aitken R.J, 01 July 2011. For further details see: http://ec.europa.eu/environment/chemicals/nanotech/pdf/report_ripon2.pdf and Specific Advice on Exposure Assessment and Hazard/Risk Characterisation for Nanomaterials under REACH (RIP-On 3) – Final Project Report. Aitken, R.A, Bassan, A., Friedrichs, S., Hankin, S.M., Hansen, S.F., Holmqvist, J., Peters, S.A.K., Poland, C.A., Tran, C.L. 7 July 2011. For further details see: http://ec.europa.eu/environment/chemicals/nanotech/pdf/report_ripon3.pdf.

¹⁴⁷ For the latest drafts please see consultation procedure, available online at: <https://echa.europa.eu/support/guidance/consultation-procedure/ongoing-reach>

¹⁴⁸ Review of Environmental Legislation for the Regulatory Control of Nanomaterials, Amec, September 2011, available online at: http://ec.europa.eu/environment/chemicals/nanotech/pdf/review_legislation.pdf.

¹⁴⁹ BIO Intelligence Service (2011), Study on coherence of waste legislation, Final report for the EU (DG ENV), 2011

It can be seen that at present, there is inadequate information on risks associated to nanomaterials and in order to better assess their safety new test methodologies taking into account specific characteristics of nanomaterials are needed, also the lack of scientific evidence regarding their use and related impacts is an important factor to consider.

Concerns related to nanomaterials

In a nutshell the concerns related to nanomaterials are linked to the so called "nanomaterials paradox", i.e. desired effects versus unexpected hazardous impact on health. The very same properties that are desirable and potentially useful from a technological perspective, such as the high degree of surface reactivity, are also the properties that may give rise to unexpected and undesired effects. It can be noted, however, that the nanomaterials paradox is not unique to nanomaterials as this principle applies also to pharmaceuticals.

According to the opinion of the Scientific Committee on Consumer Products (SCCP)¹⁵⁰, there is insufficient knowledge on: hazard identification, exposure, uptake, absorption and transport across membranes, accumulation in secondary target organs, possible health effects, translocation of nanoparticles via the placenta to the foetus and in vitro and in vivo test methods validated or optimized for nanomaterial. The current methods used in REACH to assess the toxicological and ecotoxicological risk may not be adequate to evaluate the risks related to nanomaterials. Consequently, **there is a lack of knowledge regarding the damage nanomaterials may cause.**

Nanomaterials – Technology trends in Lubricants market

Many scientific research have been published on the tribological properties of nanoparticles-based lubricants regarding any mechanical system in relation to control friction and wear. It strongly depends upon the characteristics of the nanoparticles, such as shape, size and concentration within the lubricant. Because of the nature (inorganic and refractory) of the nanoparticles generally used as filler, the optimal performances achieved by the nano-lubricant can also be maintained in the working conditions at high temperature, avoiding the typical degradation of the traditional organic additives. However, a major challenge to face in order to scale up the use of nanoparticles as filler for lubricants, is related to their dispersion within fluids causing aggregation and precipitation of nanoparticles due to its small size. This can be solved by the introduction of surface-functionalized with organic treatments in order to optimize their stability.

An overview on the use of various classes of nanomaterials in lubricant formulations is described below. The following classes of nanomaterials are considered: fullerenes, nanodiamonds, ultradispersed boric acid and polytetrafluoroethylene (PTFE). Current advances in using nanomaterials in engine oils, industrial lubricants and greases strongly suggest that nanomaterials have potential for enhancing

¹⁵⁰ Scientific Committee on Consumer Safety, Guidance on the safety of nanomaterials in cosmetics, June 2012, available online at: http://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_s_005.pdf.

certain lubricant properties; however there is still a long way to go before balanced formulations are developed¹⁵¹.

Fullerenes

Fullerenes are cage molecules which are claimed to enable "rolling" lubrication mechanism. Inorganic fullerenes comprise another class of nanomaterials with "fullerene". For instance, inorganic fullerene-like material (IF-WS₂) nanoparticles can be synthesized by reacting sulphur with tungsten trioxide (WO₃) nanoparticles in a hydrogen atmosphere at 500-650 °C. The IF-WS₂ nanoparticles have a closed hollow cage structure with an average size of about 50nm which is much larger than the size of the C₆₀ molecule.

Studies suggest that addition of C₆₀ fullerene soot in a lubricant significantly increases the weld load and seizure resistance. C₆₀ fullerene soot and IF-WS₂ form much more stable dispersions in hydrocarbons as compared to regular graphite and WS₂ powders. Apart from improved dispersion stability, IF-WS₂ does not appear to offer any performance benefits over regular WS₂ powder.

Nanodiamonds

Nanodiamonds are claimed to embed into the sliding surfaces rendering them more resistant to wear, or enable "rolling lubrication" between the surfaces, thus reducing friction and wear. However, the reduction in friction is consistent with their micropolishing effect resulting in faster running-in and smoother mating surfaces.

The micropolishing effect of nanodiamonds becomes insignificant in the case of aged oil, where wear rate and steady-state surface roughness is dominated by other factors, such as oil contamination. However, there is a risk for excessive wear over a longer period of time, due to the abrasiveness of nanodiamonds does not go away after the initial running-in period. Analysis of oils from engine oils doped by nanodiamonds reveals unusually high levels of wear metals such as aluminium, copper and chromium, indicative of accelerated wear of bearings and piston rings. Therefore, more studies are needed in order to discern possible unintended consequences.

Boric Acid

Boric acid was used as a common additive in metal-working fluids (MWFs) formulations thanks to its excellent extreme pressure antiwear (EP/AW) properties and bacteriostatic and bactericidal actions. Nowadays it has been largely phased out from MWFs because of health, safety and environmental concerns. Nevertheless, some recent studies mention boron-based nanoparticulate lubrication additives that can drastically lower friction and wear in a wide range of industrial and transportation applications.

By replacing sulphur and phosphorous, boron additives are hoped to eliminate the main sources of environmentally hazardous emissions and wastes. However, there are some technical problems associated, first of all boric acid has no antioxidant

¹⁵¹ Zhmud B. and Pasalskiy B. Nanomaterials in Lubricants: An Industrial Perspective on Current Research. Lubricants 2013, 1, 95-101.

effect, so it cannot replace zinc dithiophosphate (ZDDP). And second, it is not compatible with some essential lubricant additives, specifically with the total base number buffer in the engine oil, which may lead to corrosion and sludge problems. Recently, it has been proposed to combine electrochemical boriding with the use of colloidal boron nitride for improving tribological performance of drivetrain components in advanced wind turbines. This may be promising future applications of this new technology.

Polytetrafluoroethylene (PTFE)

PTFE has an impressive performance profile in greases, chain oils, dry-film lubricants, etc. Recognition of potential to reduce friction and wear has led to use of PTFE as a dry-film lubricant and friction modifier. However, the use of PTFE in engine oils is rather limited due to its inherent instability in oil, the risk of oil filter clogging, as well as difficulties with recycling.

In general, nanoadditives open new ways to maximizing lubricant performance; however its large-scale market introduction is still facing serious technical and legislative obstacles. One practical issue is that lubricant formulations must be balanced with respect to a number of properties. Therefore, their market penetration into lubricant sector is low; however these will be interesting developments that may reach the market in the near future according to the following section.

Nanotechnology-based consumer products introduced on the market

To document the marketing and distribution of nano-enabled products in the commercial market, some nano-specific product databases has been analysed in order to list lubricant products containing nanoforms and currently introduced on the market.

Some of these nano-specific product databases used are indicated below:

- **Woodrow Wilson database** (The project on Emerging Nanotechnologies): The American Woodrow Wilson database was the first publicly available on-line inventory (since 2005) of nanotechnology-based consumer products supported from US EPA. This inventory is freely accessible online and it acknowledges the CPI in its website¹⁵². This inventory compiles consumer products claiming to contain nanomaterials and has become one of the most frequently cited resources showing the widespread applications of nanotechnology.
- **ANEC-BEUC 2010 inventory**. The ANEC/BEUC¹⁵³ 2010 inventory is a European inventory of products available to consumers with a claim of containing nanomaterials. The inventory is a Microsoft Excel table available free of charge on: www.beuc.org.
- **Online database of German Environmental NGO 'BUND'**. This product database focuses on consumer products claimed to contain nanomaterials in Germany. It is accessible on the BUND website free of charge:

¹⁵²More information available on-line at: <http://www.nanotechproject.org/cpi/about/>

¹⁵³ ANEC: European Association for the Coordination of Consumer Representation in Standardisation, BEUC: Bureau Européen des Unions de Consommateurs.

http://www.bund.net/nc/themen_und_projekte/nanotechnologie/nanoprodukt Datenbank/produktsuche/.

ANEC-BEUC 2010 inventory

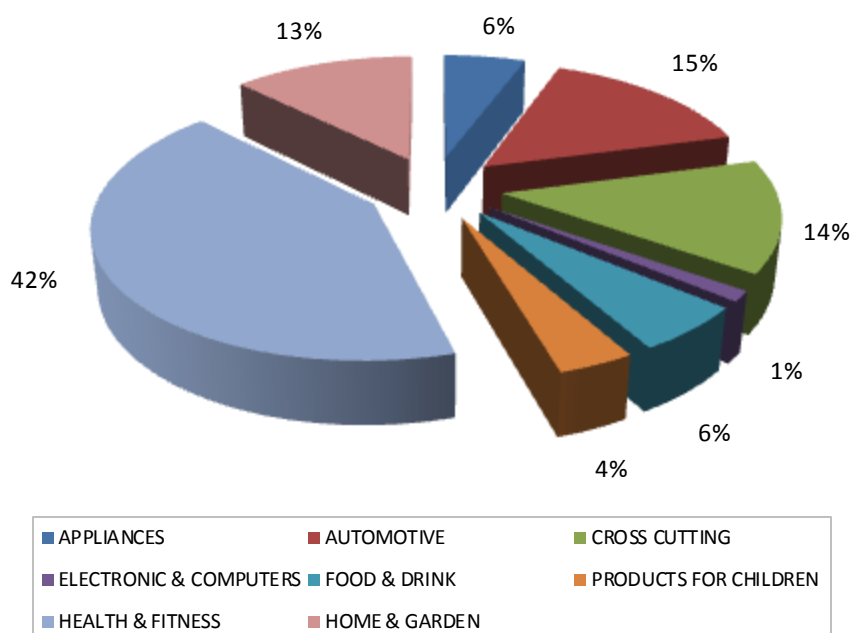
The search for products was carried out in 2010 in shops and on internet and it is based on the claims that the product contains nanomaterials. However, the inventory should not be considered as an exhaustive list of products available on the EU market. It is only intended to give an overview of what consumers could find in the EU market.

The percentage of products per category is summarized according to the table below¹⁵⁴:

Table 46: Percentage of products per category in 2010

CATEGORIES	NUMBER OF PRODUCTS INVESTIGATED	PERCENTAGE
APPLIANCES	27	6%
AUTOMOTIVE	72	15%
CROSS CUTTING	66	14%
ELECTRONIC & COMPUTERS	6	1%
FOOD & DRINK	27	6%
PRODUCTS FOR CHILDREN	18	4%
HEALTH & FITNESS	199	42%
HOME & GARDEN	60	13%
TOTAL	475	100%

¹⁵⁴ ANEC & BEUC updated inventory on products claiming to contain nanomaterials. More information available on-line at:
http://www.anec.eu/attachments/ANEC%20BEUC%20leaflet%20on%20nano%20inventory_How%20much%20nano%20do%20we%20buy.pdf



Automotive is the second category with more products claiming contained nanomaterials. Currently, there are three products in automotive category (TopEfekt® KOK NANO, Textil PROT Nano and Sani Plus Nano Silver) all containing silver nanoparticles. However, none of them has the functionality of lubricant. They are mainly used as anti-reflecting cleaning agent recommended for plastic surfaces.

Woodrow Wilson database (The project on Emerging Nanotechnologies)

The updated Nanotechnology Consumer Products Inventory currently contains 1.814 consumer products from 622 companies in 32 countries that have been introduced to market since 2005, representing a 24 percent increase since the last update in 2010. The Virginia Tech Center for Sustainable Nanotechnology worked in the revision of the inventory with the objective to improve the reliability, functionality and scientific credibility of this database with more accurate information on consumer products. Registered users are encouraged to submit relevant data pertaining to nanoparticle function, location, properties, potential exposure pathways, toxicity and life cycle assessment.

Through the “How much we know” descriptor, consumer products are rated according to the reliability of the manufacturer’s claim that products contain nanomaterials. These descriptors are divided into the following categories:

- Category 1: Extensively verified claim
- Category 2: Verified claim
- Category 3: Manufacturer -supported
- Category 4: Unsupported claim
- Category 5: Not advertised

To date, 1259 products have been evaluated in the inventory for the “How much we know” descriptor and the majority (71%) of products are not accompanied by sufficient information to support claims that nanomaterials are indeed used in the products, such as the safety data sheet containing technical information about nanomaterial components (e.g. median size, size distribution, morphology,

concentration, etc...). Regarding the "How much we know" descriptor, it is stressed to note that only 9 of 1259 evaluated products have been classified in Category 1 "Extensively verified claim" due to the availability of scientific papers or patents describing the nanomaterial used in these products.

An overview of the nanotechnology-based lubricants products are described in the table below. The lubricant functionality contains 21 products divided mainly in three categories: automotive (15), health and fitness (2) and home and garden (3). IF-WS₂ is the most frequently used nanomaterial; however most products do not provide the composition of the nanomaterial used in them. The majority of products contain nanomaterials suspended in a variety of liquid media and dermal contact and inhalation is the most likely exposure scenario from their use.

