American Carbon Registry
AT WINROCK INTERNATIONAL

METHODOLOGY FOR THE QUANTIFICATION, MONITORING, REPORTING AND VERIFICATION OF GREENHOUSE GAS EMISSIONS REDUCTIONS AND REMOVALS FROM

RE-REFINING USED LUBRICATING OILS

VERSION 1.0

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ABOUT AMERICAN CARBON REGISTRY® (ACR)

A leading carbon offset program founded in 1996 as the first private voluntary GHG registry in the world, ACR operates in the voluntary and regulated carbon markets. ACR has unparal-leled experience in the development of environmentally rigorous, science-based offset meth-odologies as well as operational experience in the oversight of offset project verification, reg-istration, offset issuance and retirement reporting through its online registry system.

ACKNOWLEDGEMENTS

Methodology developed by ACR with contributions from:

safety-kleen®
A Clean Harbors Company

ACRONYMS

API	American Petroleum Institute
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
Offsets	Carbon offset credits
SSR	GHG Source, Sink, or Reservoir
GWP	Global Warming Potential
VOC	Volatile Organic Compound

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1 BACKGROUND AND APPLICABILITY

1.1 SUMMARY DESCRIPTION OF THE METHODOLOGY

Lubricating oils are used to minimize friction and wear between mechanical parts in contact with each other and are essential to a wide variety of automotive, industrial, and marine applications. The lifecycle of lubricating oils is associated with environmental impacts including greenhouse gas emissions. The manufacture of lubricating oil is the most energy-intensive process in a crude oil refinery, and used lubricating oils are often burned in industrial or commercial boilers, releasing multiple pollutants including carbon dioxide.[1]

An alternative option exists for used lubricating oil: collection and re-refining. Used oil management programs have been developed throughout North America to reduce the amount of practical loss[2] of used oil and to encourage the recycle and reuse of used oil. Lubricating oil must be taken out of service when it no longer performs to expected specifications. This occurs when additive packages become depleted and the lubricant becomes contaminated. The base oil portion of the lubricant, however, does not break down during use. As a result, used engine oil and other lubricating oils can be re-refined to remove water, contaminants and additives to produce base oil of the same quality as the virgin base oil. Lubricants formulated using re-refined base oils in turn can meet the same performance standards as those using virgin base stocks.

The purpose of the Methodology is to quantify greenhouse gas (GHG) emission reductions associated with the re-refining of used lubricating oils. Re-refining used lubricating oils avoids GHG emissions associated with combustion of used oil. This Methodology provides the quantifi-

[1] Used lubricating oil is often improperly disposed, for example dumped into storm sewers or garbage bins, or burned in unregulated boilers. Burning used oil without proper controls releases harmful compounds into the atmosphere including Polycyclic Aromatic Hydrocarbons (PAHs) and heavy metals. Dumping used oil can impact both the environment and human health as contaminated oil migrates downward through soil and possibly impacting surface water, groundwater and causing soil contamination.

[2] Practical loss is the amount of used oil that is improperly disposed, discarded or burned for energy recovery prior to being collected as defined in the Kline/CalRecycle Report “Lubricant Consumption and Used Oil Generation in California: A Segmented Market Analysis”)

cation and accounting frameworks, including eligibility and monitoring requirements, for the creation of carbon offset credits from the reductions in GHG emissions resulting from the re-refining of used lubricating oils.

1.2 APPLICABILITY CONDITIONS

Finished lubricants are produced by blending base oil with additives to control viscosity and achieve specific quality and performance targets. Under a project scenario, used lubricating oil is collected and re-refined into base oil that meets the same rigid quality assurance/quality control standards referenced in API Standard Publication 1509 (Fifteenth Edition). Base oils derived from crude oil refining, chemical synthesis, and the re-refining of used lubricating oil must meet the American Petroleum Institute (API) standards or equivalent standards to deliver the same performance.

This Methodology defines a set of activities designed to reduce GHG emissions through the re-refining of used lubricating oils. This methodology is applicable under the following conditions:

- The re-refined lubricating oils produced by the project activity in a re-refinery (hereafter referred to as "Project Site") are of the same quality as virgin lubricating oils, as evidenced by the fact that they can be used for the same purpose and meet all relevant product specifications.
- The Project Site is in North America.
- Used lubricating oils eligible under this protocol are those included in the definition of used lubricating oils in the Definitions section.
- The Project complies with all local or national regulations related to proper treatment and disposal of contaminants.

1.3 START DATE

The project start date is the date on which the Project Site began to reduce GHG emissions against its baseline.

1.4 REPORTING PERIODS

- Projects may define the length of each reporting period taking into consideration ACR's requirements for validation and verification intervals[3].
- Emission reductions shall be quantified for the duration of the chosen reporting period based on the total amount of re-refined lubricating oil produced during the reporting period and the

[3] See the ACR Standard

subsequent sale, title transfer or return of the re-refined lubricating oil to a re-refined lubricating oil distributor, wholesaler, or end-user.

