SUMMARY

Updating the study
Ecological and energetic assessment of re-refining waste oils to base oils
Substitution of primarily produced base oils including semi-synthetic and synthetic compounds

Nabil Abdalla, Horst Fehrenbach

Heidelberg, August 2018

ifeu Wilckensstraße 3 D - 69120 Heidelberg Telephone +49 (0)6 221. 47 67 - 0 Fax +49 (0)6 221. 47 67 - 19 E-Mail ifeu@ifeu.de www.ifeu.de

On behalf of GEIR

IMPRESSUM

Authors: Nabil Abdalla, Horst Fehrenbach

Editor: ifeu – Institut für Energie- und
Umweltforschung Heidelberg GmbH
Wilckensstr. 3, D-69120 Heidelberg

Year of publication: 2018

Summary

The European Waste legislation gives preference to waste treatment options that deliver the best overall environmental outcome. Life cycle assessment (LCA) is the commonly used instrument to identify such options. There is a large number of LCAs dealing with waste oil treatment. One of these LCA studies was performed by ifeu on behalf of the GEIR (Fehrenbach 2005), and policymakers still refer to this study published more than ten years ago. Considering the current state of technology and key developments in the industry, the original set of data has to be regarded as outdated taking the actual state of technical practice into account.

Hence, the **goal** of this study is to provide an updated and forward-looking view on the environmental aspects of regeneration of waste oil. The conclusions of the earlier study refer to the situation of the last decade. They shall be amended to reflect the current situation. Information regarding the regeneration processes draws upon the conditions practiced at four leading companies operating across Europe.

This study has been **reviewed** by a panel of experts in accordance with ISO 14040 section 7.3. The review process was started after the finalization of a draft report of the assessment. All amendments have been taken into consideration during the final editing of the study.

This study and its predecessor share the same **scope**. However, apart from the refreshing of data, the determination of the reference needed an update: What constitutes the alternative option, if waste oil is not regenerated to base oil? In 2005, the answer was direct use as fuel in cement works. Today, the most relevant alternative option is treatment to fuel oil. This represents a major change, which has to be taken into account, accordingly.

The waste oil qualities for regeneration are based on separately collected used engine and waste oil and other industrial oils suitable for regeneration to base oil. Qualities which don't meet the specification for regeneration (e.g. oils contaminated with very high chlorine or PCB, or so-called MARPOL oils) are not within the scope of this assessment.

The **reference unit** of this study is 950,000 Mg waste oil per year. This comprises the entire quantity of regenerated waste oil within the European Union. The waste oil qualities for regeneration are based on separately collected used engine oils and other industrial waste oils suitable for regeneration to base oil.

The four regeneration techniques represent the range of advanced refining technologies including hydro-treatment and solvent extraction. The produced base oils are low on sulfur- and unsaturated content and contain very low aromatics content. They fulfill specifications of high-graded base oils, leading to a key question: Which quality of virgin base oil is substituted and has to be considered within this LCA? We assume a range from a minimum to a presumed achievable optimum, describing the minimum as base oil corresponding to group I base oil ("standard") and an optimum described by a mix of 70 % group I base oil and 30 % group IV base oil ("advanced"). This hypothetical blend corresponds to a **v**iscosity **i**ndex (VI) of 115, matching widely the qualities of regenerated base oil under study.

Results from comparing regeneration with the substituted production processes of primary base oil are shown in Fig. 1: Regeneration of waste oil to base oil causes less environmental

impact than processing base oil from crude oil across the board. Regeneration therefore clearly leads to a decrease in environmental burdens.

Does this still apply when comparing the regeneration to the alternative reference system, the processing to fuel oil? The answer is clearly yes. As fig. 2 shows, the treatment to fuel is disadvantageous throughout all impact categories when compared with regeneration.