According to the table below, the lubricant functionality contains 21 products classified into the following categories:

- Category 1 (Extensively verified claim): 5 products
- Category 2 (Verified claim): 2 products
- Category 3 (Manufacturer –supported): 11 products
- Category 4 (Unsupported claim): 3 products
- Category 5 (Not advertised): 0 products

Category 1 represents 55,6% of the total evaluated products classified as extensively verified claim. Therefore, nanotechnology-based lubricant products represent a high percentage of overall nanoproducts introduced on the market, mainly in automotive category. In fact, considering the information available¹⁵⁵, the most important product categories in Europe where nanomaterials are used are expected to be motor vehicles, electronics and computers.

¹⁵⁵ Nanomaterials in consumer products, Availability on the European market and adequacy of the regulatory framework RIVM/SIR Advisory 11014 (IP/A/ENVI/IC/2006-193): http://static.sdu.dk/mediafiles//Files/Om_SDU/Fakulteterne/Teknik/NANO/4%20nanomaterials%20in%20consumer%20products_2006.pdf

Table 47: Overview of nanotechnology-based lubricant products introduced on the market

NAME OF THE NANO-BASED PRODUCT	THE NANO-LUBRICANT	ORIGIN	COMPANY	NANO MATERIAL	FUNCTION OF NANOMATERIAL	SHAPE/DIMENSIONS	CONCENTRATION	LOCATION OF NANOMATERIAL	POTENTIAL EXPOSURE PATHWAYS	HOW MUCH WE KNOW
CATEGORY: AUTOMOTIVE SUBCATEGORY: LUBRICANTS										
NANO DRY LUBRICANT		USA	-	-	LUBRICANT	-	-	Suspended in liquid	Dermal Inhalation	Category 3 (Manufacturer-supported claim)
NANO HIGH PERFORMANCE MARINE GREASE		USA	-	-	LUBRICANT	-	< 1%	Suspended in liquid	Dermal Inhalation	Category 3 (Manufacturer-supported claim)
NANO PENETRATING OIL		-	-	-	LUBRICANT	-	-	-	Dermal Inhalation	Category 3 (Manufacturer-supported claim)
NANOLUB © GH-X		ISRAEL	AP NANO MATERIALS INC.	IF-WS ₂	LUBRICANT	Nanoparticles, Nanofilms, 30-70 nm	3 – 5 %	Suspended in liquid	-	Category 2 (Verified claim)
NANOLUB © MP-X CHAIN		ISRAEL	AP NANO MATERIALS INC.	IF-WS ₂	LUBRICANT	Nanoparticles, Nanofilms, 30-70 nm	3 – 5 %	Suspended in liquid	-	Category 1 (Extensively verified claim)
NANOLUB © MP-X COMPRESSOR		ISRAEL	AP NANO MATERIALS INC.	IF-WS ₂	LUBRICANT	Nanoparticles, Nanofilms, 30-70 nm	3 – 5 %	Suspended in liquid	-	Category 1 (Extensively verified claim)
NANOLUB © MP-X GEAR		ISRAEL	AP NANO MATERIALS INC.	IF-WS ₂	LUBRICANT	Nanoparticles, Nanofilms, 30-70 nm	3 – 5 %	Suspended in liquid	-	Category 1 (Extensively verified claim)
NANOLUB © RC-X ENGINE		ISRAEL	AP NANO MATERIALS INC.	IF-WS ₂	LUBRICANT	Nanoparticles, Nanofilms, 30-70 nm	2 – 7 %	Suspended in liquid	Dermal Inhalation	Category 1 (Extensively verified claim)
NANOSAVE N1 – ORGANIC NANOENGINEERED HIGH PERFORMANCE BIOBASED MOTOR OIL		-	-	Organics	LUBRICANT	-	-	Suspended in liquid	Dermal	Category 2 (Verified claim)
NANO HIGH TEMP/EXTREME PRESSURE GREASE		USA	-	-	LUBRICANT	-	-	Suspended in liquid	Dermal Inhalation	Category 3 (Manufacturer-supported claim)
CATEGORY: AUTOMOTIVE SUBCATEGORY: MAINTENANCE AND ACCESSORIES										
CERMET NANO-PARTICLE CERAMIC CONDITIONER		USA	CERMET	CERAMICS	LUBRICANT	-	-	Suspended in liquid	Dermal	Category 4 (Unsupported claim)
G-OIL™ GREEN ENGINE OIL		USA	GREEN EARTH TECHNOLOGIES, INC	-	LUBRICANT	-	-	Suspended in liquid	-	CATEGORY 3 (MANUFACTURER-SUPPORTED)

NAME OF THE NANO-BASED LUBRICANT PRODUCT	ORIGIN	COMPANY	NANO MATERIAL	FUNCTION OF NANOMATERIAL	SHAPE/DIMENSIONS	CONCENTRATION	LOCATION OF NANOMATERIAL	POTENTIAL EXPOSURE PATHWAYS	HOW MUCH WE KNOW
									CLAIM
G-OIL™ MARINE TC-W3 2 CYCLE GREEN ENGINE OIL	USA	GREEN EARTH TECHNOLOGIES, INC	POLYESTER 65% WITH SILVER NANOTECHNOLOGY	LUBRICANT	-	-	Suspended in liquid	-	CATEGORY 3 (MANUFACTURER-SUPPORTED CLAIM)
G-TIRE™ ULTIMATE TIRE SHINE	USA	GREEN EARTH TECHNOLOGIES, INC	-	LUBRICANT	-	-	Suspended in liquid	DERMAL INHALATION	CATEGORY 3 (MANUFACTURER-SUPPORTED CLAIM)
G-WHEEL™ WHEEL CLEANER	USA	GREEN EARTH TECHNOLOGIES, INC	-	LUBRICANT	-	-	Suspended in liquid	DERMAL INHALATION	CATEGORY 3 (MANUFACTURER-SUPPORTED CLAIM)
CATEGORY: HEALTH AND FITNESS SUBCATEGORY: SPORTING GOODS									
BIBYCLE CARE PRODUCT: KETTEN SPRAY NANO CHAINLUBE	GERMANY	REMA TIP TOP	-	LUBRICANT	-	-	Suspended in liquid	Inhalation	Category 4 (Unsupported claim)
http://muc-off.com/lube/179-c3-dry-ceramic-lube.html	UK	MUC-OFF	CERAMICS	LUBRICANT	-	-	-	-	Category 4 (Unsupported claim)
CATEGORY: HOME AND GARDEN SUBCATEGORY: CLEANING									
G-CLEAN CONCRETE CLEANER & DEGREASER	USA	GREEN EARTH TECHNOLOGIES, INC	-	ANTIMICROBIAL LUBRICANT	-	-	Bulk	DERMAL INHALATION	CATEGORY 3 (MANUFACTURER-SUPPORTED CLAIM)
G-CLEAN MOLD & MILDEW STAIN REMOVER	USA	GREEN EARTH TECHNOLOGIES, INC	-	ANTIMICROBIAL LUBRICANT	-	-	Bulk	DERMAL INHALATION	CATEGORY 3 (MANUFACTURER-SUPPORTED CLAIM)
G-CLEAN SIDING & ALL PURPOSE CLEANER	USA	GREEN EARTH TECHNOLOGIES, INC	-	ANTIMICROBIAL LUBRICANT	-	-	Bulk	DERMAL INHALATION	CATEGORY 3 (MANUFACTURER-SUPPORTED CLAIM)
CATEGORY: - SUBCATEGORY: -									
NANOCOPPER	USA	NANOCLAT, INC	CARBON COPPER GOLD IRIDIUM LITHIUM NICKEL PLATINUM SELENIUM	ANTIMICROBIAL PROTECTION COATINGS ENVIRONMENTAL TREATMENT FILTRATION HARDNESS AND STRENGTH HEALTH APPLICATIONS HYDROPHOBIC TREATMENT	Spherical nanoparticles	99,99%	Bulk	-	Category 1 (Extensively verified claim)

NAME OF THE NANO-LUBRICANT PRODUCT	ORIGIN	COMPANY	NANO MATERIAL	FUNCTION OF NANOMATERIAL	SHAPE/DIMENSIONS	CONCENTRATION	LOCATION OF NANOMATERIAL	POTENTIAL EXPOSURE PATHWAYS	HOW MUCH WE KNOW
			SILVER	LUBRICANT ELECTRONICS APPLICATIONS PIGMENT SUN PROTECTION					

It is important to note the use of two nanomaterials of possible concern that could be considered to be specifically excluded or limited in the product group was identified. It includes:

- **Silver nanoparticle:** The product G-OIL™ MARINE TC-W3 2 CYCLE GREEN ENGINE OIL, currently on the market, is engineered for all models of outboard engines and personal watercraft.
- **Boron-based nanoparticulate:** Boric acid was largely phased out from MWFS because of health, safety and environmental concerns. However, there is recent interest in boron-based nanoparticulate lubrication additives as a promising future application.

4.6.1.3. Packaging materials

According to the LCA, it is considered that the environmental impact generated by the packaging would be low in comparison with the rest of life stages. Nevertheless, some materials and substances used in the packaging could be considered important due to its potential environmental impact and its inherent toxicity.

The lack of data makes difficult to obtain a satisfactory analysis of the materials and substances used in the manufacture of packaging. Nevertheless, some strategies can be pointed in order to reduce the environmental impact of the packaging, such as, the use of non-toxic substances or less contaminants.

Generally, different materials are used for packaging of lubricant products under study. Lubricants are packaged in many different forms from low capacity packaging for particular uses since big packaging, going typically from a 250 ml bottles to big capacity pails or tanks. Usually, small lubricant packs are made of plastic while metal containers have been used for decades for packaging lubricants. Nevertheless, metal containers easily can be dented and damaged resulting in leakages. This was a reason for the shift toward the use of plastic containers in recent years. Plastic containers present robust durability, ensuring leak-proof storage even in the case of direct impact to the container.

Generally, packaging can be made of different kinds of plastic. Plastics constitute a large range of products conventionally produced from natural gas or crude oil. Some of the main impacts related to plastic production are the use of additives from the manufacturing stage (phthalates, halogenated organic compounds, heavy metals...) which encompass a large number of substances harmful to health and environment.

In accordance with the information given at the Plastics Europe website the following substances included in the Candidate list are used in plastic materials¹⁵⁶:

Table 48: Substances included in the Candidate list used in plastic materials

Name of substance	Articles category	EC number	CAS number	Reason for inclusion in Candidate List
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¹⁵⁶<http://www.plasticseurope.org/plastics-sustainability/consumer-protection/reach.aspx>

Name of substance	Articles category	EC number	CAS number	Reason for inclusion in Candidate List
2,4-Dinitrotoluene	Monomer	204-450-0	121-14-2	Carcinogenic (article 57a)
4,4'-Diaminodiphenylmethane (MDA)	Monomer	202-974-4	101-77-9	Carcinogenic (article 57a)
Acrylamide	PA Monomer	201-173-7	79-06-1	Carcinogenic and mutagenic (articles 57 a and 57 b)
Alkanes, C10-13, chloro (Short Chain Chlorinated Paraffins)	PVC	287-476-5	85535-84-8	PBT and vPvB (articles 57 d and 57 e)
Benzyl butyl phthalate (BBP)	PVC PP catalysts	201-622-7	85-68-7	Toxic for reproduction (article 57c)
Bis (2-ethylhexyl)phthalate (DEHP)	PVC PP catalysts	204-211-0	117-81-7	Toxic for reproduction (article 57c)
Chromium trioxide	HDPE catalysts	215-607-8	1333-82-0	CMR
Dibutyl phthalate (DBP)	PVC PP catalysts	201-557-4	84-74-2	Toxic for reproduction (article 57c)
Diisobutyl phthalate	PVC PP catalysts	201-553-2	84-69-5	Toxic for reproduction (article 57c)
Hexabromocyclododecane (HBCDD) and all major diastereoisomers	Flame Retardant EPS, XPS	247-148-4 221-695-9	25637-99-4	PBT (article 57d)
Lead chromate	Pigment	231-846-0	7758-97-6	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)
Lead chromate molybdate sulphate red (C.I. Pigment Red 104)	Pigment	235-759-9	12656-85-8	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)
Lead sulfochromate yellow (C.I. Pigment Yellow 34)	Pigment	215-693-7	1344-37-2	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)
Tris(2-chloroethyl)phosphate	Flame Retardant, plasticiser	204-118-5	115-96-8	Toxic for reproduction (article 57c)

Source: Website of PlasticsEurope

Short-chain chlorinated paraffins and certain phthalates (dibutylphthalate (DBP), diethylhexylphthalate (DEHP)) are also included in the list of chemicals requiring priority action of the OSPAR Strategy on Hazardous Substances¹⁵⁷. The main concern regarding phthalates is the potential for endocrine disruption of phthalates esters. Short-chain

¹⁵⁷ More information available on-line at: <http://www.ospar.org/work-areas/hasec/chemicals/priority-action>

chlorinated paraffins have a very negative impact in the management of the end-of-life of the products. The halogenated waste, when incinerated without precautions, has the potential to form toxic polychlorinated dioxins and furans (Zennegg et al. 2009, Wong et al. 2007) and many show persistent and bioaccumulative properties from the waste incineration plant. Dioxins and furans are commonly regarded as highly toxic compounds that are environmental pollutants and persistent organic pollutants (POPs).