- A project's first reporting period may begin on the project start date or thereafter taking into consideration the timeframe during which project validation must be achieved following the project start date[4].

1.5 CREDITING PERIOD

- The crediting period begins on the first day of the first reporting period.
- The crediting period shall be ten years.

1.6 PERIODIC REVIEWS AND REVISIONS

ACR may require revisions to this Methodology to ensure that monitoring, reporting, and verification systems adequately reflect changes in the project's activities. This Methodology may also be periodically updated to reflect regulatory changes, emission factor revisions, or expanded applicability criteria. Before beginning a project, the project proponent should ensure that they are using the latest version of the Methodology.

[4] See the ACR Standard

2 PROJECT BOUNDARIES

2.1 GEOGRAPHIC BOUNDARY

The GHG assessment boundary, or offset project boundary, delineates the SSRs that must be included or excluded when quantifying the net changes in emissions associated with the re-refining of used lubricating oils.

The project boundary, depicted by the light grey box in Figure 1, include the physical and geographical sites where used lubricating oil is either burned as heating fuel, or re-refined for further use.

For purposes of this assessment, the extraction, transport, and refining of crude oil, and the collection, aggregation, and transport of used lubricating oil to locations where it is either burned as fuel or re-refined, and any associated GHG emissions, are not included in the project boundaries. The extraction, transport, and refining of crude oil has been excluded based on the assumption that extracted crude will most likely continue to be refined into other products despite adoption of lubricant re-refining processes. Avoided GHG emissions from displaced base oil production are also not included in this Methodology to prevent potential double-counting in jurisdictions with a GHG emission control program (either carbon tax or a cap-and-trade program). Also, the production of additives which are added to base oil to create finished lubricant products is not included. Lastly, the transportation and distribution emissions associated with re-refined lubricating oil are outside the project boundary and are excluded from project emissions.

Figure 1: Project Boundary Diagram for Re-refining Used Lubricating Oils

Illustration of the GHG assessment boundary for re-refining of used lubricating oils. SSRs inside the grey box are included and must be accounted for under this Methodology.