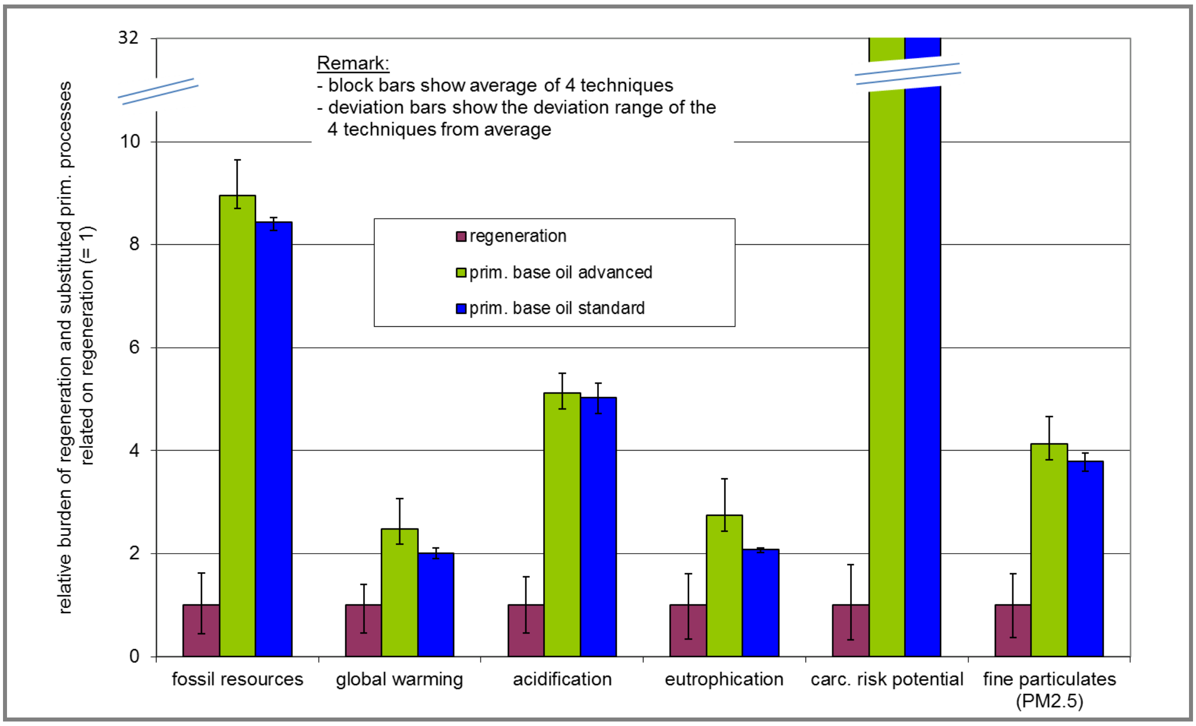

Fig. 1: Overview of the impact assessment results; all figures related to the particular result of “regeneration”, main bars: average result of the four techniques (normalized to one), deviation bars: range of the four techniques (n. b.: scale not continuous)

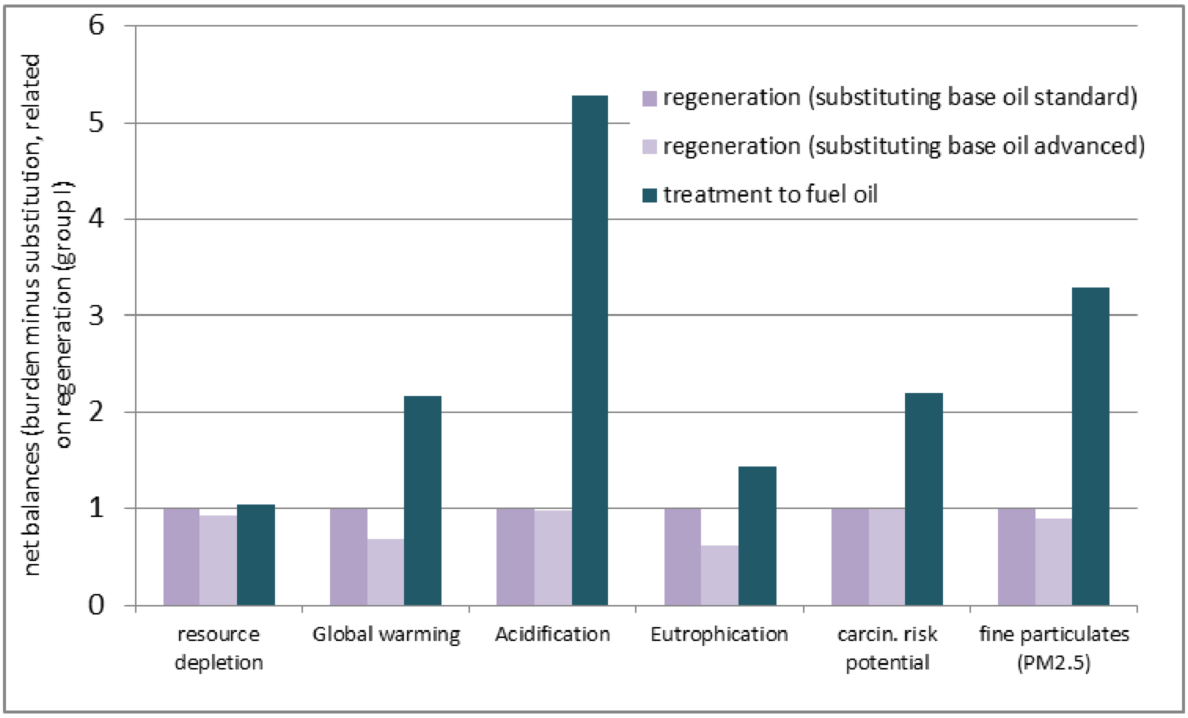

Fig. 2: Synopsis on the comparable impact assessment results – regeneration substituting base oil standard (normalized to one) (average) vs. regeneration substituting base oil advanced (average) vs. treatment to fuel; values <1 describe better performance than regeneration and substitution of standard base oil and vice versa.