Halogenated compounds are not suited for combustion; however the problem is that halogenated waste may end in the rubbish deposited by consumers, which may be finally combusted. It should be considered that approximately 50% of all traditional lubricants are released into the environment during use, spills, and disposal. For example, during normal use four-stroke engine oils are not released to the environment, but their main environmental concerns come from improper disposal of used oil. It is therefore recommended to include information on disposal information requirements for waste oil in the case of lubricants designed to be sold to private end consumers when the lubricant is used for nonprofessional or non industrial users due to it could generate a spillage to the environment.

4 Prioritisation methodology

In the light of the preliminary information of this report, a prioritisation methodology is proposed in order to evaluate all the multidimensional (e.g. market, technical, environmental) aspects that influence this revision. This will serve as a basis to prepare a proposal of the revised scope attending to aspects described previously including market, technical and environmental aspects, as well as to help us to identify the environmental hotspots associated to the categories included in the scope in order to set the revised criteria that target the main relevant environmental hotspots associated to this product group.

An overview of the prioritization is presented in the following figure, where the types of lubricants that have been prioritized to be included and the main considerations in terms of environmental and health impacts can be seen. Also the rationale of the main criteria of inclusion (harmonization of ecolabelling schemes, current market penetration and EU regulations/policies) is represented.

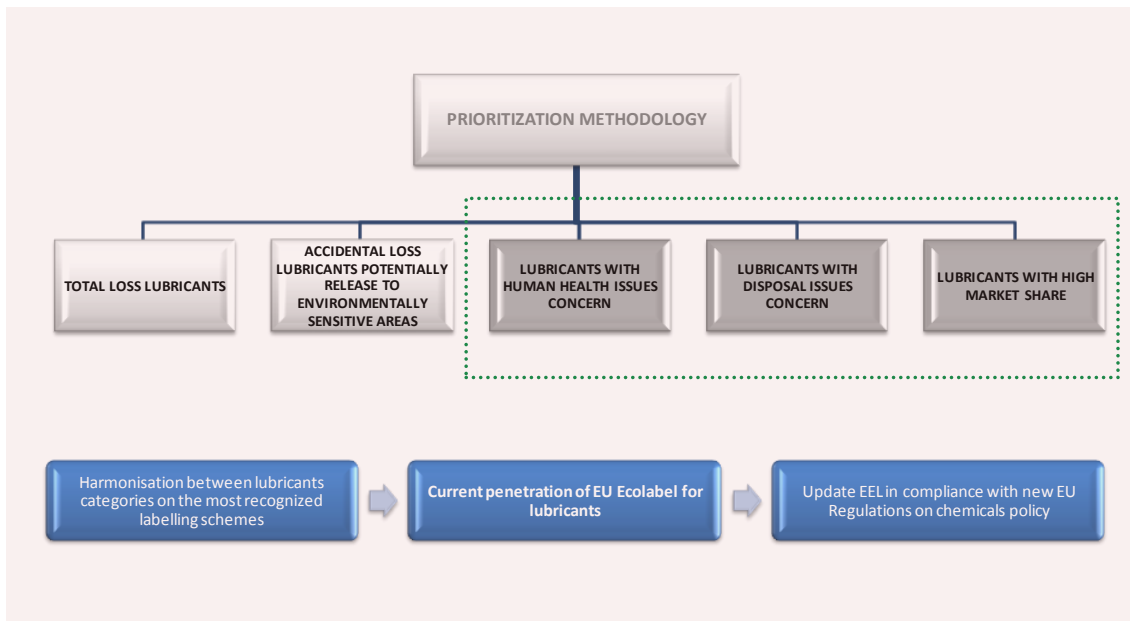


Figure 33: Flow diagram of the prioritization methodology

The relevant points of the prioritization methodology are the following:

- **Total loss lubricants** where a major environmental impact is expected. This category is in line with previous revision.
- **Accidental loss lubricants potentially release to environmentally sensitive areas.** This type of lubricants corresponds to lubricants which are often released into the environment due to accidental releases. Although the possibility of spillage is lower, the amount of impact generated could be important.

Although it is considered reasonable to focus on lubricant loss and potential impact to the environment (environmental impacts of a lubricant product can be caused in any stage of its life cycle (e.g. during raw material extraction or at the end of life), and not only from its potential release to the environment. Following lubricant types are also considered relevant:

- **Lubricants with concerns regarding human health.** The scope of the revised EU Ecolabel is proposed to be enlarged in order to include health and safety issues concern.
- **Lubricants with concerns regarding disposal.** i.e., lubricants with high potential environmental impacts at their end-of-life (waste lubricants). According to the environmental considerations on end-of-life, used lubricating oils represent the largest amount of liquid, non-aqueous hazardous waste in the world. Severe contamination can result from waste oils being left on the ground or released to aquatic ecosystems. Thus, it is crucial to collect as much as possible this very valuable resource, in order to avoid the contamination of the environment and to be able to profit from the very high recovery potential of this waste stream¹⁵⁸. Therefore, it is suggested to keep a focus on re-refined oils, as well as information on handling and disposal information and packaging requirements.
- **Lubricants with high market share and/or target end-consumer** according to the market analysis in order to extend the scope and cover most of lubricants available on the market (e.g. engine oils currently not covered by the EEL). According to the market analysis, only the 16% of the lubricants market are included on the current EU Ecolabel scope. Therefore, it is considered reasonable to analyse for potential scope extension on engine oils, i.e. on 4-T stroke oil currently not covered under EEL, which represents the 40% of the lubricants market. This recommendation on the potential scope extension from 16% to 56% (16% + 40%) can be made on the basis of the market analysis and the feasibility to include this type of oils. In addition, most of the current categories covered mostly encompass professional and industrial products. However, the EU Ecolabel is a label that mainly target consumers and it is therefore suggested to include categories of lubricants that are usually sold to **private end consumers** as well (e.g. automotive lubricants).

Moreover, in addition to the environmental assessment, following issues are considered relevant for guidance on the criteria revision:

- **Harmonisation** between the criteria for this product group and the criteria from other lubricants categories on the most recognized labelling schemes in order to ensure a general more horizontal approach. A comparison of the scope and specifications criteria established for the most recognized labelling schemes has been prepared. Moreover, the success, i.e. the number of certified products in each ecolabel and environmental schemes applicable to lubricants have been taken into account as far as possible. An overview of the scope and criteria of the other schemes for lubricants is indicated in APPENDIX II: Overview of scope and criteria of the other schemes.
- **Current penetration of EU Ecolabel for lubricants**, i.e. the number of licenses obtained in each category and type of product in order to analyse and/or revise the possible problems of the industry to obtain the Ecolabel.

Table 49: Number of products certified in each EU Ecolabel Category for lubricants

¹⁵⁸ More information available online at: http://ec.europa.eu/environment/waste/oil_index.htm

EU Ecolabel Category		Number of products certified
Category 1	Hydraulic fluids	85
Category 2	Greases	29
	Stern tube greases	6
Category 3	Chainsaw oil	20
	Concrete release agents	7
	Wire rope lubricants	2
Category 4	Two-stroke oils	2
Category 5	Industrial and marine gear oils	25

- The revision of the current EEL in order to **update** it in compliance with new EU **regulations** on chemicals policy.

4.7. Potential scope extension in the light of the prioritization proposed

According to the prioritization methodology the lubricant families that are currently excluded from the EU Ecolabel scope and these that were identified as being susceptible to be included during the revision process are: metalworking fluids (MWFs), 4-stroke engine oils and temporary protection against corrosion lubricants.

Regarding other labelling schemes (APPENDIX II: Overview of scope and criteria of the other schemes):

- Metalworking fluids are addressed in Nordic Ecolabel and Korea Ecolabel
- Temporary protection against corrosion lubricants are addressed in the Korea Ecolabel, named as "anti-rust lubricating oil"
- Four-stroke engine oils: it is to notice that in Europe there are no eco-labels addressing 4T engine oils (APPENDIX II: Overview of scope and criteria of the other schemes). The Korea Eco-Label has three Product Categories for engine oils apart from the one of Lubricants (each one for: 4T engine oils, 2T engine oils, diesel gasoline oils) which criteria are different from those of Lubricants, and are related to emissions of air pollutants and resource consumption. The Korea Eco-Label for 2T also includes a biodegradability criterion (APPENDIX III: Overview of scope and criteria of Korea Eco-Label for engine oils category).

Against this background, the initial proposal on scope broadening (See section 4 of Task 1, scope and definition) has been further defined as follow:

Table 50: Included and excluded categories following ISO 6743 classification in the current and revised EU Ecolabel

ISO Family	ISO 6743-99 Description		Current EU Ecolabel	Proposed EU Ecolabel	Lubricant loss
A	Total loss systems		Included	Included	Total
B	Mould release	Concrete	Included	Included	Total
		Industrial	Excluded	Excluded	Accidental

C	Gears		Included	Included	Accidental/Partial
D	Compressors		Excluded	Excluded	Accidental
E	Internal combustion engine oils	4-T stroke oil	Excluded	Included	Accidental
		2-T stroke oil	Included	Included	Total
F	Spindle bearings, bearings, and associated clutches		Excluded	Excluded	Accidental/Partial
G	Slideways		Excluded	Excluded	Partial
H	Hydraulic systems		Included	Included	Accidental/Partial
M	Metalworking		Excluded	Included	Accidental
P	Pneumatic tools		Excluded	Excluded	Accidental/Partial
Q	Heat transfer fluids		Excluded	Excluded	Accidental
R	Temporary protection against corrosion		Excluded	Included	Total
T	Turbines	Stern tube	Included	Included	Total
		Industrial	Excluded	Excluded	Accidental/Partial
U	Heat treatment		Excluded	Excluded	Accidental
X	Greases		Included	Included	Accidental /Partial/Total

The following product groups and the potential inclusion into the new proposed scope are discussed below:

- Total loss systems: are those that entry into environment unavoidably and are irretrievable. They are included into the current classification on the category 3 as chainsaw oils, wire rope lubricants, marine gear oils and other total loss lubricants. They are proposed to be maintained into the scope due to their total release to the environment and their potential impacts.
- Mould release: currently only the concrete release agents (Category 3) are included since they are classified as total loss. The inclusion of the industrial release agents is not proposed in this revision due to the low problematic associated and the lack of data.
- Gears: previous revisions and current criteria considered gear oils as total loss. Although this revision considers industrial gear lubricants as Accidental/Partial loss, it is proposed to maintain them within the scope. It should be noticed that, according to ISO, marine gear oils are classified as Family A: total loss systems (as open system gears).
- Internal combustion engine oils: the category includes the 2-stroke oil and the 4-T stroke oil lubricants. 2-stroke oil lubricants are included in the current scope since they are considered as total loss. Moreover, 2-stroke have a severe impact in the atmosphere due to the emission to air with burnt combustible. In this revision, the 4-T stroke oil will be also analysed because of the high market share, the fact that they are usually sold to private end consumers and the problematic on collecting waste oil produced (especially at particular level).

- Hydraulic systems: they correspond with category 1 of the existing classification: hydraulic fluids and tractor transmission oils. On the current revision they have not been considered as total loss, however the environmental impact could be relevant if they are used in sensitive areas and they are proposed to be maintained within the scope.
- Metalworking: despite they are classified as accidental loss, the metalworking fluids could be important due to the impact on human health for the worker exposure. Also the impacts linked with waste could be relevant from an environmental point of view. Temporary protection against corrosion: They are proposed to be included since they are often used on open systems and in environmentally sensitive areas. Sometimes they are not recovered after use and waste lubricant can be lost into the environment, for this reason they are classified as total loss.
- Stern tube: they are included in family T: turbines of the ISO. They are currently included into the scope of the current criteria as they are total loss. They are proposed to be included into the new scope as well, because they can be used on environmental sensitive areas in direct contact with marine water. Industrial turbines are proposed to be left out of the scope for this revision process.
- Greases: included in the category 2, greases and stern tube greases. They are proposed to be maintained within the scope of the product group since they could generate an important environmental impact depending on the use (they have a broad set of possible applications).

The rest of lubricant categories that are currently excluded from the EU Ecolabel scope are proposed to be left out of this revision process following the criteria:

- they do not have a high market share,
- they are partial/accidental loss without special potential impacts during use,
- they do not have specific environmental problematic linked to waste since controlled collection and treatment is normally done at industrial level.

4.8. Analysis of new lubricants proposed in the revised scope

Following the prioritization methodology, this section will be focused in the lubricant families that are currently excluded from the EU Ecolabel scope and were identified as being susceptible to be included during this revision process.

4.8.1. Metalworking fluids (MWFs)

Metalworking fluids (MWFs) is the name given to a range of oils and other liquids that are used to cool and/or lubricate metal work pieces when they are being machined, ground, milled, etc. MWFs reduce the heat and friction between the cutting tool and the work piece and help prevent burning and smoking.

There are four basic classes of MWFs:

1. **Straight oils:** Also called “**cutting oils**”. This type is made up of mineral (petroleum), animal, marine, vegetable or synthetic oils. Straight oils are not diluted with water but other additives may be present.
2. **Soluble oils (emulsifiable oils):** This category contains 30 to 85 percent severely refined petroleum oils, as well as emulsifiers to disperse the oil in water.
3. **Semi-synthetic fluids:** This category contains 5 to 30 percent severely refined petroleum oils, 30 to 50 percent water and a number of additives.
4. **Synthetic fluids:** This category does not contain petroleum oils. Instead, they use detergent-like components and other additives to help “wet” the work piece.