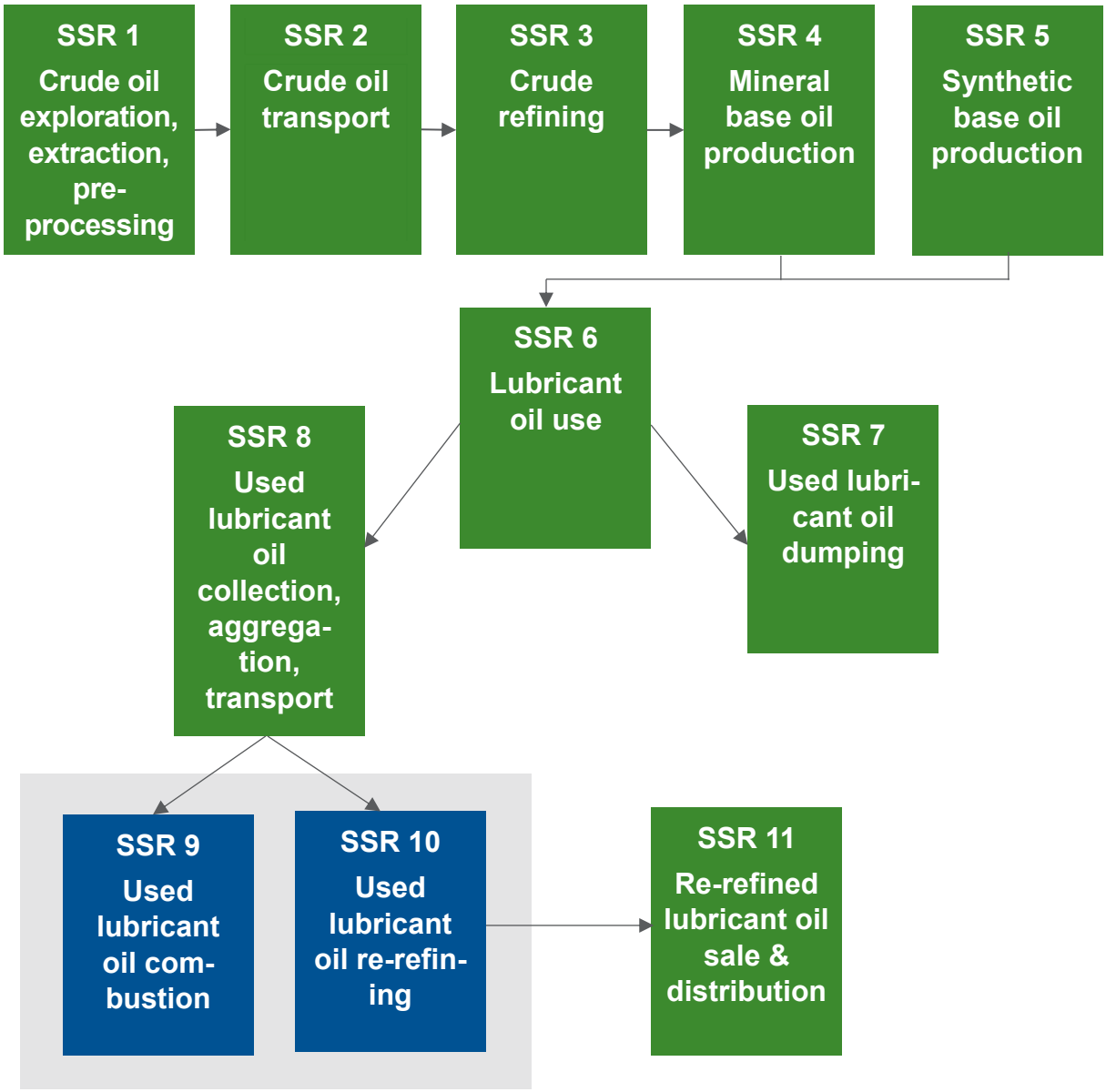

Table 1: Greenhouse Gases and Sources, Sinks and Reservoirs

List of the GHG sources included and excluded in the quantification under this Methodology, depending on whether the sources are within or outside project boundaries.

SSR	SOURCE DESCRIPTION	GAS	INCLUDED (I) OR EXCLUDED (E)	QUANTIFICATION METHOD
1	Crude Oil Exploration, Extraction, Processing	CO_2	E	N/A
		CH_4	E	N/A
		N_2O	E	N/A
2	Crude Oil Transport	CO_2	E	N/A
		CH_4	E	N/A
		N_2O	E	N/A
3	Crude Refining	CO_2	E	N/A
		CH_4	E	N/A
		N_2O	E	N/A
4	Mineral Base Oil Production	CO_2	E	N/A
		CH_4	E	N/A
		N_2O	E	N/A
5	Synthetic Base Oil Production	CO_2	E	N/A
		CH_4	E	N/A
		N_2O	E	N/A
6	Lubricant Oil Use	CO_2	E	N/A
		CH_4	E	N/A
		N_2O	E	N/A

SSR	SOURCE DESCRIPTION	GAS	INCLUDED (I) OR EXCLUDED (E)	QUANTIFICATION METHOD
7	Used Lubricant Oil Dumping	CO_2	E	N/A
		CH_4	E	N/A
		N_2O	E	N/A
8	Used Oil Collection, Aggregation, Transport	CO_2	E	N/A
		CH_4	E	N/A
		N_2O	E	N/A
9	Used Lubricant Oil Combustion	CO_2	I	Equations 1 and 5
		CH_4	E	N/A
		N_2O	E	N/A
10	Used Lubricant Oil Re-Refining	CO_2	I	Equations 3 and 4
		CH_4	E	N/A
		N_2O	E	N/A
11	Re-Refined Lubricant Oil Sale and Distribution	CO_2	E	N/A
		CH_4	E	N/A
		N_2O	E	N/A

3 BASELINE DETERMINATION

The baseline scenario considers:

- the baseline rates of used lubricant collection, re-refining and combustion for energy recovery;
- emission factors for combustion of used lubricating oil.

3.1 BASELINE RATES OF RE-REFINING AND COMBUSTION

The current rates by which lubricants are re-refined in North America are accounted for in determining the baseline scenario. An industry survey conducted in 2015 provides the most recent data on lubricant re-refining in North America[5] (Kline & Company, 2016).

Based on the Kline and Company survey, it is assumed that for the baseline scenario, of the used lubricant oil generated across North America that is collected or that could be collected (6,134 kt.), 13.6% (833 kt.) is re-refined into base oil (See Appendix A).

3.2 GHG EMISSIONS FROM COMBUSTION OF USED LUBRICATING OIL

GHG emissions from combustion of used lubricating oil are assessed in this Methodology. Burning used lubricating oil for heat recovery results in direct CO_2 emissions. Most lubricating oils are made from heavier, thicker, petroleum-base stock, and are designed for lubrication rather than as fuel. The hydrocarbon composition of lubricating oil varies, especially for used oil that is frequently mixed with heavy oils to improve the quality of the fuel. As such, a wide range of values are reported in the literature for the energy content of lubricating oils and resulting CO_2 emissions from combustion. This Methodology uses default factors from the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

[5] Kline Report "Global Used Oil Markets and Re-Refined Lubricants 2015: Market Analysis and Opportunities – North America"), Kline &Company (2016).

4 ADDITIONALITY ASSESSMENT

Emission reductions from the project must be additional or deemed not to occur in the "business-as-usual" scenario. Assessment of the additionality of a project will be made based on passing the two tests cited below. These two tests require the project proponent to demonstrate that the project activity is surplus to regulations and reduces emissions below the level established in the Methodology.