In summary, a thorough benefit of regeneration can be observed when compared to the most common alternative use in Europe, treatment to fuel oil.

Moreover, a sensitivity analysis was carried out regarding the following key questions:

- Fuel substitution: Which fuel is substituted with respect to the reference system?
- Does the average of four regeneration techniques properly represent the single techniques?
- Is there a temporal bias concerning the reference system?
- How does the base oil quality affect the results?

Regarding the fuel substitution, the authors determined a fuel oil with light to medium density and (corresponding) low sulfur content to be the right choice as a reference product. Heavy fuel oil could be regarded as an alternative, resulting in a slightly more advantageous performance of regeneration across the board. Consequential life cycle thinking, however, would clearly argue against assuming heavy fuel oil to be substituted, because in general, refineries do the utmost to reduce the share of heavy fuel oil in their product portfolios. Thus, it is unlikely that offering an alternative (recycling) fuel would lead to reduced production of heavy fuel oil.

Concerning the question, whether or not the average represents the different single techniques, it can be summarized that the average result gives a solid picture of the overall performance of the assessed regeneration techniques, taking into account that – varying from impact category to impact category – some perform better than others and vice versa.

In respect of a potential temporal bias, we found that the impact of the treatment process is in most cases significantly lower that from regeneration. This might be clear taking the much higher effort into account for regeneration to high quality products as base oils. Furthermore, apart from acidification and carcinogenic risk potential, the equivalency processes do not determine the results. Even if there would be a massive improvement compared to the used data, effects would be negligible at best.

With regard to the impact of base oil quality, the authors assumed that a continuously increasing technical quality should correlate with deployed effort – in other words: caused environmental impacts. Of course this presumption means uncertainty. We cannot exclude, however unlikely, the possibility that a group II/III primary base oil could be produced with lower environmental burden than group I virgin base oil. As long as the environmental burden from producing high quality virgin base oil (up to group III) still exceeds the LCA performance of group I base oil, the conclusions of this study will be still valid.

In total, considering the number of analyzed sensitive aspects, the authors deem the result and subsequent conclusions robust in the light of the goal and scope as defined in this study.

Comparing these **results** with the results of the study carried out in 2005, we discovered the following aspects:

- First of all: the environmental advantages of the regeneration of waste oil to base oil hold true throughout all the applied impact categories;
- This also applies in the case of just base oil group I quality is substituted
- Substitution of higher base oil groups (e.g. group II+) leads to even better results in favor of regeneration for all applied impact categories.

We discovered that, in comparison to the study carried out in 2005, the change with regard to the reference, the alternative treatment, was the essential difference. In the past, a significant amount of used oil was thermally used in cement works to substitute predominantly diverse types of coal as main fuel. As pointed out before, this option is but of limited commercial importance today. However, substitution any type of coal consequently leads to extraordinary high credits – credits in favor of the cement work option. As a result, LCAs investigating the regeneration of used oil were always captivated by this fact/issue. Therefore, a key takeaway of the 2005 study can be stated as follows: as long as the competing reference system is able to claim it desists from a highly climate-crucial practice, e.g. coal burning, any regeneration system – even the most efficient and most sophisticated – will hardly excel the coal-substitution credit.

In the present, combustion of used oil in cement works is of increasingly marginal relevance regarding the European practice of waste oil treatment. In view of this development, the reference system applied in this study has been adjusted accordingly. Treatment to fuel oil is the most significant alternative to regeneration processes.

Moreover, there are a number of further points of attention, in particular those referring to the update of data:

- The update of data by the regeneration companies leads to improved results with regard to some aspects, but not to others: in fact, we applied data from real practice within this study and eliminated uncertainties from former assumptions based on few experiences.
  Nevertheless, the results for regeneration are positive in all respects.
- The update of refinery data also included some improvements within the system producing the substituted base oils and other mineral oil products;
  these improvements lower the positive net results for the regeneration but do not lead to real significant changes, regarding the overall result.

In summary, we found that the regeneration of waste oil for the recovery of base oils is considerably advantageous, especially in terms of resource preservation and relief from other environmental burdens.

This study underlines the results of 2005 and enhances the previous conclusions, stating that an advanced regeneration technology shall be the favored way to keep waste oil as long as possible as high-graded material within the circular economy. In brief: this LCA supports the higher ranking of regeneration versus energy recovery according to the waste hierarchy required by EU policies.