Although each class will vary greatly in composition, each may contain additives such as:

- Sulphurized or chlorinated compounds
- Corrosion inhibitors (e.g. calcium sulfonate, sodium sulfonates, fatty acid soaps, amines, boric acid)
- Extreme pressure additives (e.g. sulphurized fatty materials, chlorinated paraffins, phosphorus derivatives)
- Anti-mist agents (e.g. polyisobutylene polymer)
- Emulsifiers (e.g. triethanolamine, sodium petroleum sulphonates, salts of fatty acids and non-ionic surfactants)
- Alkanolamines
- Biocides
- Stabilizers
- Dispersants
- Defoamers
- Colourants
- Dyes
- Odourants
- Fragrances

When metalworking fluids are stored for a long period of time, nitrosamines can be formed slowly in the water-based MWFs and may be the result of interaction of nitrites in the fluid, lining of the cans used for storage or from nitrogen oxides in air. Moreover, MWFs can increase the problem if more reactants are added. The formation of nitrosamines in the MWFs is a concern since many nitrosamines are classified as carcinogen.

The primary concern related to MWFs is the presence of contaminants that encourage the growth of bacteria and fungi in water-based MWFs. The bacteria can degrade the

emulsions and change the properties of MWFs. Biocides are added to reduce the amount of microbial growth; nevertheless biocides products themselves have hazardous properties. Biocides are typically used in MWFs, hydraulic fluids and mould release.

MWFs are also contaminated by small particles of the metal that come off the machined parts. Common metals used include steel or alloys containing nickel, cobalt and chromium. Moreover, there is the potential for straight oils to be heated during use (usually at the site where the cutting tool works on the metal workpiece) and the temperature may increase high enough to cause the formation of polynuclear hydrocarbons (or polyaromatic hydrocarbons, PAHs).

MWFs may also be contaminated by water, cleaning products used for routine housekeeping, or other products at the work site. Improper recycling of materials or the addition of unspecified fluids (such as old lubricating oils) to the MWF will also change the composition of fluid.

Boric acid is used to be a common additive in metal-working fluid (MWF) formulations thanks to its excellent EP/AW properties and bacteriostatic and bactericidal actions. Nowadays, it has been largely phased out from MWFs because of HSE concerns. However, some recent studies mention "boron-based nanoparticulate lubrication additives that can drastically lower friction and wear in a wide range of industrial and transportation applications", indicating renewed interest in boric acid. Boric acid is identified as a substance meeting the criteria of Article 57 (c) of REACH regulation (substance of very high concern (SVHC), and included in the candidate list for authorization) owing to its classification as toxic for reproduction.

According to the National Institute for Occupational Safety and Health (NIOSH)¹⁵⁹, some 1.2 million workers in machine finishing, machine tooling and other metalworking and metal-forming operations are potentially exposed. Workers can be exposed to the fluids by breathing aerosols generated in the machining process, or through **skin contact** when they handle parts, tools and equipment covered with the fluids. Occupational exposures to metalworking fluids may cause a variety of health effects. Respiratory conditions include hypersensitivity pneumonitis (HP), chronic bronchitis, impaired lung function and asthma. The last is one of today's most prevalent occupational disorders, imposing significant costs in healthcare and workers' compensation. **Dermatologic exposures** are most commonly associated with, but not limited to, **allergic and irritant dermatitis**.

In addition, substantial evidence shows that past exposures to some metalworking fluids were associated with increased risk of some types of cancer.

The three major areas of concern associated to the use of MWFs are skin, respiratory and cancer.

SKIN

All types of MWFs can cause skin irritation. Dermatitis can be caused by:

- Bacteria and their by-products

¹⁵⁹More information available on line at:
<http://www.cdc.gov/niosh/topics/metalworking/default.html>

- Biocides
- Chemicals added to control rust and corrosion
- Contact with metal contaminants such as nickel, cobalt and chromium, which are known sensitizing agents.

RESPIRATORY

Exposure to mist, aerosol and vapor can lead to the development of respiratory conditions or can aggravate the existing ones. It is not clear whether respiratory problems are caused by specific fluid components, contaminants, biocides, or a combination of these factors. However, biocides themselves can cause either allergic or contact dermatitis due to their sensitizing potential.

Regarding occupational exposure limits, NIOSH recommends that exposures to MWF aerosols be limited to 0.4 milligrams per cubic meter of air (thoracic particulate mass) or 0.5 milligrams per cubic meter of air (total particulate mass), as a time-weighted average concentration up to 10 hours per day during a 40-hour workweek. The recommended exposure limit (REL) is intended to prevent or greatly reduce respiratory disorders associated to MWF exposure. This REL is technologically feasible for most metalworking operations.

Summary of different national exposure limits applied to mist derived from mineral oil-based and water-miscible MWFs are summarized according to the table below.

Table 51: Summary of different national guidance and exposure limits applied to mist derived from mineral oil-based and water-miscible MWFs.

COUNTRY	PEL/REL/MAK	FLUID	SIZE FRACTION	METHODOLOGY
USA: OSHA	PEL 5.0 mg / m ³ (10hr TWA)	Mineral Oil	Total	Gravimetric
USA: NIOSH	REL 0.5 mg / m ³ (10hr TWA) REL 0.4 mg / m ³ (10hr TWA)*	All types All types	Total	Thoracic Gravimetric Extraction following gravimetric
Finland	5.0 mg / m ³ (8h TWA)	Mineral oil	Total	Extraction following gravimetric
Germany	10.0 mg / m ³	Mineral oil	Total including vapour	Infra-red absorbance + GCFID for vapour fraction
Netherlands: DECOS	5.0 mg / m ³ (8hr TWA) REL 0.1 mg / m ³ (8hr TWA)	Mineral oil HBROEL (*particulate mass)	Total	Extraction following gravimetric
Sweden/ Denmark	1.0 mg / m ³ (8hr TWA)	All types (*particulate mass)	Total	Extraction following gravimetric
France	1.0 mg / m ³	All types I	Total	Extraction following gravimetric
Switzerland	PEL (MAK) 0.2 mg / m ³	Heavy mineral oil	Total	Gravimetric
Withdrawn guidance values				
UK: HSE	3.0 mg / m ³ (10hr TWA)	Mineral oil	Total	Gravimetric
UK: HSE	1.0 mg / m ³ (10hr TWA)	Water-miscible	Total	Boron marker

PEL = Permissible Exposure Limit REL = Recommended Exposure Limit

TWA = Time-Weighted Average MAK = Maximum Workplace Concentration (German)

In 2015, HSE¹⁶⁰ examined metal working fluids exposure limits and new techniques to monitor water-miscible MWF mist¹⁶¹. The following conclusions were drawn:

- The majority of exposure limits for MWF mist relate to mineral oil and not watermiscible fluids.
- Historically, average mist levels have not changed over time; the majority was below the previous UK guidance value of 1.0 mg/m³ with a large proportion below the NIOSH REL of 0.5 mg/m³. This suggests that as ill health was reported at these low levels of mist, the exposure limits have no relevance to health risk.

Therefore, main problematic issue is related to worker exposure. Swedish Standard includes specific criterion related to sensitizing compounds.

4.8.2. Temporary protection against corrosion

A Temporary Protection Against Corrosion lubricant (also named as *rust preventive oil, or corrosion preventive*) is by definition a material that can be easily removed from the metal surface after treatment. It is not designed to be permanent, or difficult to remove. Sometimes they are used in environment sensitive areas and the protective system may be left in place.

Rust preventives are used in many applications including protecting unfinished pipe, steel consumer products, car underbodies, steel fasteners and coiled steel. Rust preventives are applied as barrier films to metal surfaces after the machining and grinding stages. They displace water and protect metal parts from corrosive environments during shipping or storage.

Corrosion inhibitors can be divided into several categories depending on their duration of use, chemical composition, and end-use application. Primarily the performance property that determines the type of chemistry desired for a corrosion inhibitor is the intended duration of use of the rust protective coating. In particular, some coatings require long service periods due to outdoor exposure in extreme climates where reapplication is difficult, whereas other corrosion inhibitors are only intended for short-term storage before a part is manufactured or painted.

There are essentially three broad classes of corrosion inhibitors, which can be divided into the following areas:

- Oil coatings. These are temporary liquid coatings used to prevent corrosion during transport of the metal part or for temporary indoor (months) or outdoor (weeks) storage. The rust protective oil can be applied during the metal-forming operation or after the part is completed.
- Soft coatings. These are temporary soft solid coatings typically made of wax, petrolatum, or grease. These coatings are used to coat structures exposed to the elements such as bridges, cars, or trucks and last from a few months up to many years.

¹⁶⁰ HSE: Health and Safety Executive

¹⁶¹ More information available online at: <http://www.hse.gov.uk/research/rrpdf/rr1044.pdf>

- Hard coatings. These coatings are typically applied as an alkyd resin or as an inorganic coating (or galvanized coating) and are used to form a hard permanent barrier from corrosion.

Moreover, the coatings can be classified into three different categories based on the method of application to the metal surface as follows:

- Water soluble. The additives are mainly inorganic materials (nitrite or arsenate) used for aqueous systems such as water treatment or drilling muds.
- Soluble oils. The additives used are mainly oil-soluble sulfonates and organic amines that can be used in emulsions used for metal deformation and metal removal processes.
- Oil soluble. The additives used are mainly oil-soluble additives that can be used in lubricant oils for machinery or slushing oils.

Table 52: Summary of Common Rust-Preventative Chemistries and Applications

	Water Soluble	Soluble Oil	Oil Soluble
			Carboxylates Sulfonates
	Carboxylates Sulfonates Alkyl amines Alkyl amine Phosphates Alkyl amines Borates	Carboxylates Sulfonates Alkyl amines Alkyl amines Borates	Alkyl amines Alkyl amine Phosphates Alkyl amines Borates Imidazolines Thiazole Benzotriazoles Triazole
Oil coatings			
Soft coatings	—	Oxidates Sulfonates Alkyl amines	Oxidates Sulfonates Alkyl amines
Hard coatings	Nitrites Chromates Hydrazines Phosphates	—	—

The demand for rust preventive lubricants will continue in part due to higher demand in the developing countries such as Brazil, Russia, China, and India (BRIC) and the aging of existing equipment that is currently used in the developed world. The current market drivers for new rust preventives will continue to be environmental and health concerns. For instance, for amine-based products, there is a desire for lower marine toxicity (ecotoxicity), which is driving the industry toward alternative eco-friendly products, also there is a drive to reduce the heavy metal content and replace them with less-hazardous metals (i.e., Na, Ca, or Mg). Additionally, the waste disposal of the final end product has been a great and has driven the market to pursue more biodegradable products that could be based on new chemistries or natural fats and esters. Regarding health concerns, generally workers employed in industrial manufacturing are safer at the present due to tougher regulations, which have led to the search for alternative chemistries.

4.8.3. Engine oils

Contrary to four-stroke oil lubricants, two-stroke are included in the existing EEL scope. According to the previous revision background documents on the development of the EEL, automotive lubricants (four-stroke oils) were not included in the EEL, because they were not perceived as “loss or high risk” lubricants¹⁶², and the most relevant issues for these types of lubricant differ from those addressed in the EEL *specifically their impact on the fuel consumption and issues related to the proper collection and recycling of used oil*¹⁶³.

Two-stroke oils are used as lubricants in small (two-stroke) engines. Due to their simple design and power-to-weight ratios, two-stroke engines are suitable for outboard motors, snowmobiles, scooter, jet-ski, small boats, often used in environmentally sensitive areas. Two-stroke engines give rise to significantly higher emissions of different toxic substances than four-stroke engines. The reason for this is the design of the motor, differently from 4-stroke engines, in 2-stroke engines there is no dedicated lubrication system, the lubricant is mixed with the fuel. For instance for boat applications, 20% to 30% of the mixture of fuel and lubricant that these two-strokes use are emitted unburned directly into the water. In addition, different exhaust purifiers can often not be used in these inefficient engines.

Four-stroke engines emit 97% less pollution than two-strokes, they do not mix oil with fuel and are designed for complete combustion before exhausting. In addition to this, four-strokes are more fuel-efficient and cost-competitive compared to two-stroke engines. Following table indicates the differences between 2-stroke and 4-stroke engines.

Table 53: Difference between 2-stroke and 4-stroke engines¹⁶⁴

Four stroke engine	Two stroke engine
1. It has one power stroke for every two revolutions of the crankshaft.	It has one power stroke for each revolution of the crankshaft.
2. Heavy flywheel is required and engine runs unbalanced because turning moment on the crankshaft is not even due to one power stroke for every two revolutions of the crankshaft.	Lighter flywheel is required and engine runs balanced because turning moment is more even due to one power stroke for each revolution of the crankshaft.
3. Engine is heavy	Engine is light
4. Engine design is complicated due to valve mechanism.	Engine design is simple due to absence of valve mechanism.
5. More cost.	Less cost than 4 stroke.
6. Less mechanical efficiency due to more friction on many parts.	More mechanical efficiency due to less friction on a few parts.
7. More output due to full fresh charge intake and full burnt gases exhaust.	Less output due to mixing of fresh charge with the hot burnt gases.
8. Engine runs cooler.	Engine runs hotter.
9. Engine is water cooled.	Engine is air cooled.
10. Less fuel consumption and complete burning of fuel.	More fuel consumption and fresh charge is mixed with exhaust gases.