1. Regulatory Surplus Test, and
2. Practice-Based Performance Standard

4.1 REGULATORY SURPLUS TEST

In order to pass the regulatory surplus test a project must not be mandated by existing laws, regulations, statutes, legal rulings, or other regulatory frameworks in effect as of the project start date that directly or indirectly affect the credited GHG emissions associated with a project. The project proponent must demonstrate that there is no existing regulation that mandates the project or effectively requires the GHG emission reductions associated re-refining used lubricating oil.

Currently, there are no such requirements in the U.S. or elsewhere in North America. Consumers are free to use virgin lubricating oil or re-refined lubricating oil in any amount. Likewise, there are no restrictions in North America on the quantities of re-refined lubricating oil that can be produced, imported, or used for any application.

4.2 PRACTICE-BASED PERFORMANCE STANDARD

The second test is whether used lubricating oil is routinely re-refined under common business practice, instead of being combusted. The most recent available industry data indicate that 13.6% of collected used oil in North America is re-refined to base oil. Given the low adoption rate for used oil re-refining, a project activity meeting the requirements of this methodology is deemed additional.

5 QUANTIFICATION OF GHG EMISSION REDUCTIONS

Quantification of emission reductions requires calculation of baseline emissions and project emissions.

5.1 BASELINE EMISSIONS

Baseline emissions (BE) must be estimated by using Equation 1 and by summing the baseline emissions for all SSRs identified as included in the baseline in Table 1. Baseline emissions are from the combustion of used lubricating oil that would be avoided by additional production of re-refined used lubricating oil.

Default values for the parameters needed to calculate baseline emissions are listed in Table 2.

Table 2: Default Values for Baseline Emissions

PARAMETER (EQUATION #)	VALUE	SOURCE
Volumetric Heat Content of Lubricant Oil (Eq 1) HC_v	0.0402 GJ/L	IPCC (2006)[6], Table 1. 2
Carbon content of lubricant oil on heating value basis (Eq 1) CC_{LO}	20 kg/GJ	IPCC (2006), Table 1.3

The GHG emissions from combustion of used lubricating oil that would be avoided by additional production of re-refined lubricating oil can be calculated in the following equation:

Equation 1: Total Baseline Emissions

$$BE_t = (HC_{LO_t} \times \frac{CC_{LO}}{1,000}) \times (\frac{44}{12})$$

WHERE

[6] IPCC (2006) Guidelines for National Greenhouse Gas Inventories, Volumes 1 (Introduction) and 2 (Energy)

BE_t	Baseline emissions from the combustion of used lubricating oil that are avoided through re-refining during the reporting period, t (tCO_2)
HC_{LO_t}	Heat content of lubricant that would have been combusted in the baseline during reporting period, t (GJ)
CC_{LO}	Carbon content of lubricant oil on heating value basis – see Table 3 (kg/GJ)
$1,000$	Conversion from kilograms to metric tons
$\frac{44}{12}$	Ratio of molecular weight of CO_2 to carbon

WITH

$$HC_{LO_t} = (HC_v \times (Q_{LO_t} - HBP_{LO}) \times 3.78541)$$

WHERE

HC_{LO_t}	Heat content of lubricant that would have been combusted in the baseline during reporting period, t (GJ)
Q_{LO_t}	Total quantity of used lubricating oil that is re-refined to base oil[7] in reporting period, t (Gallons)
HBP_{LO}	Historic baseline production of used lubricating oil that is re-refined to base oil (Gallons)[8]
HC_v	Volumetric heat content of lubricant oil – see Table 3 (GJ/L)
3.78541	Conversion from gallons to liters

5.2 PROJECT EMISSIONS

Project emissions are determined from energy requirements and emissions from the Project Site (i.e., the facility conducting re-refining).

[7] This quantity shall only include the gallons of re-refined base oil and not the volume of other re-refined products that may be produced in the re-refining process.

[8] See Table 3 for applicability

Equation 2: Total Project Emissions

$$PE_t = PE_{elec,t} + PE_{ff,t}$$

WHERE

PE_t	Project emissions in reporting period, t (tCO_2)
$PE_{elec,t}$	Project emissions from the use of electricity at the refining facility during reporting period, t (tCO_2)
$PE_{ff,t}$	Project emissions from the combustion of fossil fuels used at the refining facility during reporting period, t (tCO_2)

Equation 3: Project Emissions from the Use of Electricity at the Refining Facility

$$PE_{elec,t} = Q_{elec_t} \times \frac{EF_{EL}}{2,204.62}$$

WHERE

$PE_{elec,t}$	Project emissions from the use of electricity at the refining facility during reporting period, t (tCO_2)
Q_{elec_t}	Quantity of electricity used by the refining facility in reporting period, t (MWh)
EF_{EL}	Carbon emission factor for grid electricity[9] ($lbCO_2$/MWh)
$2,204.62$	$lbCO_2/tCO_2$

Equation 4: Project Emissions from the Combustion of Fossil Fuels Used at the Refining Facility

$$PE_{ff,t} = \sum_y \frac{(FF_{y_t} \times EF_y)}{1,000}$$

WHERE

[9] Project proponents shall use the current version of the U.S. Environmental Protection Agency's Power Profiler (http://oaspub.epa.gov/powpro/ept_pack.charts) to determine what regional emission factor should be used in accordance with the Emissions & Generation Resource Integrated Database (eGRID) for EF_{EL}. eGRID emission factors are available at http://www.epa.gov/energy/egrid.