¹⁶² here “high risk” relates to the susceptibility of accidental spillage

¹⁶³ Background doc 2004

¹⁶⁴ <http://www.mechanicalbooster.com/2014/06/difference-between-2-stroke-and-4-stroke-engines.html>

11.	Engine requires more space.	Engine requires less space.
12.	Complicated lubricating system.	Simple lubricating system.
13.	Less noise is created by engine.	More noise is created by engine.
14.	Engine consists of inlet and exhaust valve.	Engine consists of inlet and exhaust ports.
15.	More thermal efficiency.	Less thermal efficiency.
16.	It consumes less lubricating oil.	It consumes more lubricating oil.
17.	Less wear and tear of moving parts.	More wear and tear of moving parts.
18.	Used in cars, buses, trucks etc.	Used in mopeds, scooters, motorcycles etc.

A typical engine lubricant incorporates a base oil and a package of additives that may include viscosity improvers, anti-wear compounds, friction modifiers, corrosion inhibitors, dispersants, anti-foaming agents, anti-oxidants and detergents.

According to Section 2.1.3, during normal use **four-stroke** engine oils are not released to the environment, their **main environmental concerns come from improper disposal of used oil.**

Used oil

The main environmental concern regarding 4-stroke engine oil comes from improper disposal of used oil.

According to European Commission resources¹⁶⁵ regarding the situation of waste oil (WO) management in Europe:

- About 4930 kt of base oils were consumed in Europe in 2000, among which about 65% of automotive oils.
- About 50% of consumed oils are lost during use (combustion, evaporation, residues left in the containers...). The remaining 50% represent the collectable WO.
- Engine oils represent more than 70% of 2 400 kt of the collectable WO and are potentially suitable for regeneration.
- The efficiency of the WO collection systems is often very high for engine oils (more than 80%)
- Appropriate collection and disposal arrangements for WO from industrial or automotive origin (garages...) are generally well established in Europe. However, WO from particular user's oil changes the greatest risk of improper disposal.

Used motor oil contains numerous toxic substances, including polycyclic aromatic hydrocarbons (PAHs), which are known to cause cancer. The PAH content of engine oil increases with operating time, because the PAH formed during combustion in petrol engines is accumulated in the oil. In addition, tiny pieces of metal from engine wear and tear, such as lead, zinc and arsenic, make their way into lubricants, further contributing to the polluting potential of used motor oil.

¹⁶⁵ http://ec.europa.eu/environment/waste/studies/waste_oil.htm

Trends regarding 4T engine oils

One of the biggest challenges facing the automotive industry is to improve fuel economy, extend drain intervals and reduce climate emissions. These issues have motivated advances on engine oil quality and the development of new formulations.

- **Regarding exhaust emissions**

Reducing the exhaust and CO₂ emissions constitutes a major challenge for automotive industry and has been the most significant driver of lubricant quality. Emissions produced by internal combustion engines (exhaust emissions) are regulated in Europe by "Euro emissions standards"¹⁶⁶. They establish emission limits for particulate matter (PM), nitrogen oxides (NO and NO₂, when measured combined, they are referred to as NO_x), un-burnt hydrocarbons (HC) and carbon monoxide (CO).

Engine oils help to improve vehicle efficiency but investigations have also shown that they contribute to engine exhaust emissions. This contribution depends on lubricant oil characteristics, especially sulphur content, metal content, volatility and density. The key elements used in lubricant formulation that can contribute to the exhaust emissions are sulfated ash, phosphorus and sulphur; they contribute to the so-called SAPS profile of the lubricant. The principal sulfated ash sources in a lubricant are the metallic detergent zinc di-alkyl di-thiophosphate (ZnDTP).

Table 54: Sources of SAPS (Sulphated Ash, Phosphorous and Sulphur) in lubricants additives.¹⁶⁷

Component	SAPS contribution
Dispersant	-
Detergents	Ash and sulphur
Anti-oxidants	Sulphur
Friction modifiers	Sulphur
Anti-wear	Phosphorus and sulphur
Diluent oil	Sulphur
Viscosity modifier	-
Corrosion inhibitor	Sulphur

It was made evident that mineral engine oil produces higher PM and NO_x emissions than synthetic oil. The NO_x emissions of synthetic engine oil are 8 % lower than those of mineral oil. Particulate emissions (PM) of synthetic oil are 19–24 % lower than those of mineral oils.

- **Regarding fuel economy**

Other of the challenges facing the automotive industry is to improve fuel economy, both to conserve natural resources and to limit pollutants and CO₂ emissions. This has led to increased interest in the role of lubricants, since appropriate lubricant formulations can bring about a beneficial reduction in engine friction, thus improving fuel economy.

¹⁶⁶ <http://ec.europa.eu/environment/air/transport/road.htm>

¹⁶⁷ Ignatio Madanhire, Mitigating Environmental Impact of Petroleum Lubricants. 2016

- Regarding drain interval

In relation to the vehicles maintenance, there has also been a strong trend towards extended drain intervals (oil changes). The oil and especially the additives undergo thermal and mechanical degradation and need to be periodically replaced based on the time in service or the distance that the vehicle has travelled. While there is a full industry surrounding regular oil changes and maintenance, an oil change is a fairly simple operation that most car owners can do themselves.

5 Improvement potential

In the light of the environmental impact assessment, the hazardous substances analysis and the guidelines established in the prioritisation methodology for the revision, this chapter summarises the areas of improvement of the existing criteria that will be further investigated and addressed in more detail in the technical report.

Following figure and table show an overview of the prioritization methodology and key areas of potential improvement.

Figure 34: Prioritization methodology and key areas of potential improvement

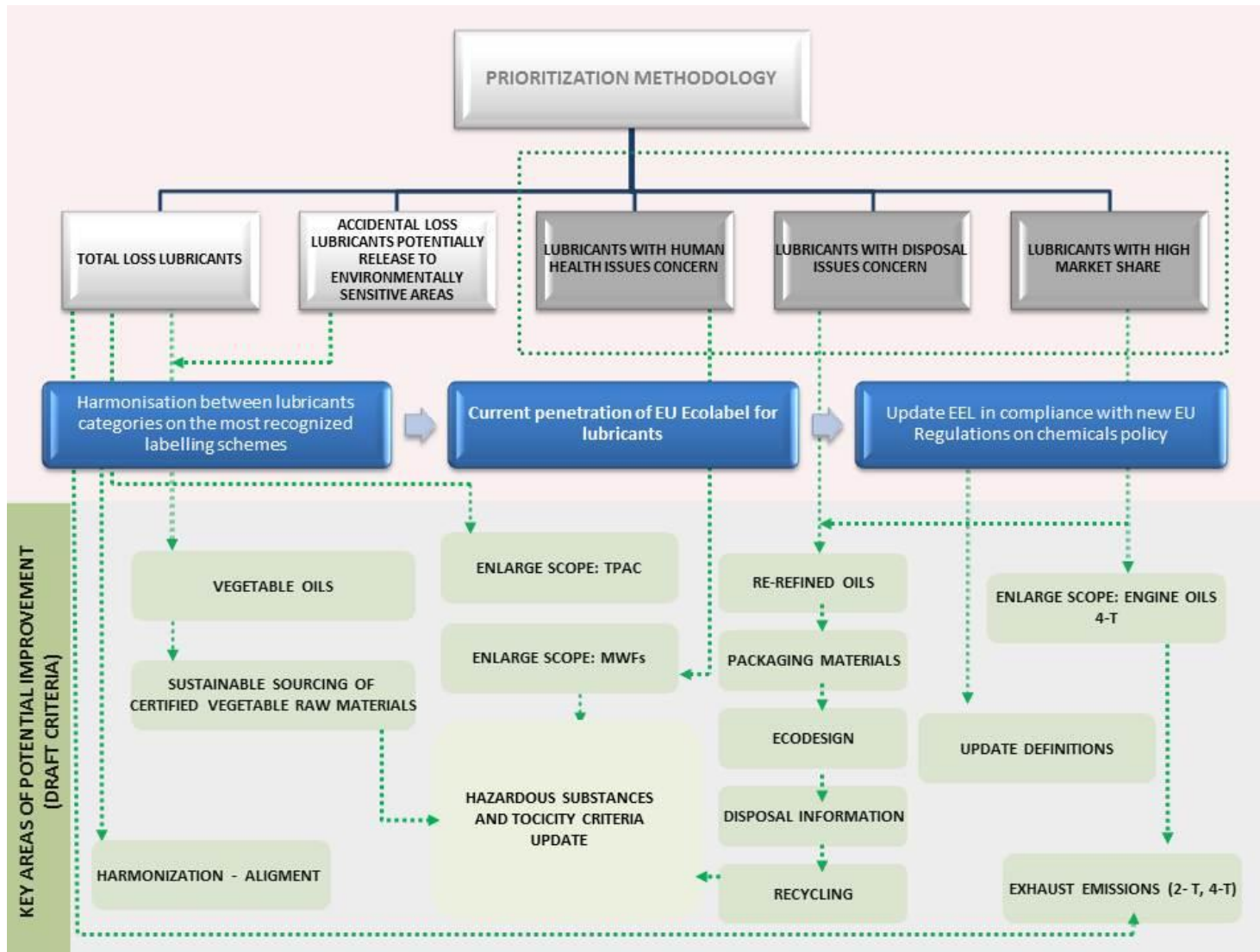


Table 55: Summary of the suggested areas for further research and improvement of the existing criteria.

Environmental aspects of relevance	Existing EU Ecolabel criteria	Areas to explore for improvement
Emission to soil/ water Hazardous substances	1. Excluded or limited substances and mixtures 2. Exclusion of specific substances 3. Additional aquatic toxicity requirements 4. Biodegradability and bioaccumulative potential	Criterion 1 and 2 limits the hazardous substances and mixtures that can be included in the product, limiting environmental and health risks for users. Criterion 3 ensures that the overall aquatic toxicity is limited. Criterion 4 ensures that the ingredients are biodegradable and will not persist in water. In this revision it is suggested to explore: <ul style="list-style-type: none"> • Update according to current legislation and REACH regulation. • Thresholds revision harmonizing them with other ecolabel schemes and according with actual values of current labeled products within the different categories. • Further research of the market and the industry which committed to develop more sustainable and less hazardous products.
Raw materials extraction and processing	5. Renewable raw materials	Criterion 5 promotes sustainable alternatives to mineral oils In this revision it is suggested to explore: <ul style="list-style-type: none"> • Inclusion of synthetic and re-refined oils • Requirement on origin and traceability of vegetable raw materials to ensure that the vegetable oil used for the lubricant manufacturing comes from a sustainably management plantation. • Packaging requirements on recyclability and/or recycled content for packaging materials.

Spillage during use phase		<p>In this revision it is suggested to explore:</p> <ul style="list-style-type: none"> • Packaging requirements to ensure prevention of spillage during use.
Efficiency during use	6. Minimum technical performance	<p>Criterion 6 guarantees that the product meets certain quality (technical performance) requirements foreseen for the different applications.</p> <ul style="list-style-type: none"> • In this revision should be studied the standards that can be used for each of the categories covered in the scope.
Waste generation and disposal		<p>In this revision it is suggested to explore:</p> <ul style="list-style-type: none"> • Packaging requirements to ensure that a limited amount of waste will be generated and that the packaging can be recycled, as far as possible. • Consumer information that reminds consumers to dispose of the packaging in a responsible manner.
Emissions to air		<p>In this revision it could be explore:</p> <ul style="list-style-type: none"> • Inclusion of exhaust emissions requirement to limit the air emissions of 2-stroke engine oils.

6 Conclusions on the technical analysis

The environmental assessment done using the life cycle approach have shown that besides raw materials (which can have relevant impacts related to their extraction and processing, as well as their inherent biodegradability and toxicity characteristics), the life stages of use and end-of-use can have high environmental impacts, since they are the stages where lubricants can reach the different environmental compartments depending on the application. These impacts are highly important since approximately 50% of all traditional lubricants are released into the environment during use, spills, or disposal stages.

With regard the scope, the approach followed is to maintain those lubricants currently included into the EU Ecolabel scope, and exploring the possibility of extending it by including new types of lubricants following a prioritization methodology, that was based on the following points:

- Total Loss lubricants
- Accidental Loss lubricants with potential release to environmentally sensitive areas
- Lubricants linked with human health issues concern
- Lubricants that have disposal issues concerns
- Lubricants that have a high market share and/or target end consumers.

Moreover, in addition to the environmental assessment, following issues are relevant for consideration during the revision for the criteria proposal:

- Harmonization between the criteria of other labelling schemes for lubricants
- Current penetration of EU Ecolabel for lubricants
- Alignment with the EU regulations on chemicals.

Following this prioritization procedure, this revision proposes to extent the current EU Ecolabel scope to: **metalworking fluids (MWFs), 4-stroke engine oils and temporary protection against corrosion lubricants**, bearing in mind that the lubricant market is too broad to cover all market in only one revision.

In the light of the technical analysis, the following **relevant impacts on environment and human health** have been identified and **key areas of potential improvement** in order to minimize these impacts have been suggested:

- **Raw materials extraction and processing:** According to the environmental assessment, relevant contribution of energy consumption to life cycle impacts were detected for raw materials extraction and processing:
 - Raw materials: Regarding energy consumption during processing, **vegetable oils have lower impacts** while the refining process of synthetic oils has higher impacts. LCA comparative studies indicate lower energy consumption during processing and lower impacts for the global warming potential than mineral and synthetic oils.
 - **Sustainable sourcing of certified vegetable raw materials:** Since most impacts of vegetable oils come from agriculture operation, it can be proposed that they must be sourced from plantations that meet criteria for sustainable management.

- Regarding **synthetic oils**, the refining/synthesis phase is the main contributor of impacts. In the production stage they have higher impacts than mineral oil due to more complex processing and higher energy consumption. However they have a longer life and lower impact during use.
 - **Re-refined** oils bring environmental advantages. With modern re-refining technologies, CO₂ emissions can be reduced by more than 50% as compared to the conventional production of base oil.
 - Manufacturing stage (blending) can have relevant impacts going to 3% to 70% depending on the impact category.
- **Emission to soil/ water and Hazardous substances**
 In general the chemicals used in the formulation of the product significantly contribute to the overall environmental impacts. It is suggested to explore the possibility to increase the ambition level for criteria limiting toxic or harmful substances, especially for **Total loss lubricants and accidental loss lubricants potentially release to environmentally sensitive areas** where a major environmental impact is expected, aiming to ensure that the EU Ecolabel is only awarded to the least environmentally impacting products.
 - **Lubricants with human health issues concern.** Feasibility to enlarge the scope including **metalworking fluids (MWFs)** based on its health and safety issues concern. Some specific substances which raise health related concern must be discussed and considered to be addressed in the draft criteria proposal such as **sensitising compounds**.
 - **Spillage during use phase and waste generation and disposal**
 - **Lubricants with disposal issues concern**, i.e., lubricants with high potential environmental impacts at their end-of-life due to an improper disposal of the used lubricant especially by particular users (engine oils, greases and gear oils). Key areas of potential improvement:
 - **Re-refined oils:** are established as a priority in the preferable hierarchy for lubricant waste according to the Waste Framework Directive ¹⁶⁸. Moreover, have environmental advantages according to the environmental impact assessment.
 - **Packaging requirements:**
 - **Packaging materials:** Some specific substances which raise health and environmental related concern must be discussed and considered to be addressed in the draft criteria proposal such as halogenated organic compounds and phthalates.
 - **Ecodesign:** Packaging must be designed to preserve the product integrity and limit losses of lubricant.
 - **Recycling:** Package should be easily recyclable: the plastic parts should be easily removed and their type identified.

¹⁶⁸ Waste Framework Directive (Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008)

- **Disposal information:** Consider including information on handling and disposal especially for lubricants intended to be sold to the general public.
- **Emissions to air.** It is to notice that main environmental concern regarding 4-stroke engine oil comes from improper disposal of used oil. Furthermore, the feasibility of criterion related to exhaust emissions associated to two-stroke engine oils must be discussed and considered to be addressed in the draft criteria proposal.
 - Lubricants **with high market share and/or target end consumers.** Feasibility to enlarge the scope including Four-stroke engine oils which represents the major percentage of the lubricants market which are usually sold to private end consumers, currently not covered by the EEL.

List of abbreviations and definitions

AA: Aquatic acidification
AO: Antioxidants
AW: Anti-wear
ADP: Abiotic Depletion Potential
AE: Aquatic eco-toxicity
AEu: Aquatic eutrophication
AP: Acidification Potential
API: American Petroleum Institute
ATF: Automatic Transmission Fluid
BAT: Best Available Techniques
BPR: Biocidal Product Regulation
BREF: Best Available Techniques Reference Documents
BRICS: Brazil, Russia, India, China, and South Africa.
B-USD: billion US dollar.
CAGR: Compound annual growth rate.
CBM: Coal Bed Methane
CMIT: Chloromethylisothiazolinone
CLP: Classification, Labelling and Packaging of substances and mixtures
COM-A: Commercial Automotive
CON-A: Consumer Automotive
C&SA: Central & South America.
ECHA: European Chemicals Agency
EEL: European Ecolabel Lubricants
EP: Ecotoxicity Potential
EP: Extreme pressure
EPA: United States Environmental Protection Agency.
EPD: Environmental Product Declaration
EPD: Environmental Product Declaration
EPR: Extended Producer Responsibility
EU: European Union
FEP: Freshwater eutrophication potential
FU: Functional Unit
GEIR: Groupement Européen de l'Industrie de la Régénération
GHS: Globally Harmonised System
GHG: Greenhouse Gas
GIO: General Industrial Oils.
GPP: Green Public Procurement

GWP: Global Warming Potential
HT: Human toxicity
HDEO: Heavy Duty Engine Oil.
HMCS: Harmonized Mandatory Control Scheme
H&TF: Hydraulic & Transmission Fluid.
ICIS: Independent Chemical Information System.
IEO: Industrial Engine Oils.
ILMA: Independent Lubricant Manufacturers Association.
ILCD: International Reference Life Cycle Data System
IND: Industrial
IPPC: Integrated Pollution Prevention and Control
ISO: International Organization for Standards.
IR: Ionizing radiation
LCA: Life Cycle Assessment
LC: Lethal Concentration
LO: Land occupation
ME&A: Middle East & Africa
ME or MEP: Mineral extraction
MIT: methylisothiazolinone
MWF: Metalworking fluid
MT: million tons
M-USD: million US dollar.
NIOSH: National Institute for Occupational Safety and Health
NOEC: No Observed Effect Concentration
NRE: Non-renewable energy
OLD: Ozone layer depletion, and ODP: Ozone depletion potential
OATS: Oil Advisory Technical Services.
OECD: Organisation for Economic Co-operation and Development
PAGs: Poly-alkylene-glycols
PAH: Polycyclic Aromatic Hydrocarbon
PAO: Poly-alpha-olefins
PDC: Pressure Die Casting.
PO: Process oils.
PV & MO: Passenger Vehicle & Motor Oil
PBT: Persistent, Bioaccumulative and Toxic
PCR: Product Category Rules
PM: Particulate Matter
POP: Photochemical oxidation potential

REACH: Regulation (EC) 1907/2006, concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals

RI: Respiratory inorganics

RO: Respiratory organics

SDS: Safety Data Sheet

SMEs: Small and Medium Enterprises

SVHC: Substances of Very High Concern

TAN: Terrestrial acidification/nitrification

TPAC: Temporary Protection Against Corrosion

TE: Terrestrial eco-toxicity

TLL: Total Loss Lubricants

UAE: United Arab Emirates

UEIL: Union of the European Lubricants Industry.

USD: US dollar

VGP: Vessels General Permit

VOCs: Volatile Organic Compounds

VPvB: very persistent, very bioaccumulative

WO: Waste Oil

ZDDP: Zinc dithiophosphate

APPENDIX I: Preliminary stakeholder survey on the upcoming revision of EU Ecolabel criteria for Lubricants

Preliminary stakeholder survey on the upcoming revision of EU Ecolabel criteria for Lubricants

Fields marked with * are mandatory.

Disclaimer

The European Commission is not responsible for the content of questionnaires created using the EUSurvey service - it remains the sole responsibility of the form creator and manager. The use of EUSurvey service does not imply a recommendation or endorsement, by the European Commission, of the views expressed within them.

General details

* Name

* Email address

Which of the following options best represents the type of organisation/interests that you represent

- Buyer / Consumer interests
- EU Member / Competent Body
- Government (local, regional or national)
- Industry - Manufacturer
- Industry - Supplier of raw materials
- Non Governmental Organization (NGO)
- Others

If others, please specify

Has your organisation:

- Been actively involved with the EU Ecolabel criteria development process previously for Lubricants?
- Obtained an EU Ecolabel license for Lubricant products?
- Participated in the process of applying for an EU Ecolabel license for Lubricants?
- Potentially considered to apply for an EU Ecolabel license in the future?
- None of the above

Please specify

Background

In case you have applied for a lubricant EU ecolabel in the past. Have you had difficulties to understand the current scope?

- No, it is clear
- Yes, please specify what did you find unclear
- No opinion

Please specify

Have you ever had a lubricant product that could have not been awarded with the EU Ecolabel because it did not fit the scope?

- No, all the products are enclosed in the current scope
- Yes, please specify wich ones below
- No opinion

Please specify

Scope

The current **definition of lubricant** is “a preparation consisting of base fluids and additives “. This definition is wide broad and it could include related products based in mineral oil that are not lubricants

i.e. rust preventive fluids.

A more accurate definition could be **“A substance or mixture capable of reducing friction and wear when introduced between two surfaces which are in relative movement”**.

What do you think?

- Yes, I agree with the new definition because the related products such as rust preventive fluids are not lubricants.
- No, the current definition is fine and should remain as it is now: "a preparation consisting of base fluids and additives".
- No opinion
- Other, please specify below

Please specify

The current EU Ecolabel **classification** comprises five categories:

Category 1: hydraulic fluids and tractor transmission oils

Category 2: greases and stern tube greases

Category 3: chainsaw oils, concrete release agents, wire rope lubricants, stern tube oils and other total loss lubricants

Category 4: two-stroke oils

Category 5: industrial and marine gear oils.

These categories comprise different lubricant types classified according to life cycle considerations and turns complicate to increase the scope in a systematically way. Several new categories should be created and different lubricant types without connection should be included in the existing categories.

For this revision, it is proposed to standardise the classification according to **ISO 6743**, which allowing the classification of the product easily according to the application areas and covers lubricants, industrial oils and related products.

What do you think?

- Yes, I agree with a new classification according the ISO 6743 (several families classified according to application of use)
- No, the current classification with five categories is fine
- Some other classification, please specify below
- No opinion

Please specify

There are lubricant products that are not considered in the current scope. If you agree in **extending the scope**, please select which products should be included (according to the standard ISO 6743):

- Family B mould release (currently only concrete release agents are considered)
- Family E internal combustion engine oils (extending to 4T)
- Family F spindle bearings, bearings and associated clutches
- Family G slideways
- Family M metalworking
- Family P pneumatic tools
- Family T turbines
- Other not listed above

(Optional) Please provide any more detailed comments on proposals for the EU Ecolabel Lubricants scope here.

* Some products are formulated based on water, known as water base lubricants. Some examples of water based lubricants are hydraulic fluids (family H according to ISO 6743), more detailed are classified as HFAE, HFAS, HFB and HFC (according to ISO 6743-4).

Do you agree to **include water base lubricants** in the revised EU Ecolabel?

- Yes, I agree to include water base products because the market tendency is increasing in this direction
- No, I prefer to keep the EU Ecolabel only for oil base lubricants
- No opinion

If No, please specify your reasons:

* Not all lubricants are used in the same environmental conditions. It is possible that a lubricant that belongs to a same family is used in a closed area or in an open area. It is believed that the criteria restriction should be linked to its application area. Therefore it is proposed to distinguish between those lubricants that are used in **indoor and outdoor areas**.

Should the EU Ecolabel take into consideration these two environments to define different criteria depending on the environmental aspects of each category?

- Yes, outdoor and indoor products should have different criteria
- No, the criteria should be the same regardless the application area
- No opinion

Further comments and proposal:

EU Ecolabel existing criteria

Please answer the general questions about the applicability of current EU Ecolabel Criteria

Criterion 1. Excluded or limited substances and mixtures

According to current Criterion 1 (a), the product or any part of it shall not contain substances (in any forms, including nanoforms) meeting the criteria for classification with the hazard statements or risk phrases specified below in accordance with Regulation (EC) No 1272/2008 of the European Parliament and of the Council or Council Directive 67/548/EEC nor shall it contain substances referred to in Article 57 of Regulation (EC) No 1907/2006 of the European Parliament and of the Council. The risk phrases below generally refer to substances. Nanoforms intentionally added to the product shall prove compliance with this criterion for any concentration.

For further information on existing criteria check the [Commission Decision](#)

	Yes	No
If applicable (Competent Bodies and current applicants), could you give details on how the compliance has been demonstrated for current criterion 1 (a)?	<input type="radio"/>	<input type="radio"/>
If applicable (industry), are there any substance or ingredient used in the lubricant formulation that does not comply with the criterion 1 (a) but is still needed or cannot be replaced by a non-classified substance?	<input type="radio"/>	<input type="radio"/>

If yes, please provide additional information by using this [derogation form](#) in and submit to JRC-IPTS-LUBRICANTS@ec.europa.eu

Please add any further comments or opinions that you have regarding

Exclusion or limited substances and mixtures criteria here

Criterion 2. Exclusion of specific substances

According to Criterion 2, the following stated substances are not allowed in quantities exceeding 0,010% (w/w) of the final product: Substances appearing in the Union List of priority substances in the field of water policy in Annex X to Directive 2000/60/EC and the OSPAR List of Chemicals for Priority Action; Organic halogen compounds and nitrite compounds; Metals or metallic compounds with the exception of sodium, potassium, magnesium and calcium. In the case of thickeners, also lithium

and/or aluminium compounds may be used up to concentrations limited by the other criteria included in the Annex to the [Commission Decision](#)

Do you consider that other substances should be added to this exclusion list?

	Yes	No
Exclusion of Secondary amines	<input type="radio"/>	<input type="radio"/>
Exclusion of substances containing boron	<input type="radio"/>	<input type="radio"/>
Exclusion of Formaldehyde releasing agents	<input type="radio"/>	<input type="radio"/>
Exclusion of VOC	<input type="radio"/>	<input type="radio"/>
Others (please specify below)	<input type="radio"/>	<input type="radio"/>

Please add any further comments or opinions that you have regarding *Exclusion of specific substances* criteria here.

Criterion 3. Additional aquatic toxicity

According to Criterion 3, the applicant shall demonstrate compliance by meeting the aquatic toxicity requirements of either 3.1 or 3.2. Please refer to the [Commission Decision](#) for the current thresholds.