$PE_{ff,t}$	Project emissions from the combustion of fossil fuels used for the refining facility during reporting period, t (tCO_2)
FF_{y_t}	Total quantity of fossil fuel, y, consumed in reporting period, t (Volume/mass of fuel)
EF_y	Fuel specific emission factor for fuel, y[10] (kg CO_2/volume or mass of fuel)
$1,000$	Conversion from kilograms to metric tons

5.3 LEAKAGE

In GHG project literature, leakage is a term that refers to secondary effects where the GHG emission reductions of a project may be negated by shifts in market activity or shifts in materials, infrastructure, or other physical assets associated with the project. In cases where leakage occurs, it must be accounted for and subtracted from the reported net GHG emission reductions for the reporting period.

5.3.1 Market Shifting Leakage Emissions

GHG emissions from the fossil fuel sources required to provide heat and power in place of the used lubricating oil which is re-refined as part of the project must be quantified. This is due to the fact that the heat and power previously produced through the combustion of lubricating oils continues to be produced in the project scenario. However, due to increased re-refining, lubricating oils are not available to produce the heat and power in the same supply in the project scenario as they are in the baseline scenario. Given the smaller supply of lubricating oils, alternative fuels are combusted to produce heat and power and therefore market shifting leakage emissions need to be considered.

5.3.2 Activity Shifting Leakage Emissions

It is not expected that the production of re-refined oils will result in increased emissions due to activity shifting outside of the project boundary and, therefore, activity shifting leakage emissions can be disregarded.

Equation 5: Market Shifting Leakage Emissions

[10] See Table 4 - Appendix C.

$$\mathbf{LE_t = \frac{HC_{LO_t} \times CC_{FF}}{1,000} \times \frac{44}{12}}$$

WHERE

$\mathbf{LE_t}$	Leakage emissions from the combustion of fossil fuels burned to produce heat previously produced with used lubricating oil, in reporting period, $\mathbf{t}$ (tCO_2)
$\mathbf{HC_{LO_t}}$	Heat content of lubricant that would have been combusted in the baseline during reporting period, $\mathbf{t}$ (GJ)
$\mathbf{CC_{FF}}$	Integrated carbon content of replacement fossil fuels on heating value basis[11] (18.867 kg/GJ)
$\mathbf{1,000}$	Conversion from kilograms to metric tons
$\mathbf{\frac{44}{12}}$	Ratio of molecular weight of CO_2 to carbon

5.4 TOTAL EMISSION REDUCTIONS

GHG emission reductions (ER) from a used lubricating oil re-refining project are quantified by subtracting the project emissions (PE_t) and leakage emissions (LE_t) from the baseline emissions (BE_t) as shown in Equation 6.

Equation 6: Total Emission Reductions

$$\mathbf{ER_t = BE_t - PE_t - LE_t}$$

WHERE

$\mathbf{ER_t}$	Total quantity of GHG emission reductions during the reporting period, $\mathbf{t}$ (tCO_2)
$\mathbf{BE_t}$	Total quantity of baseline emissions during the reporting period, $\mathbf{t}$ (tCO_2)
$\mathbf{PE_t}$	Total quantity of project emissions during the reporting period, $\mathbf{t}$ (tCO_2)
$\mathbf{LE_t}$	Leakage emissions from the combustion of fossil fuels burned to produce heat and power previously produced with used lubricating oil, in reporting period, $\mathbf{t}$ (tCO_2)

[11] See Appendix C for derivation of the integrated carbon content factor.

6 MONITORING AND DATA COLLECTION

Each project shall include a monitoring, reporting and verification plan sufficient to meet the requirements of the ACR Standard. The plan shall collect all data required to be monitored in a manner that meets the requirements for accuracy and precision of this Methodology.

6.1 DESCRIPTION OF THE MONITORING PLAN

The project proponent must prepare a monitoring plan describing (for each separately) the following: a) project implementation; b) technical description of the monitoring task; c) data to be monitored and collected; d) overview of data collection procedure; e) frequency of the monitoring; f) quality control and quality assurance procedure; g) data archiving; and h) organization and responsibilities of the parties involved in all the above.

The rationale of monitoring project implementation is to document all project activities implemented by the project that could cause an increase in GHG emissions compared to the baseline scenario.