3.1 Aquatic toxicity requirements for the lubricant and its main components.

	Yes	No	No opinion
*Do you consider the current threshold for existing categories adequate?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*Would you be able to provide data or information to asses in setting potential on the tresholds, if the scope is extended?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3.2 Aquatic toxicity requirements for each stated substance present above 0,10% (w/w)

	Yes	No	No opinion
*Do you consider the current threshold for existing categories adequate?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*Would you be able to provide data or information to asses in setting potential			

on the thresholds, if the scope is extended?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
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Please add any further comments or opinions that you have regarding *Aquatic Toxicity* here.

Criterion 4. Biodegradability and bioaccumulative potentials

According to Criterion 4, requirements for biodegradability and bioaccumulative potential shall be fulfilled for each stated substance present above 0,10 % (w/w). Please refer to the [EU Ecolabel legal text](#) for the current thresholds.

4.1 Biodegradability

	Yes	No	No opinion
Do you consider the current thresholds appropriate for biodegradability?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Would you be able to provide data or information to asses in setting potential on the thresholds, if the scope is extended?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4.2 Bioaccumulative potential

	Yes	No	No opinion
Do you consider the current thresholds for the existing categories appropriate?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Would you be able to provide data or information to asses in setting potential on the thresholds, if the scope is extended?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please add any further comments or opinions that you have regarding *Biodegradability and bioaccumulation potentials* here.

Criterion 5. Renewable raw materials

Lubricant oils are obtained from petroleum. The use of regenerated waste mineral oil as well as other renewable materials could reduce the amount of waste going to final disposal, reducing environmental impacts.

The current criteria shall have the following Carbon content from renewable materials:

>= 50% Category 1, Category 4, Category 5

>= 45% Category 2

>= 70% Category 3

	Yes	No
*Do you consider the current criterion formulation appropriate?	<input type="radio"/>	<input type="radio"/>
*Do you consider the current formulation of assessment and verification procedure sufficient and appropriate?	<input type="radio"/>	<input type="radio"/>
Do you agree with the threshold value?	<input type="radio"/>	<input type="radio"/>

In case you agree with extending the scope, should the use of regenerated mineral oil specially in a indoor lubricant formulation be considered ?

- Yes, please specify threshold value in the table below
- No, it should not be considered
- No opinion

Please specify

If you agree with the scope extension, could you please provide data to set potential tresholds values of regenerated oil and renewable materials for the new categories? Please mark in the list below for which ones:

	Threshold value of Regenerated oil
Family A, Total loss systems	<input type="checkbox"/>
Family B: Mould release	<input type="checkbox"/>
Family C: Gears	<input type="checkbox"/>

Family F: Spindle bearings, bearings and associate clutches	<input type="checkbox"/>
Family G: slideways	<input type="checkbox"/>
Family H: Hydraulic systems	<input type="checkbox"/>
Family M : Metalworking Fluids	<input type="checkbox"/>
Family P: pneumatic tools	<input type="checkbox"/>
Family T: Turbines	<input type="checkbox"/>
Family X: Greases	<input type="checkbox"/>
Other Relevant Family	<input type="checkbox"/>

(Optional), please specify threshold value, add further comments or indicate contact details to enable ITPS to contact you for further information

Criterion 6. Minimum Technical Performance

If you agree with the classification according to ISO 6743 proposed in previous questions could you please provide information on the available standards used test to evaluate the minimum technical performance? would you agree as a the minimum technical performance to fit for purpose? In which family?

	Test for evaluation	Fit for purpose	Please specify
Family A, Total loss systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family B: Mould release	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family C: Gears	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family E: internal combustion Engine oils	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family F: Spindle bearings, bearings and associate clutches	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family G: slideways	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family H: Hydraulic systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family M : Metalworking Fluids	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family P: pneumatic tools	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Family T: Turbines	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Family X: Greases	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other Relevant Family	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please specify the test used

7. Information appearing on the EU Ecolabel

Current criteria considers an optional label containing the following text: *"Reduced harm for water and soil during use. Contain a large fraction of biobased material"*

	Yes	No
*Do you consider the current criterion formulation appropriate?	<input type="radio"/>	<input type="radio"/>
*Do you consider the current formulation of assessment and verification procedure sufficient and appropriate?	<input type="radio"/>	<input type="radio"/>

Do you have any suggestion to improve the User Manual ?

Do you have any suggestion to improve the criteria document?

APPENDIX II: Overview of scope and criteria of the other schemes

The following table indicates an overview of the scope and the criteria of the other schemes for lubricants.

EU Ecolabel	Blue Angel	Nordic Ecolabel (withdrawn)	Eco Mark Japan	Korea Eco-Label	NF Environment	Swedish Standard
Scope						
<p>1) hydraulic fluids and tractor transmission oils 2) greases and stern tube greases 3) chainsaw oils, concrete release agents, wire rope lubricants, stern tube oils and other total loss lubricants 4) two-stroke oils 5) industrial and marine gear oils.</p>	<p>1) Lubricants for areas in which lubricant loss occurs during their intended use:</p> <ul style="list-style-type: none"> Lubricants that primarily escape into the environment during their intended use e.g. point and rail lubricants and lubricants for open bearings, guides or sealing purposes (incl. stern tube greases) Lubricants for the glass industry Concrete release agents for use in formwork Release agents for use in asphalt paving work <p>2) Hydraulic fluids (pressure fluids) particularly in environmentally sensitive hydraulic systems and tractor transmission oils 3) Chain lubricants for motor saws 4) Gear lubricants for industry and shipping 5) Greases</p> <p>An extension to cover Other products can be issued</p>	<p>Chain oil Mould oil Hydraulic oil 2-stroke oil Lubricating grease Metal cutting fluid Gear-/ transmission oil</p>	<p>Hydraulic oil 2-cycle engine oil Grease Other lubricating oil (other than de above mentioned) (Excluding spray type oils)</p>	<p>-Greases -Anti-rust lubricating oils -Hydraulic oils -Lubrication oils that are discharged after use (defined as, those lubricating oils which are discharged into environment after end of their usage thus difficult to be recovered (for example, chainsaw oils, water soluble cutting oils))</p>	<p>Chainsaw oils</p>	<p>Hydraulic fluids Lubricating greases</p>
Criteria						
Final Product must not Classify for Health and Environmental Hazards						

EU Ecolabel	Blue Angel	Nordic Ecolabel (withdrawn)	Eco Mark Japan	Korea Eco-Label	NF Environment	Swedish Standard
Y	Y	Y	N (not specifically stated but) ¹⁶⁹	N (not specifically stated but) ¹⁷⁰	N (not specifically stated but) ¹⁷¹	Y
Substances restriction (due to intrinsic properties of the substances; and additional lists)						
<p>The product must not contain:</p> <p>Substances classified for Health and Environmental Hazards; Substances meeting criteria Art.57 REACH¹⁷²</p> <p>Following substances cannot exceed >0,010% (w/w):</p> <ul style="list-style-type: none"> REACH SVHC Candidate List (Art 59) OSPAR List EU list of priority substances according to the Water Framework Directive 	<p>Product must not contain any substance classified as:</p> <p>CMR (1A,1B,2), AcuteTox (1,2,3), STOT (RE1,SE1), Aquatic Acute 1, Aquatic Chronic 1.</p> <p>For the rest of hazard categories a % is allowed but always below the classification limit (refer to the Criteria document for the values)</p> <p>Following substances cannot exceed >0,010% (w/w):</p> <ul style="list-style-type: none"> REACH SVHC Candidate List OSPAR List EU list of priority substances according to the Water Framework Directive Classified as CMR in the MAK List¹⁷³ With a water hazard class 2 or 3 according to VwVwS¹⁷⁴ 	–	–	<p>Shall not be used:</p> <ul style="list-style-type: none"> Chemicals classified for hazard codes for aquatic life Chemicals classified as carcinogens, mutagens or toxic for reproduction (CMRs) 	<p>Product must not contain:</p> <ul style="list-style-type: none"> Substances classified as Carcinogenic, Mutagenic, toxic for Reproduction, Very toxic, Toxic, Sensitizing, Dangerous for the environment and assigned the symbol 'N' (Directive 67/548/EEC). Substances with endocrine disruptor effect 	<p>Following compounds cannot exceed % (w/w):</p> <ul style="list-style-type: none"> CMRs <0,010% (for Hydraulic Fluids and Greases Class A, B, C*) Sensitizers: <1% (for Hydraulic Fluids** and Greases Class B, C) <0,01% (for Greases Class A) <p>*Greases are classified as Class A, B, C according to the possibility of leakage into sensitive environments</p> <p>For Hydraulic Fluids, compounds with sensitising properties must be specified if the mass fraction is ≥0,01%; this applies even if the product or the additive does not classify as Sensitizer.</p>
Substances Restriction for specific substances or groups of substances						

¹⁶⁹ Final product will not classify for Environmental Hazard due the aquatic toxicity criteria

¹⁷⁰ Final product will not classify for Environmental Hazards and Health Hazard Classes: CMR, due to Substances restriction criteria

¹⁷¹ Final product will not classify due to Substances restriction criteria

¹⁷² Article 57 REACH: Establishes the Criteria for the substances to be included in Annex XIV. Article 59 refers to the Identification of substances referred to in Article 57. Article 59(1) Establishes the "SVHC Candidate List"

¹⁷³ MAK Collection for Occupational Health and Safety (DFG, German Research Foundation)

¹⁷⁴ (VwVwS) Administrative Regulation on the Classification of Substances Hazardous to Waters (Federal Environmental Agency)

EU Ecolabel	Blue Angel	Nordic Ecolabel (withdrawn)	Eco Mark Japan	Korea Eco-Label	NF Environment	Swedish Standard
<p>Following substances cannot exceed >0,010% (w/w):</p> <ul style="list-style-type: none"> Organic halogen compounds Nitrite compounds Metals or metallic compounds except Na, K, Mg, Ca; and for Thickeners also Li, Al 	<p>Following substances cannot exceed >0,010% (w/w):</p> <ul style="list-style-type: none"> Organic halogen compounds Nitrite compounds Metals or metallic compounds except Na, K, Mg, Ca; and for Thickeners also Li, Al Mineral oils for use in release agents for asphalt paving work Mineral oils for use in chain lubricants for motor saws. An exception to this requirement is that a cumulative mineral oil content of 5% in the final product is permitted for chain lubricants for motor saws if this occurs due to the addition of additives. 	<ul style="list-style-type: none"> Short and medium chained chloroparaffins and alkylphenolethoxylates and other known endocrine disrupters must not be present in the product. Aerosol products may not contain halogen hydrocarbon. 	<p>Shall not be added to the product as constituents:</p> <ul style="list-style-type: none"> EDTA. (ethylenediaminetetraacetic acid) alkylphenol ethoxylates whose number of carbon atoms attached to the alkyl group are 5 to 9 Chlorinated additives <p>For products using mineral oil as the base oil, the mineral oil shall not be classified as carcinogenic by OSHA HCS¹⁷⁵ and EU Directive 67/548/EEC¹⁷⁶</p>	<p>Shall not be used:</p> <ul style="list-style-type: none"> Short-chain chlorinated paraffins (C=10~13), medium-chain chlorinated paraffins (C=14~17), and alkylphenolethoxylates <p>In connection with the emission of hazardous substances during the product usage, <u>spray-typed products</u> shall not use halogenated hydrocarbons and shall meet the following criteria [weight %]:</p> <p>Volatile Organic Compounds (VOCs)¹⁷⁷ ≤ 10</p> <p>Volatile Aromatic Hydrocarbons (VACs)¹⁷⁸ ≤ 0.01</p> <p>Chlorinated hydrocarbons¹⁷⁹ ≤ 0.01</p> <p>Perfluorinated compounds and their</p>	—	—

¹⁷⁵ OSHA HCS (the Hazard Communication Standard issued by the Occupational Safety and Health Administration, Department of Labor)

<https://www.osha.gov/dsg/hazcom/>

¹⁷⁶ EU Directive 67/548/EEC, Repealed by CLP Regulation (EC) No 1272/2008 - classification, labelling and packaging of substances and mixtures

¹⁷⁷ The term "volatile organic compounds (VOCs)" means a liquid or solid form of organic compounds that are continuously volatilized by consistent temperature and pressure in the air. (Note) In this standard, all organic compounds whose boiling points are 250 °C or less are considered VOCs.

¹⁷⁸ The term "volatile aromatic hydrocarbons (VACs)" means aromatic hydrocarbons contained in VOCs. (Note) In this standard, only benzene, toluene, xylene, ethyl benzene, 1,4-dichlorobenzene, and styrene are considered as VACs.

¹⁷⁹ The content of 'Chlorinated hydrocarbons' shall be a sum of each content of dichloromethane, chloroform, carbon tetrachloride, 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethylene, trichloroethylene, and tetrachloroethylene.