6.2 DATA COLLECTION AND PARAMETERS TO BE MONITORED

For a specific quantity of used lubricating oil that is re-refined, the process for monitoring the emission reduction parameters includes:

- Documentation of the point of origin of the used lubricating oil including location, volume, and date of collection;
- Documentation of the delivery of used lubricating oil to the re-refining facility, including location, volume, and date of delivery;
- Documentation demonstrating that the used lubricating oil collected and delivered to the Project Site is well-mixed prior to entering the re-refining process to ensure uniform composition;
- Documentation demonstrating that the used lubricating oil received at the Project Site to undergo the re-refining process is tested and meets all required specifications of used lubricating oil suitable for reprocessing based on the technical capabilities of the Project Site;
- Documentation on the volume of re-refined lubricating oil that is produced;

- Documentation of the annual yield of re-refined lubricating oil[12];
- Documentation of the location where the re-refined lubricating oil is produced;
- Documentation demonstrating the Project Proponent's license to operate as a re-refiner;
- In regions where used oil is considered to be hazardous waste, documentation must be maintained to prove proper handling, processing, and disposal of contaminants and waste.

Table 3: Parameters to be Monitored

PARA-METER	DESCRIPTION	DATA UNIT	CALCU-LATED (C), MEASURED (M), REFER-ENCE (R), OPERATING RECORDS (O)	MEASUREMENT FREQUENCY	COMMENT
$Q_{LO,t}$,	Total quantity of lubricating oil that is re-refined to base oil in report-ing period, t	Gallons	M, O	Continuous and per reporting period	On-site pro-duction records
HBP_{LO}	Historic baseline production of used lubricating oil that is re-re-fined to base oil (Gallons)	Gallons	M, O	Determined once and rec-orded	This value shall only be applied by Project Sites that have been produc-ing re-refined lubricating oil for greater than 10 years (at the time of the Project Start Date) and while the methodology

[12] As stated above, this volume only includes the volume of re-refined base oil and not volumes of other re-refined products that may be produced.

PARA-METER	DESCRIPTION	DATA UNIT	CALCU-LATED (C), MEASURED (M), REFER-ENCE (R), OPERATING RECORDS (O)	MEASUREMENT FREQUENCY	COMMENT
					is considered "newly ap-proved"[13]. This value shall be the highest an-nual produc-tion of re-re-fined base oil selected from one of the 3 years preced-ing the Pro-ject Start date.
$Q_{elec,t}$	Quantity of elec-tricity used by the refining facility in reporting period, t	MWh	M, O	Continuous	On-site records from utility bills
EF_{EL}	Carbon emission factor for grid electricity	$lbCO_2$/ MWh	R	Annual value determined once and recorded	See footnote 8
$FF_{y,t}$	Total quantity of fossil fuel, y, consumed in re-porting period, t	Volume or mass	M, O	Continuous or as delivered	On-site records from utility bills or fuel purchase records

[13] See ACR standard for definition of "newly approved"

PARA-METER	DESCRIPTION	DATA UNIT	CALCU-LATED (C), MEASURED (M), REFER-ENCE (R), OPERATING RECORDS (O)	MEASUREMENT FREQUENCY	COMMENT
EF_y	Fuel specific emission factor for fuel, y	kg CO_2/ volume or mass of fuel	R	Annual value determined once and recorded	See Table 4 - Appendix C

7 VERIFICATION

See the ACR Standard for guidance on project validation and verification requirements.

DEFINITIONS

If not explicitly defined here, the current definitions in the latest version of the American Carbon Registry (ACR) Standard apply.

American Petroleum Institute	Organization which sets quality and performance standards for base oil and finished lubricants.
Base oil	A lubrication-grade hydrocarbon initially produced from refining crude oil or chemical synthesis that is then mixed with additive packages to produce finished lubricant products. The API grades base oils based on the oil characteristics, including: Group I base stocks contain less than 90 percent saturates and/or greater than .03 percent sulfur and have viscosity index greater than or equal to 80 and less than 120; Group II has base stock that contains greater than or equal to 90 percent saturates and less than or equal to .03 percent sulfur and have viscosity index greater than or equal to 80 and less than 120; Group III base stocks contain greater than or equal to 90 percent saturates and less than or equal to .03 percent sulfur and have viscosity index greater than or equal to 120; Group IV base stocks are polyalphaolefins (PAO) – true synthetic lubricants, made through a process called synthesizing. They have a much broader temperature range, a higher shear strength, and are less prone to oxidation at higher operating temperatures; Group V base stocks include all other base stocks not included in the I, II, III, IV API base oil groups. These include silicone, phosphate ester, polyalkylene glycol (PAG), polyolester, biolubes, etc.
Contaminants	Heavy metals, solvents, and particulate matter which are collected throughout the use phase of a lubricating oil.
GHG Source, Sink, or Reservoir	• **GHG Source:** Physical unit or process that releases a GHG into the atmosphere. • **GHG Sink:** Physical unit or process that removes a GHG from the atmosphere. • **GHG Reservoir:** Physical unit or component of the biosphere, geosphere or hydrosphere with the capability to store or accumulate a GHG removed from the atmosphere by a GHG sink or captured from a GHG source.

Lubricating oil	A petroleum-derived or synthetic crankcase oil, engine oil, hydraulic fluid, transmission fluid, gear oil, heat transfer fluid, or other oil or fluid used for lubricating machinery or equipment.
Mineral base oil	Base oil produced from the refining of crude oil.
Project Site/ Re-refinery	A facility capable of re-processing used lubricating oil and producing base oil that will meet the same rigid quality assurance/quality control standards required as referenced in API Standard Publication 1509 (Fifteenth Edition).
Re-refined lubricating oil	Lubricating oil that is completely treated to the point that it has the same characteristics, functionality and life span as virgin lubricating oil. Re-refined oil meets the quality and technical performance standards for base oil per API standards.
Synthetic base oil	Base oil that is produced from chemical synthesis. Group III base oils are mineral-based but are sometimes classified as synthetic based on additional chemical processing steps. Group IV base oils are produced from the synthesis of polymers.
Used lubricating oil	Lubricating oil which has been used in various applications including automotive, manufacturing, etc. and is collected; the input to the re-refining process.
Virgin base oil	Base oil that is newly produced from either crude refining or chemical synthesis – as opposed to being re-refined – and that has not yet been combined with additives to formulate finished lubricant products.
Virgin lubricating oil	Finished lubricant products that are formulated using virgin base oil and additives.
Volatile Organic Compound	An organic chemical compound whose composition makes it possible for it to evaporate under normal indoor atmospheric conditions of temperature and pressure.

APPENDIX A: BASELINE DATA INPUTS AND CONVERSIONS

In calculating baseline emissions, default values for the volumetric heat content of lubricants and the carbon content of lubricants on a heating value basis are used in Equation 1 and listed in Table 2. The default values in this Methodology for these two parameters are derived or taken from values listed in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) as follows:

A.1 VOLUMETRIC HEAT CONTENT FOR LUBRICANTS

IPCC Default Value: 40.2 TJ/Gg (Table 1.2; IPCC, 2006)

Converted into .0402 GJ/L using the following standard conversion factor:

- 1.0 kg lubricant per liter lubricant (Default value for average density of lubricant at room temperature and standard atmospheric pressure, from Table 2, CDP Guidelines for Conversion of Fuel Data (CDP, 2014))

A.2 DEFAULT CARBON CONTENT OF LUBRICATING OIL ON A HEATING VALUE BASIS

IPCC Default Value: 20 kg /GJ (Table 1.3; IPCC, 2006)

APPENDIX B: CALCULATION OF USED OIL AND RE-REFINED LUBRICANTS IN NORTH AMERICA[14]

USED OIL AVAILABLE FOR COLLECTION = Used Oil Generated × Collectable Used Oil

= 9,295 kt. × 0.66%

= 6,134 kt.

$$\textbf{BASE OIL RE-REFINED AS \% OF TOTAL USED OIL AVAILABLE} = \frac{\text{Re-refined Base Stock}}{\text{Used Oil Available for Collection}}$$

= 833 kt. / 6,134 kt.

= 13.6%

[14] All data is from Figure 3E-7 of Kline Report "Global Used Oil Markets and Re-Refined Lubricants 2015: Market Analysis and Opportunities – North America"), Kline &Company (2016), and the 2012 Kline/CalRecycle Report "Lubricant Consumption and Used Oil Generation in California: A Segmented Market Analysis"), Kline & Company (2012).

APPENDIX C: PROJECT AND LEAKAGE EMISSION DATA INPUTS

C.1 PROJECT EMISSIONS FROM COMBUSTION OF FOSSIL FUELS FOR RE-REFINING USED LUBRICATING OIL

To calculate PE_{ff}, project proponents shall use the below emission factors for EF_y which will be revised periodically based on updated information.

Table 4: Fossil Fuel Emission Factors

	CO_2 EF_y	
FOSSIL FUEL TYPE	KILOGRAMS (KG) CO_2	PER UNIT
Propane	5.76	Gallon
Butane	6.71	Gallon
Butane/Propane Mix	6.21	Gallon
Home Heating and Diesel Fuel	10.16	Gallon
Kerosene	9.75	Gallon
Coal (All types)	2,100.82	Short ton
Natural Gas	53.12	Thousand cubic feet
Gasoline	8.89	Gallon
Residual Heating Fuel (Businesses only)	11.79	Gallon
Flared natural gas	54.75	Thousand cubic feet
Petroleum coke	14.70	Gallon

	CO_2 EF_y	
Other petroleum & miscellaneous	10.02	Gallon
Source: U.S. Energy Information Administration, published February 2, 2016.		

C.2 MARKET-SHIFTING LEAKAGE: INTEGRATED CARBON CONTENT OF REPLACEMENT FOSSIL FUELS DEFAULT VALUE

Based on a lifecycle assessment done for CalRecycle by the University of California at Santa Barbara (UCSB) (2013)[15], this Methodology assumes that an even mix of three primary fuels will replace used lubricating oil — No. 2 distillate, No. 6 residual oil, and natural gas. Given this mix, it was necessary to derive a default integrated carbon content for these replacement fuels. Per the UCSB life cycle analysis, each of these fuels should be weighted equally for replacement purposes. The carbon content of each fuel was taken from Table 1.3 of IPCC 2006. The integrated carbon content factor is a simple weighted average of the carbon content of each fuel.