EU Ecolabel	Blue Angel	Nordic Ecolabel (withdrawn)	Eco Mark Japan	Korea Eco-Label	NF Environment	Swedish Standard
Assessment based on						
Ingredients	Ingredients	Ingredients	Ingredients	Ingredients (Biodeg/Bioacc) Product (Aquatic Toxicity)	Ingredients	Ingredients
Aquatic Toxicity						
<p>Compliance with either one of the following:</p> <p>1) Requirements for the lubricant and main components (>5%): <u>Acute</u> Aquatic toxicity shall be</p> <ul style="list-style-type: none"> Main components > 100 mg/L Lubricant Category 1 and 5 > 100 mg/L. Category 2, 3 and 4 > 1000 mg/L <p>2) Requirements for each component above 0,1%: <u>Chronic</u> Aquatic toxicity test results in the form of No Observed Effect Concentration (NOEC) should be stated; <u>Substances are allowed in each of the lubricant categories</u> for a</p>	<p>Y</p> <p>Equivalent to EU Ecolabel (the thresholds are also comparable)</p>	<p>Y (except for Gear/Transmission Oils: No requirement)</p> <ul style="list-style-type: none"> Base oil cannot classify for Environmental Hazards nor classify as carcinogenic Additives classified for Environmental Hazards must not exceed a % depending on the H statement and on the family of the lubricant¹⁸¹ 	<ul style="list-style-type: none"> 96-hour LC₅₀ of fish acute test ≥ 100 mg/L 48-hour EC₅₀ of Daphnia inhibition of the mobility ≥ 100 mg/L 	<p><i>In regards to water and soil contaminants from the product during the disposal phase, the following criteria shall be met:</i></p> <p>72-hour EC₅₀ algae acute test or 48-hour EC₅₀ Daphnia acute test ≥ 100 mg/L</p> <p>48-hour EC₅₀ of Daphnia inhibition of the mobility ≥ 100 mg/L</p>	<p>For main components > 5%: Absence of a substances having BCF > 100 or log Pow > 3 and aquatic toxicity between 10 and 100 mg / L.</p> <p>For components < 5%: The sum of components classified with the risk phrases R53 or R52 / R53, should not exceed 3% of weight of the lubricant.</p>	<p>Y</p> <p>Different cumulative % mass fraction is allowed depending on the Aquatic Toxicity of the compounds (% indicated in the legal text)</p>

¹⁸⁰ The content of 'Perfluorinated hydrocarbons and their precursors' shall be a sum of each content of the following compounds: CAS No 1763-23-1, perfluorooctanoate (PFOA); CAS No 335-67-1, perfluorooctane sulfonate (PFOS); CAS No 355-46-4, perfluorohexanesulfonate (PFHxS); CAS No 678-39-7, perfluorooctyl ethanol (8 : 2 FTOH)

¹⁸¹ Components classified with the risk phrases R50 or R50/53 must not exceed 2% in metal cutting fluid and hydraulic oil and 1% in chain oil, mould oil, 2-stroke oil and lubricating grease. Components classified with the risk phrase R51/53 must not exceed 1% in chain oil, mould oil, hydraulic oil, 2-stroke oil and lubricating grease and 2% in metal cutting fluid. Components classified with the risk phrases R52/53 or R53 must not exceed 3% in chain oil, mould oil and hydraulic oil, 17% (15% for thickeners and 2% for others) in lubricating grease, 5% in metal cutting fluid and 15% in 2-stroke oil.

EU Ecolabel	Blue Angel	Nordic Ecolabel (withdrawn)	Eco Mark Japan	Korea Eco-Label	NF Environment	Swedish Standard
cumulative concentration as indicated in the legal text.						
Biodegradation/Bioaccumulation						
Requirements must be fulfilled for each substance present above 0,10%. The lubricant should not contain substances that are both non-biodegradable and bioaccumulative. However the lubricant may contain one or more substances with a certain degree of degradability and/or bioaccumulation up to a cumulative concentration as indicated in the legal text (different % per lubricant category).	Y Equivalent to EEL (the thresholds are also more or less comparable)	Base oil must be readily degradable	Biodegradability ≥ 60% within 28 days	<i>In regards to water and soil contaminants from the product during the disposal phase, the following criteria shall be met:</i> 5% or more of the raw materials shall be biodegradable Biodegradability ≥ 60% within 28 days. Bioaccumulation criteria equivalent to EEL	For main components > 5%: must present biodegradability greater than 70% (at 28 days). For components < 5%: should have a biodegradability > 20% (28 days). The amount of components being not "easily biodegradable" should be less than 5% by mass of lubricant weight. (immobility of polymers) For components < 5% : If these components are polymers non biodegradable, then the proof of immobility must be reported (refer to the criteria document for the test requirements).	Y Different cumulative % mass fraction is allowed depending on the Biodegradability of the compounds (% indicated in the legal text)
Renewability						
Category 1 ≥ 50 % Category 2 ≥ 45 % Category 3 ≥ 70 % Category 4 ≥ 50 % Category 5 ≥ 50 %	N	Chain oil ≥ 85 % Mould oil ≥ 85 % Hydraulic oil ≥ 65 % 2-stroke oil ≥ 50 % Lubricating grease ≥ 65 % Metal cutting fluid ≥ 65 % (optionally)* Gear-/transmission oil ≥ 65 % (optionally)* *(Optionally basis between choosing this criterion or the Re-refined Criterion)	N	N	N	Y (only for Greases) Greases Class A > 65 % Greases Class B > 45 % Greases Class C (no requirement)
Re-refined oil						
N	N	Y	N	N	N	N

EU Ecolabel	Blue Angel	Nordic Ecolabel (withdrawn)	Eco Mark Japan	Korea Eco-Label	NF Environment	Swedish Standard
		<p>(only for Metal cutting fluids, Gear-/ transmission fluids, and on an optionally basis between choosing this criterion or the Renewability Criterion)</p> <ul style="list-style-type: none"> Re-refined oil min 65% 				
Technical Performance¹⁸²						
Y	Y	Y	Y	Y	Y	Y
Information on handling and disposal						
N	<p>The container of the lubricant must carry relevant user information, such as the waste code according to the European Waste Catalogue¹⁸³, recommendations on suitable disposal methods.</p> <p>In the case of lubricants designed to be sold to private end consumers, the following information is to be given on the container: "Store out of reach of children"; "Do not allow unused quantities of the product to reach the sewerage system,</p>	<p>The product label must be carrying a text equivalent to the following: "Lubricating oil may be harmful to health and the environment and must accordingly not be deposited in waste water systems, the ground or water recipients. Lubricating oils must be delivered to an approved site or collector of toxic waste."</p>	<p>Product handling and disposal precautions shall be indicated on the MSDS, container or label.</p> <p>Precautions such as: "biodegradable oil has little impact on the environment compared to normal oil, but this does not mean that it has none. Minimize discharge and leakage into the environment"; "appropriate waste disposal required also for biodegradable oil"</p>	N	<p>The following information should appear on the packaging:</p> <ul style="list-style-type: none"> Recommendations on storage conditions of lubricant, Recommendations in respect to environment, incorporating the sentence: "All lubricating oils can present a risk to the environment and health and therefore should not be discharged into sewers, water or soil". 	<p>For Hydraulic Fluids:</p> <p>Hydraulic fluids that are to be discarded should be collected in separate containers and disposed of in a responsible manner in accordance with legislative requirements and industry safety standards. Suppliers of hydraulic fluids should provide end users with recommendations for safe handling of both hydraulic fluids and packaging.</p> <p>Hydraulic fluids must not discharge into drains, water courses or onto the ground. A accidental spillage should be collected with appropriate absorbent such as sand or active clay.</p>

¹⁸² The criteria are specific for each family of lubricant

¹⁸³ <http://ec.europa.eu/environment/waste/framework/list.htm>

EU Ecolabel	Blue Angel	Nordic Ecolabel (withdrawn)	Eco Mark Japan	Korea Eco-Label	NF Environment	Swedish Standard
	watercourses or soil"; "Product residue is to be disposed of in municipal collection points for harmful substances"; "Only return empty containers for recycling"					
Packaging						
N	N	Product packaging, including caps and labels, must <u>not contain halogenated plastics</u> . Plastic parts must be marked in accordance with DIN 6120 or other similar labelling schemes. In the case of packaging of up to five litres an account must be provided of the design used to prevent the retention of oil.	Packaging shall not contain resins made of halogens and halogenids as constituents.	N	Identification of the constitutive material of packaging: a symbol will identify the constituent material packaging. Packaging materials must be marked in accordance existing standards (NF EN ISO 6120 or DIN 11 469). To limit losses when the use, it is recommended that the packaging of lubricant is designed to: · To limit the retention lubricant in the package · That users can put the right dose lubricant on the chain or in the tank.	N

APPENDIX III: Overview of scope and criteria of Korea Eco-Label for engine oils category

2T Engine oil	4T Engine oil	Diesel																		
Document Reference / Product Category / Scope																				
EL505. Two-cycle Engine Oil [EL505-1993/5/2005-68]	EL503. Gasoline Engine Oil [EL503-1999/5/2005-68]	EL504. Diesel Engine Oil [EL504-2000/2/2005-68]																		
Two-cycle engine oil for internal combustion engine used for the two-cycle engine which is equipped in ship or motorcycle.	Engine oil for gasoline car among four-cycle engine oil.	Engine oil for diesel car among four-cycle engine oil.																		
Criteria																				
Environmental Criteria																				
<p>At the stage of use, <u>in regard to emissions of air pollutant or resource consumption</u>, the following conditions shall be satisfied.</p> <ul style="list-style-type: none"> Sulfated ash shall be less than 0.15 weight % <ul style="list-style-type: none"> "Sulfated ash content" refers to the remaining substance measured after heating carbonic substance generated in burning engine oil with sulfuric acid." The sulfur content shall be less than 0.3 weight %. Lubricity shall be 95 or more The initial torque shall be 98 or more. Cleanliness shall be 95 or more Exhaust emissions shall be 85 or more The obstructive of the exhaust system shall be 90 or more 	<p>At the stage of use, <u>in regard to emissions of air pollutants or resource consumption</u>, the following conditions shall be satisfied.</p> <ul style="list-style-type: none"> Phosphorus content shall be 0.06 weight % or more, and 0.08 weight % or less. Sulphur content should meet the following standards for each viscosity classification: <table border="1"> <tr> <td>Division for Viscosity Classification</td> <td>0 W- X X, 5 W - X X</td> <td>10 W- X X</td> </tr> <tr> <td>Sulfur Content [Weight %]</td> <td>0.5 or less</td> <td>0.7 or less</td> </tr> </table> <ul style="list-style-type: none"> With respect to the evaporation stability of engine oil, loss of heating of NOACK shall be less than 13 weight%. In regard to shear stability, viscosity measurement shall be within the SAE (Society of Automotive Engineers) viscosity classification. High temperature deposits shall be 35 mg or less. Oxidation stability during 48 hours shall meet the following conditions: <table border="1"> <tr> <td>Viscosity ratio</td> <td>Increase of Comp utation [mg KOH/g]</td> <td>Lacquer Rate</td> </tr> <tr> <td>≤1.5</td> <td>≤1.6</td> <td>'Light' or less</td> </tr> </table> <ul style="list-style-type: none"> Engine oil shall meet or exceed GF-4 of ILSAC 	Division for Viscosity Classification	0 W- X X, 5 W - X X	10 W- X X	Sulfur Content [Weight %]	0.5 or less	0.7 or less	Viscosity ratio	Increase of Comp utation [mg KOH/g]	Lacquer Rate	≤1.5	≤1.6	'Light' or less	<p>At the stage of use, <u>in regard to emissions of air pollutant or resource consumption</u>, the following conditions shall be satisfied.</p> <ul style="list-style-type: none"> Sulfated ash shall be 1.5 weight % or less <ul style="list-style-type: none"> "Sulfated ash" refers to the residue measured after adding sulfuric acid to the carbon quality materials that occur when the engine oil burns, and then the same is heated. Evaporation stability shall be less than 13 weight% of loss of heating of NOACK High-temperature deposit shall be 7.0 points or more High-temperature and high-shear viscosity shall be more than 3.5 With respect to the shear stability, the measurement viscosity shall be within SAE viscosity classification <ul style="list-style-type: none"> "Shear stability" refers to the value evaluating the reduction of viscosity by shearing high molecular substance such as viscosity index improving material among engine oil ingredients. Oxidation safety shall satisfy the following requirements for 120 hours <table border="1"> <tr> <td>Viscosity ratio</td> <td>Increase in Total Acid Number [mg KOH/g]</td> <td>Lacquer Rate</td> </tr> <tr> <td>≤1.5</td> <td>≤1.6</td> <td>≤'Pale'</td> </tr> </table>	Viscosity ratio	Increase in Total Acid Number [mg KOH/g]	Lacquer Rate	≤1.5	≤1.6	≤'Pale'
Division for Viscosity Classification	0 W- X X, 5 W - X X	10 W- X X																		
Sulfur Content [Weight %]	0.5 or less	0.7 or less																		
Viscosity ratio	Increase of Comp utation [mg KOH/g]	Lacquer Rate																		
≤1.5	≤1.6	'Light' or less																		
Viscosity ratio	Increase in Total Acid Number [mg KOH/g]	Lacquer Rate																		
≤1.5	≤1.6	≤'Pale'																		

2T Engine oil	4T Engine oil	Diesel
	(International Lubricants Standards Accreditation Committee).	
<p>At the stage of use, <u>in regard to the emission of water pollution</u>, engine oil for water combustion* s shall be easily biodegradable.</p> <p>*("Water-fueled internal-combustion" refers to combustion engines used in waters, including rivers and seas, such as outboard motor, water vehicles and so forth.)</p>	-	-
Technical performance Criteria		
Y	Y	Y
Information for Consumers		
<ul style="list-style-type: none"> • Indication on what the product contributes to the reasons for certification (less air pollutants or well discomposed in nature) at the use and disposal stage. • Attentions for treatment 	<ul style="list-style-type: none"> • Display factors that the relevant product contributes to the reasons of certification (Improving fuel efficiency, long life and air pollution reduction) at the stage of consumption. • Display information regarding the period of engine oil change under normal driving conditions. 	<ul style="list-style-type: none"> • Indication on the items that the product contributes to the reasons for certification (Long-lived, less air pollutants) during its consumption stage • Information on replacing cycle of engine oil at the normal driving condition

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