Table 5: Integrated Carbon Content of Replacement Fossil Fuels

FUEL	DISPLACEMENT RATE*	CARBON CONTENT ON HEATING VALUE BASIS $KGCO_2/GJ$
No. 2 Distillate	0.33	20.20
No. 6 Residual Oil	0.33	21.10
Natural Gas	0.33	15.30
Integrated Carbon Content of Replacement Fossil Fuels		18.867

[15] Life Cycle Assessment of Used Oil Management in California. Pursuant to Senate Bill 546 (Lowenthal), R. Geyer et al. CalRecycle, July 29, 2013

APPENDIX D: REFERENCES

ASTM (2003) Fuels and Lubricants Handbook: Technology, Properties, Performance, and Testing. G.E. Totten, Editor, ASTM International.

CalRecycle (2010) Used Oil Recycling Rate Annual Report: 2008. Publication #DRRR-2010-005. California Department of Resources Recycling and Recovery.

CalRecycle (2012) Lubricant Consumption and Used Oil Generation in California. Publication Part II. #DRR12004. California Department of Resources Recycling and Recovery.

CDP (2014) Technical Note: Conversion of fuel data

El-Houjeiri, H.M., Vafi, K., Duffy, J., McNally, S. and A.R. Brandt (2015) Oil Production Greenhouse Gas Emissions Estimator OPGEE v1.1 Draft E. User guide & Technical documentation. Funded by California Air Resources Board, April 1, 2015.

Energetics (2007). Energy and Environmental Profile of the U.S. Petroleum Refining Industry. Report prepared for the U.S. Department of Energy, Industrial Technologies Program. November 2007. Available online: http://energy.gov/sites/prod/files/2013/11/f4/profile.pdf

Environ (2009) Safety-Kleen Product Carbon Footprint for Re-refined Base Oil. Oct 2009.

EPA (2008). Direct Emissions from Stationary Combustion Sources. U.S. Environmental Protection Agency.

EPA (2014) Greenhouse Gas Reporting Program 2014; Refineries http://www2.epa.gov/ghgreporting/ghgrp-2014-refineries

Freedonia (2016) Lubricants. Freedonia Group, April 21, 2016. https://www.freedoniagroup.com

Grice. L., C.E. Nobel, L. Longshore, R. Huntley, A. L. DeVierno (2013) Life Cycle Carbon Footprint of Re-Refined vs. Base Oil That Is Not Re-Refined. American Chemical Society Sustainable Chem. Eng 2:158-164.

Honary, L. and Richter, E. (2011). Biobased Lubricants and Greases: Technology and Products. John Wiley and Sons.

IPCC (2006) Guidelines for National Greenhouse Gas Inventories, Volume 2 (Energy).

ISO (2012) ISO 14049 International Standard. Environmental Management-Life Cycle Assessment. Illustrative Examples on How to Apply ISO 14044 to Goal and Scope Definition and Inventory Analysis. International Organization for Standardization. Geneva.

Kline & Company (2016). Global Used Oil Markets and Re-refined Lubricants 2015: Market Analysis and Opportunities – North America. Report was generated for use by Safety-Kleen; data cited here with permission from Kline & Company.

Mulvaney, D. (2014) Life Cycle Analysis of Greenhouse Gas Emissions from Biosynthetic Base Oil (BBO) compared to Poly-Alpha Olefin (PAO) Base Oil. EcoShift Consulting, Prepared for Biosynthetic Technologies, February 3, 2014.

National Energy Technology Laboratory (NETL) (2008). Development of Baseline Data and Analysis of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels. Available online: http://www.netl.doe.gov/energy- analyses/pubs/NETL%20LCA%20Petroleum-Based%20Fuels%20Nov%202008.pdf

Randles, K., L. Mazur, C. Milanes (2007) A review of the potential health and environmental health impacts of synthetic motor oils. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment.

Safety-Kleen (2017a) Synthetic lubricant demand 2005-2025. Data provided by The Fredonia Group.

Safety-Kleen (2017b) Finished oil distribution. Personal communication.

Stipanovic, A.J. (2003) Hydrocarbon Base Oil Chemistry. In Fuels and Lubricants Handbook: Technology, Properties, Performance, and Testing, George E. Totten, Ed., ASTM International.

Society of Tribologists and Lubrication Engineers (STLE) (2015). Base Oil Groups: Manufacture, Properties and Performance.

UCSB (2013) Life Cycle Assessment of Used Oil Management in California. Produced under contract for California Department of Resources Recovery and Recycling (CalRecycle) by Geyer, R., B.Kuczenski, A. Henderson, T. Zink. School of Environmental Science and Management, University of California, Santa Barbara.

Unnasch. S., et al. (2009) Assessment of Life Cycle GHG Emissions Associated with Petroleum Fuels,‖ Life Cycle Associates Report LCA-6004-3P. 2009. Prepared for New Fuels Alliance.